ELECTRICIAN

NSQF LEVEL - 4

1st Year

TRADE THEORY

SECTOR: POWER

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : Power

Duration : 2 - Years

Trade : Electrician 1st Year - Trade Theory - NSQF Level - 4 (Revised 2022)

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, an autonomous body under the Directorate General of Training (DGT), Ministry of Skill Development & Entrepreneurship is entrusted with developing producing and disseminating Instructional Media Packages (IMPs) required for ITIs and other related institutions.

The institute has now come up with instructional material to suit the revised curriculum for **Electrician 1st Year - Trade Theory - NSQF Level - 4 (Revised 2022) in Power Sector under Annual Pattern.** The NSQF Level - 4 (Revised 2022) Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

SHRI. ATUL KUMAR TIWARI., I.A.S.,
Secretary
Ministry of Skill Development & Entrepreneurship,
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New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi NSQF Level - 4 (Revised 2022) under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package (IMF) in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this instructional material **(Trade Theory)** for the trade of **Electrician - NSQF Level - 4 (Revised 2022)** under **Power** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

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NIMI records its appreciation for the Data Entry, CAD, DTP operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks the invaluable efforts rendered by all other NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

INTRODUCTION

This manual for trade practical is intended for use in the ITI workshop. It consists of a series of practical exercises that are to be completed by the trainees during the first year of course is the **Electrician trade under Power Sector. It is National Skills Qualifications Framework NSQF Level - 4 (Revised 2022),** supplemented and supported by instructions/information to assist the trainees in performing the exercise. The exercises are designed to ensure that all the skills prescribed in the syllabus are covered including the allied trades.The syllabus for the 1st Year **Electrician** Trade under **Power Sector** Trade Practical is divided into Twelve Modules.The allocation of time for the various modules is given below:

Module 1 - Safety Practice and Hand Tools	40 Hrs
Module 2 - Wires, Joints - Soldering - U.G. Cables	95 Hrs
Module 3 - Basic Electrical Practice	51 Hrs
Module 4 - Magnetism and Capacitors	32 Hrs
Module 5 - AC Circuits	77 Hrs
Module 6 - Magnetism and Capacitors	50 Hrs
Module 7 - Basic Wiring Practice	110 Hrs
Module 8 - Wiring Installation and earthing	115 Hrs
Module 9 - Illumination	45 Hrs
Module 10 - Measuring Instruments	75 Hrs
Module 11 - Domestic Appliances	75 Hrs
Module 12 - Transformers	75 Hrs
Total Hrs	840 Hrs

The syllabus and the content in the modules are interlinked. As the number of workstations available in the electrical section is limited by the machinery and equipment, it is necessary to interpolate the exercises in the modules to form a proper teaching and learning sequence. The sequence of instruction is given in the schedule of instruction which is incorporated in the Instructor's Guide. With 25 practical hours a week of 5 working days 100 hours of practical per month is available.

Contents of Trade Practical

The procedure for working through the 106 exercises for the 1st Year with the specific objectives as the learning out comes at the end of each exercise is given is this book.

The skill objectives and tools/instruments, equipment/machines and materials required to perform the exercise are given in the beginning of each exercise.Skill training in the shop floor is planned through a series of practical exercises/experiments to support the related theory to make the trainees get hands on trainning in the Electrician trade along with the relevant cognitive skills appropriate for the level. A minimum number of projects have been included to make the training more effective and develop attitude to work in a team. Pictorial, schematic, wiring and circuit diagrams have been included in the exercises, wherever necessary, to assist the trainees broaden their views. The symbols used in the diagrams comply with the Bureau of Indian Standards (BIS) specifications.

Illustrations in this manual, help trainess visual perspective of the ideas and concepts.The procedures to be followed for completing the exercises is also given. Different forms of intermediate test questions have been included in the exercises, to enhance the trainee to trainee and trainee to instructor interactions.

Skill Information

Skill areas which are repetitive in nature are given as separate skill information sheets. Skills which are to be developed in specific areas are included in the exercises itself. Some subexercises are developed to fulfill the sequence of exercises in keeping with the syllabus.

This manual on trade practical forms part of the Written Instructional Material (WIM). Which includes manual on trade theory and assignment/test.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

SI.No.	Learning Outcome	Exercise No.
1	Prepare profile with an appropriate accuracy as per drawing following safety precautions. **(NOS: PSS/N2001)**	1.1.01 - 1.1.16
2	Prepare electrical wire joints, carry out soldering, crimping and measure insulation resistance of underground cable. **(NOS: PSS/N0108)**	1.2.17 - 1.2.26
3	Verify characteristics of electrical and magnetic circuits. **(NOS: PSS/N6001, PSS/N6003)**	1.3.27 - 1.5.56
4	Install, test and maintenance of batteries and solar cell.**(NOS: PSS/N6001)**	1.6.57 - 1.6.61
5	Estimate, Assemble, install and test wiring system. **(NOS: PSS/N6001)**	1.7.62 - 1.8.74
6	Plan and prepare Earthing installation. **(NOS: PSS/N6002)**	1.8.75 - 1.8.77
7	Plan and execute electrical illumination system and test. **(NOS: N/A)**	1.9.78 - 1.9.82
8	Select and perform measurements using analog / digital instruments and install/ diagnose smart meters. **(NOS: PSS/N1707)**	1.10.83 - 1.10.89
9	Perform testing, verify errors and calibrate instruments. **(NOS: N/A)**	1.10.90 - 1.10.92
10	Plan and carry out installation, fault detection and repairing of domestic appliances. **(NOS: PSS/N6003)**	1.11.93 - 1.11.97
11	Execute testing, evaluate performance and maintenance of transformer. **(NOS: PSS/N2406, PSS/N2407)**	1.12.98 - 1.12.106

NOTE :

- **ITI students can obtain certificate of competency (Trade license) from respective Labour/ Industries department under State/ UT Govt.**
- **Refer to notification available in public domain for concern states/ UT. Principal & Trade Instructors to facilitate trainees.**

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 40 Hrs.; Professional Knowledge 10 Hrs.	Prepare profile with an appropriate accuracy as per drawing following safety precautions. **(NOS: PSS/N2001)**	1. Visit various sections of the institutes and location of electrical installations. (01hrs.) 2. Identify safety symbols and hazards. (02Hrs.) 3. Preventive measures for electrical accidents and practice steps to be taken in such accidents. (03hrs.) 4. Practice safe methods of fire fighting in case of electrical fire. (02hrs.) 5. Use of fire extinguishers. (03Hrs.)	Scope of the electrician trade. Safety rules and safety signs. Types and working of fire extinguishers. (03 hrs.)
		6. Practice elementary first aid. (02hrs.) 7. Rescue a person and practice artificial respiration. (01Hrs.) 8. Disposal procedure of waste materials. (01Hrs.) 9. Use of personal protective equipment. (01hrs.) 10. Practice on cleanliness and procedure to maintain it. (02 hrs.)	First aid safety practice. Hazard identification and prevention. Personal safety and factory safety. Response to emergencies e.g. power failure, system failure and fire etc. (03 hrs.)
		11. Identify trade tools and machineries. (03Hrs.) 12. Practice safe methods of lifting and handling of tools & equipment. (03Hrs.) 13. Select proper tools for operation and precautions in operation. (03Hrs.) 14. Care & maintenance of trade tools. (03Hrs.)	Concept of Standards and advantages of BIS/ISI. Trade tools specifications. Introduction to National Electrical Code-2011. (02 hrs.)
		15. Operations of allied trade tools. (05 Hrs.) 16. Workshop practice on filing and hacksawing. (05Hrs.)	Allied trades: Introduction to fitting tools, safety precautions. Description of files, hammers, chisels hacksaw frames, blades, their specification and grades. Types of drills, description & drilling machines. (02 hrs.)
Professional Skill 95 Hrs.; Professional Knowledge 20 Hrs.	Prepare electrical wire joints, carry out soldering, crimping and measure insulation resistance of underground cable. **(NOS: PSS/N0108)**	17. Prepare terminations of cable ends (03 hrs.) 18. Practice on skinning, twisting and crimping. (08 Hrs.) 19. Identify various types of cables and measure conductor size using SWG and micrometer. (06Hrs.)	Fundamentals of electricity, definitions, units & effects of electric current. Conductors and insulators. Conducting materials and their comparison. (06 hrs.)
		20. Make simple twist, married, Tee and western union joints. (15 Hrs.)	Joints in electrical conductors. Techniques of soldering.

		21. Make britannia straight, britannia Tee and rat tail joints. (15Hrs.) 22. Practice in Soldering of joints / lugs. (12 Hrs.)	Types of solders and flux. (07 hrs.)
		23. Identify various parts, skinning and dressing of underground cable. (10Hrs.) 24. Make straight joint of different types of underground cable. (10Hrs.) 25. Test insulation resistance of underground cable using megger. (06 hrs.) 26. Test underground cables for faults and remove the fault. (10Hrs.)	Underground cables: Description, types, various joints and testing procedure. Cable insulation & voltage grades Precautions in using various types of cables. (07 hrs.)
Professional Skill 160 Hrs.; Professional Knowledge 36 Hrs.	Verify characteristics of electrical and magnetic circuits. **(NOS: PSS/N6001, PSS/N6003)**	27. Practice on measurement of parameters in combinational electrical circuit by applying Ohm's Law for different resistor values and voltage sources and analyse by drawing graphs. (08 Hrs.) 28. Measure current and voltage in electrical circuits to verify Kirchhoff's Law (08Hrs.) 29. Verify laws of series and parallel circuits with voltage source in different combinations. (05Hrs.) 30. Measure voltage and current against individual resistance in electrical circuit (05hrs.) 31. Measure current and voltage and analyse the effects of shorts and opens in series circuit. (05 Hrs.) 32. Measure current and voltage and analyse the effects of shorts and opens in parallel circuit. (05 Hrs.)	Ohm's Law; Simple electrical circuits and problems. Kirchoff's Laws and applications. Series and parallel circuits. Open and short circuits in series and parallel networks.(04 hrs.)
		33. Measure resistance using voltage drop method. (03Hrs.) 34. Measure resistance using wheatstone bridge. (02 Hrs.) 35. Determine the thermal effect of electric current. (03Hrs.) 36. Determine the change in resistance due to temperature. (02Hrs.) 37. Verify the characteristics of series parallel combination of resistors. (03Hrs.)	Laws of Resistance and various types of resistors. Wheatstone bridge; principle and its applications. Effect of variation of temperature on resistance. Different methods of measuring the values of resistance. Series and parallel combinations of resistors. (04 hrs.)
		38. Determine the poles and plot the field of a magnet bar. (05Hrs.) 39. Wind a solenoid and determine the magnetic effect of electric current. (05Hrs.)	Magnetic terms, magnetic materials and properties of magnet. Principles and laws of electro-magnetism. Self and mutually induced EMFs.

		40. Determine direction of induced emf and current. (03hrs.) 41. Practice on generation of mutually induced emf. (03hrs.) 42. Measure the resistance, impedance and determine inductance of choke coils in different combinations. (05Hrs.) 43. Identify various types of capacitors, charging / discharging and testing. (05 Hrs.) 44. Group the given capacitors to get the required capacity and voltage rating. (05 Hrs.)	Electrostatics: Capacitor- Different types, functions, grouping and uses. (08 hrs.)
		45. Measure current, voltage and PF and determine the characteristics of RL, RC and RLC in AC series circuits. (06Hrs.) 46. Measure the resonance frequency in AC series circuit and determine its effect on the circuit. (05hrs.) 47. Measure current, voltage and PF and determine the characteristics of RL, RC and RLC in AC parallel circuits. (06Hrs.) 48. Measure the resonance frequency in AC parallel circuit and determine its effects on the circuit. (05hrs.) 49. Measure power, energy for lagging and leading power factors in single phase circuits and compare characteristic graphically. (06Hrs.) 50. Measure Current, voltage, power, energy and power factor in three phase circuits. (05hrs.) 51. Practice improvement of PF by use of capacitor in three phase circuit.(03Hrs.)	Inductive and capacitive reactance, their effect on AC circuit and related vector concepts. Comparison and Advantages of DC and AC systems. Related terms frequency, Instantaneous value, R.M.S. value Average value, Peak factor, form factor, power factor and Impedance etc. Sine wave, phase and phase difference. Active and Reactive power. Single Phase and three-phase system. Problems on A.C. circuits. (10 hrs.)
		52. Ascertain use of neutral by identifying wires of a 3-phase 4 wire system and find the phase sequence using phase sequence meter. (07Hrs.) 53. Determine effect of broken neutral wire in three phase four wire system.(04hrs.) 54. Determine the relationship between Line and Phase values for star and delta connections. (07Hrs.) 55. Measure the Power of three phase circuit for balanced and unbalanced loads. (10Hrs.) 56. Measure current and voltage of two phases in case of one phase is short-circuited in three phase four wire system and compare with healthy system. (07hrs.)	Advantages of AC poly-phase system. Concept of three-phase Star and Delta connection. Line and phase voltage, current and power in a 3 phase circuits with balanced and unbalanced load. Phase sequence meter. (10 hrs.)

Professional Skill 50 Hrs.; Professional Knowledge 10 Hrs.	Install, test and maintenance of batteries and solar cell. **(NOS: PSS/N6001)**	57. Use of various types of cells. (08 Hrs.) 58. Practice on grouping of cells for specified voltage and current under different conditions and care. (12 Hrs.) 59. Prepare and practice on battery charging and details of charging circuit. (12 Hrs.) 60. Practice on routine, care/ maintenance and testing of batteries. (08 Hrs.) 61. Determine the number of solar cells in series / parallel for given power requirement. (10 Hrs.)	Chemical effect of electric current and Laws of electrolysis. Explanation of Anodes and cathodes. Types of cells, advantages / disadvantages and their applications. Lead acid cell; Principle of operation and components. Types of battery charging, Safety precautions, test equipment and maintenance. Basic principles of Electro-plating and cathodic protection Grouping of cells for specified voltage and current. Principle and operation of solar cell. (10 Hrs.)
Professional Skill 200 Hrs.; Professional Knowledge 42 Hrs.	Estimate, Assemble, install and test wiring system. **(NOS: PSS/N6001)**	62. Identify various conduits and different electrical accessories. (8 Hrs.) 63. Practice cutting, threading of different sizes & laying Installations. (17 Hrs.) 64. Prepare test boards / extension boards and mount accessories like lamp holders, various switches, sockets, fuses, relays, MCB, ELCB, MCCB etc. (25 Hrs.)	I.E. rules on electrical wiring. Types of domestic and industrial wirings. Study of wiring accessories e.g. switches, fuses, relays, MCB, ELCB, MCCB etc. Grading of cables and current ratings. Principle of laying out of domestic wiring. Voltage drop concept. (14 Hrs.)
		65. Draw layouts and practice in PVC Casing-capping, Conduit wiring with minimum to more number of points of minimum 15 mtr length. (15 Hrs.) 66. Wire up PVC conduit wiring to control one lamp from two different places. (15 Hrs.) 67. Wire up PVC conduit wiring to control one lamp from three different places. (15 Hrs.) 68. Wire up PVC conduit wiring and practice control of sockets and lamps in different combinations using switching concepts. (15 Hrs.)	PVC conduit and Casing-capping wiring system. Different types of wiring - Power, control, Communication and entertainment wiring. Wiring circuits planning, permissible load in sub-circuit and main circuit. (14 Hrs.)
		69. Wire up the consumers main board with MCB & DB's switch and distribution fuse box. (15 Hrs.) 70. Prepare and mount the energy meter board. (15 Hrs.) 71. Estimate the cost/bill of material for wiring of hostel/ residential building and workshop. (15 Hrs.)	Estimation of load, cable size, bill of material and cost. Inspection and testing of wiring installations. Special wiring circuit e.g. godown, tunnel and workshop etc. (14 Hrs.)

		72. Practice wiring of hostel and residential building as per IE rules. (15 Hrs.) 73. Practice wiring of institute and workshop as per IE rules. (15 Hrs.) 74. Practice testing / fault detection of domestic and industrial wiring installation and repair. (15Hrs.)	
Professional Skill 25 Hrs.; Professional Knowledge 07 Hrs.	Plan and prepare Earthing installation. **(NOS: PSS/N6002)**	75. Prepare pipe earthing and measure earth resistance by earth tester / megger. (10 Hrs.) 76. Prepare plate earthing and measure earth resistance by earth tester / megger. (10 Hrs.) 77. Test earth leakage by ELCB and relay. (5 Hrs.)	Importance of Earthing. Plate earthing and pipe earthing methods and IEE regulations. Earth resistance and earth leakage circuit breaker. (5 Hrs.)
Professional Skill 45Hrs.; Professional Knowledge 10Hrs.	Plan and execute electrical illumination system and test. **(NOS: N/A)**	78. Install light fitting with reflectors for direct and indirect lighting. (10 Hrs.) 79. Group different wattage of lamps in series for specified voltage. (5 Hrs.) 80. Practice installation of various lamps e.g. fluorescent tube, HP mercury vapour, LP mercury vapour, HP sodium vapour, LP sodium vapour, metal halide etc. (18 Hrs.) 81. Prepare decorative lamp circuit to produce rotating light effect/running light effect. (6 Hrs.) 82. Install light fitting for show case lighting. (6 Hrs.)	Laws of Illuminations. Types of illumination system. Illumination factors, intensity of light. Type of lamps, advantages/ disadvantages and their applications. Calculations of lumens and efficiency. (10 hrs.)
Professional Skill 50 Hrs.; Professional Knowledge 08 Hrs.	Select and perform measurements using analog / digital instruments and install/ diagnose smart meters. **(NOS: PSS/N1707)**	83. Practice on various analog and digital measuring Instruments. (5 Hrs.) 84. Practice on measuring instruments in single and three phase circuits e.g. multi-meter, Wattmeter, Energy meter, Phase sequence meter and Frequency meter etc. (12Hrs.) 85. Measure power in three phase circuit using two wattmeter methods. (8 Hrs.) 86. Measure power factor in three phase circuit by using power factor meter and verify the same with voltmeter, ammeter and wattmeter readings. (10Hrs.) 87. Measure electrical parameters using tong tester in three phase circuits. (08Hrs.) 88. Demonstrate Smart Meter, its physical components and Communication components. (03 Hrs.) 89. Perform meter readings, install and diagnose smart meters. (04 Hrs.)	Classification of electrical instruments and essential forces required in indicating instruments. PMMC and Moving iron instruments. Measurement of various electrical parameters using different analog and digital instruments. Measurement of energy in three phase circuit. Automatic meter reading infrastructures and Smart meter. Concept of Prosumer and distributed generation. Electrical supply requirements of smart meter, Detecting/clearing the tamper notifications of meter. (08 hrs.)

Professional Skill 25 Hrs.; Professional Knowledge 05Hrs.	Perform testing, verify errors and calibrate instruments. **(NOS: N/A)**	90. Practice for range extension and calibration of various measuring instruments. (10 Hrs.) 91. Determine errors in resistance measurement by voltage drop method. (8 hrs) 92. Test single phase energy meter for its errors. (7 Hrs.)	Errors and corrections in measurement. Loading effect of voltmeter and voltage drop effect of ammeter in circuits. Extension of range and calibration of measuring instruments. (05 hrs.)
Professional Skill 75 Hrs.; Professional Knowledge 10 Hrs.	Plan and carry out installation, fault detection and repairing of domestic appliances. **(NOS: PSS/N6003)**	93. Dismantle and assemble electrical parts of various electrical appliances e.g. cooking range, geyser, washing machine and pump set. (25 Hrs.) 94. Service and repair of electric iron, electric kettle, cooking range and geyser. (12 Hrs.) 95. Service and repair of induction heater and oven. (10 Hrs.) 96. Service and repair of mixer and grinder. (10 Hrs.) 97. Service and repair of washing machine. (13Hrs.)	Working principles and circuits of common domestic equipment and appliances. Concept of Neutral and Earth. (10 hrs.)
Professional Skill 75 Hrs.; Professional Knowledge 12 Hrs.	Execute testing, evaluate performance and maintenance of transformer. **(NOS: PSS/ N2406, PSS/ N2407)**	98. Verify terminals, identify components and calculate transformation ratio of single-phase transformers. (8 Hrs.) 99. Perform OC and SC test to determine and efficiency of single-phase transformer. (12Hrs.) 100 Determine voltage regulation of single-phase transformer at different loads and power factors. (12 Hrs.) 101 Perform series and parallel operation of two single phase transformers. (12 Hrs.) 102 Verify the terminals and accessories of three phase transformer HT and LT side. (6Hrs.)	Working principle, construction and classification of transformer. Single phase and three phase transformers. Turn ratio and e.m.f. equation. Series and parallel operation of transformer. Voltage Regulation and efficiency. Auto Transformer and instrument transformers (CT & PT). (12 Hrs.)
		103Perform 3 phase operation (i) delta-delta, (ii) delta-star, (iii) star-star, (iv) star-delta by use of three single phase transformers. (6 Hrs.) 104Perform testing of transformer oil. (6 Hrs.) 105Practice on winding of small transformer. (8 Hrs.) 106Practice of general maintenance of transformer. (5 Hrs.)	Method of connecting three single phase transformers for three phase operation. Types of Cooling, protective devices, bushings and termination etc. Testing of transformer oil. Materials used for winding and winding wires in small transformer. (06 Hrs.)

Organization of ITI's and scope of the electrician trade

Objectives: At the end of this lesson you shall be able to
- **state brief introduction about Industrial Training Institutes (ITI)**
- **state about the organized structure of the Institute.**

Brief Introduction of Industrial Training Institute (ITIs)

Industrial Training Institute plays a vital role in economy of the country, especially interms of providing skilled manpower.

The Directorate General of Training (DGT) comes under **Ministry of Skill Development and Entrepreneurship (MSDE)** offers a range of vocational training trades in different sectors based on economy /labour market. The vocational training programs are delivered under the aegis of **National Council of Vocational Training (NCVT).** Craftsman Training scheme (CTS) and Apprenticeship Training Scheme (ATS) and two pioneer programs of NCVT for Propagatory Vocational Training.

They are giving training about 132 trades including Engineering and Non-engineering with the duration of 1 or 2 years. The minimum eligibility for admission in ITIs 8th, 10th and 12th pass with respect to the trades and admission process will be held in every year.

At the end of each year, All India Trade Test (AITT) will be conducted in multiple choice type questions. After passing, National trade certificates (NTC), will be issued by DGT which is authorized and recognized internationally. In 2017, for some trades they have introduced and implemented **National Skill Qualification Frame** work (NSQF) with Level 4 and Level 5.

After finishing instructional training with 'NTC' certificate, they have to undergo Apprenticeship training (ATS) for one or two year in respective trades under the Apprentice ACT 1961, in various government and private establishments with stipend. At the end of the Apprenticeship training, All India Apprentice Test will be conducted and apprentice certificate will be issued. They can get job opportunities in private or government establishment in India/Abroad or they can start small scale industries in manufacturing or in service sector with subsidiary government loan.

Organizational Structure of ITIs : In most of the ITIs, the head of the institute is the principal under him one vice-principal (VP). then Training Officers (TO)/Group Instructors (GI) who are the management and supervisory staff. Then Assistant Training Officers(ATO), Junior Training Officer (JTO), and Vocational Instructors (VI) are under Training officers for each trade and for Workshop calculations, Engineering Drawing, Employability skills etc. Administrative staff, Hostel Superintendent (H.S.) physical Education Trainer (PET), Library incharge, Pharmacist, etc. will be under the head of the Institution.

Scope of the electrician trade

Objectives: At the end of this lesson you shall be able to
- **explain the duties of electrician general and electrical fitter and their NCO**
- **state the key skills and carrier pathway for electrician**
- **list out the job opportunities and self employment opportunities.**

Welcome to the electrician trade : Electrician trade under craftsman training scheme (CTS) is one of the most popular trade delivered nationwide through the network of ITIs. This trade is of two year duration.

It mainly consists of domain area and core areas. In domain area trade practical and trade theory and core area workshop calculation and science, Engineering drawing and employability skills which imparts soft and life skills. There are two professional classification in electrician trade based on National Code of Occupation (NCO) as

i Electrician general (NCO - 2015 reference is 7411.0100)

ii Electrical fitter (NCO - 2015 reference is 7412.0200)

Duties of Electrician - General and Electrical - Fitter, Electrician - General installs, maintains and repairs electrical machinery, equipment and fittings in factories, workshops, power houses, business and residential premises, etc. Studies drawings and other specifications to determine electrical circuit, installation etc. Positions and installs electrical motors, transformers, switchboards, microphones, loud-speakers and other electrical equipment, fittings and lighting fixtures. Makes connections and solder terminals. Tests electrical installations and equipment and locates faults using megger, test lamp etc.

Repairs or replaces defective wiring , burnt out fuses and defective parts and keeps fittings and fixtures in working order. may do armature winding, draw wires and cables and do simple cable joining. May operate, attend and maintain electrical motors, pumps etc. NCO - 2015 reference is 7411.0100

Record class of work in which experienced such as factory, power-house, ship etc., whether experienced in electrical repairs or detecting faults, details of experience in electrical equipment such as sound recording apparatus, air purification plant, heating apparatus etc. whether used to working do drawing, whether accustomed to high tension or low tension supply system and if in possession of competency certificate issued under electricity act.

Electrical fitter fits and assembles electrical machinery and equipment such as motors, transformers, generators, switch gears, fans, etc., Studies drawings and wiring diagrams of fittings, wiring and assemblies to be made.

Erects various equipment such as bus bars, panel board, electrical post, fuse boxes switch gears, meters, relays etc., using non-conductors, insulating and hoisting equipment as necessary for receipt and distribution of electrical current to feeder lines.

Record nature of work done; if specialized in repairing or assembling any particular item such as generator, motor, transformer, relays switchgear, domestic appliance etc. , experience of working in power-house and distribution centre and if in possession of electrician's competency certificate

Key Skills of Electrician

After passing the electrician trade, they are able to

- Read and interpret technical parameter documents, plan and organic work process, identify necessary materials and tools
- Apply professional skill knowledge and employability skills while performing jobs.
- Checking job/assembly as per drawing for functioning, identifying and rectifying errors in job/assembly.
- Document the technical parameters related to the tasks undertaken

Presently electrician syllabus again Revised and sequentially structured by National Skill Qualification Framework NSQF - level 5 and implemented from August 2017

Carrier Progress Pathways

After passing the electrician trade the trainee can appear in 10+2 examination through National Institute of Open Schooling (NIOS) for acquiring higher secondary certificate and can go further for general Technical education.

- Take admission in diploma course in notified branches of engineering by lateral entry
- Can join the apprenticeship training in different types of industries and obtain National Apprenticeship Certificate (NAC)
- Eligible to obtain directly wireman 'B' license, which is issued by the Electrical Licensing Board Authorities

Job Opportunities: There are good numbers of job opportunities for an electrician

- Electrician in local electricity boards, railways, Telephone department, airport and other government and semi-government establishments
- Electrician in factories (Public/Private) Install, test and maintain electrical equipment in auditorium and cinema halls
- Winder of electrical motors in winding shops
- Electrical appliances repairer in electrical shops.
- Electrician to Install, service and maintain electrical equipment and circuits in hotels, resorts hospitals and flats

Self-employment opportunities

- Service centre for repairing electrical switch gear and motors in rural and urban areas.
- Maintenance contractor of wiring installation in hotels/ resorts/hospitals/banks etc.
- Manufacturer of sub-assembly for electrical panels
- Contractor for domestic wiring and industrial wiring
- Service, maintain and repair of domestic appliances
- With an added training in the specified field can become Audio/Radio/ TV Mechanic

Safety rules - Safety signs - Hazards

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of adopting the safety rules**
- **list the safety rules to be followed by the electrician**
- **explain how to treat a person for electric shock/injury.**

Scan the QR Code to view the video for this exercise

Necessity of safety rules: Safety consciousness is one of the essential attitudes required for any job. A skilled electrician always should strive to form safe working habits. Safe working habits always save men, money and material. Unsafeworking habits always end up in loss of production and profits, personal injury and even death. The safety hints given below should be followed by Electrician to avoid accidents and electrical shocks as his job involves a lot of occupational hazards.

The listed safety rules should be learnt, remembered and practised by every electrician. Here a electrician should remember the famous proverb, **"Electricity is a good servant but a bad master".**

Safety rules

- Only qualified persons should do electrical work.
- Do not work on live circuits;
- Use wooden or PVC insulated handle screwdrivers when working on electrical circuits.
- When soldering, place the hot soldering irons in their stand.
- Replace or remove fuses only after switching off the circuit switches.
- Use extension cords with lamp guards to protect lamps against breakage and to avoid combustible material coming in contact with hot bulbs.
- Use accessories like sockets, plugs, switches and appliances only when they are in good condition and be sure they have the mark of BIS (ISI). Necessity of using BIS(ISI) marked accessories is explained under standardisation.
- Stand on rubber mats while working/operating switch panels, control gears etc.
- Position the ladder, on firm ground.
- Always use safety belts while working on poles or high rise points.
- Never place your hands on any moving part of rotating machine.
- Only after identifying the procedure of operation, operate any machine or apparatus.
- Use always earth connection for all electrical appliances along with 3-pin sockets and plugs.
- While working on dead circuits remove the fuse grips; keep them under safe custody and also display 'Men on line' board on the switchboard.
- Do not connect earthing to the water pipe lines.
- Discharge static voltage in HV lines/equipment and capacitors before working on them.

Safety practice - first aid

Electric shock

We are aware that the prime reasons for severity of shock are the magnitude of current and duration of contact. In addition, the other factors contribute to the severity of shock are:

- age of person
- body resistance
- not wearing insulating footwear or wearing wet footwear
- Weather condition
- Wet or dry floor
- Mains voltage etc.

If assistance is close at hand, send for medical aid, then carry on with emergency treatment.

If you are alone, proceed with the treatment immediately.

Make sure the victim is not in contact with the supply.

Effects of electric shock

The effect of current at very low levels may only be an unpleasant tingling sensation, but this itself may be sufficient to cause some persons to lose their balance and fall.

At higher levels of current the person receiving a shock may be thrown off his feet and will experience severe pain and possibly minor burns at the point of contact.

At an excessive shock can also cause burning of the skin at the point of contact.

Treatment of electric shock

Prompt treatment is essential.

Check for the victim's natural breathing and consciousness. Take steps to apply respiratory resuscitation if the victim is unconscious and not breathing.

In the case of burns/injury in the back, follow Nelson's method

In case the mouth is closed tightly, use Schafer's or Holgen-Nelson method.

Treatment for electrical burns

A person receiving an electric shock may also sustain burns when the current passes through the body.

> **Do not waste time by rendering first aid to the victim until breathing has been restored and the patient can breathe normally unaided.**

Burns are very painful. If a large area of the body is burnt, do not give treatment, except to exclude the air, eg. by covering with clean paper or a clean cloth, soaked in clean water. this relieves the pain.

Severe bleeding

Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention.

Immediate action

Always in cases of severe bleeding

- make the patient to lie down and rest
- if possible, raise the injured part above the level of the body (Fig 1)
- apply pressure to the wound
- call for medical assistance

To control severe bleeding

Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound and cover it with a pad of soft material. (Fig 2)

Fig 1

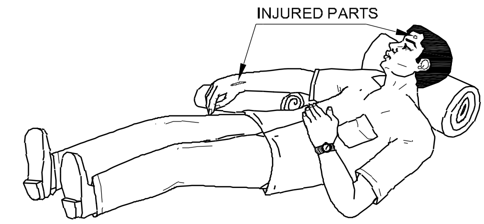
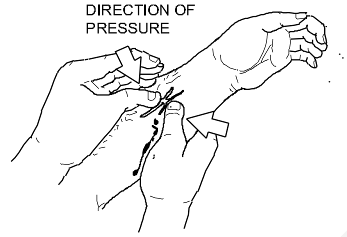


Fig 2

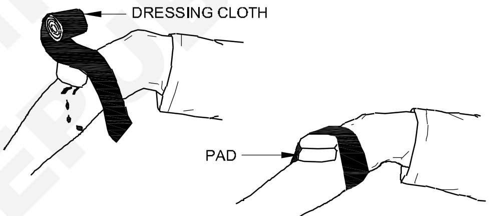


For an abdominal wound which may be caused by falling on a sharp tool, keep the patient bending over the wound to stop internal bleeding.

Large wound

Apply a clean pad and bandage firmly in place. If bleeding is very severe apply more than one dressing. (Fig 3)

Fig 3



Safety practice - Safety signs

Objectives: At the end of this lesson you shall be able to
- **state the responsibilities of employer and employees**
- **state the safety attitude and list the four basic categories of safety signs.**

Responsibilities

Safety doesn't just happen - it has to be organised and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf.

Employer's responsibilities

The effort a firm puts into planning and organising work, training people, engaging skilled and competent workers, maintaining plant and equipment, and checking, inspecting and keeping records - all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what the employees are asked to do, and the training given.

Employee's responsibilities

You will be responsible for the way you use the equipment, how you do your job, the use you make of your training, and your general attitude to safety.

A great deal is done by employers and other people to make your working life safer; but always remember you are responsible for your own actions and the effect they have on others. You must not take that responsibility lightly.

Rules and procedure at work

What you must do, by law, is often included in the various rules and procedures laid down by your employer. They may be written down, but more often than not, are just the way a firm does things - you will learn these from other workers as you do your job.

They may govern the issue and use of tools, protective clothing and equipment, reporting procedures, emergency drills, access to restricted areas, and many other matters. Such rules are essential; they contribute to the efficiency and safety of the job.

Safety signs

As you go about your work on a construction site you will see a variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others you may not have seen before. It is up to you to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

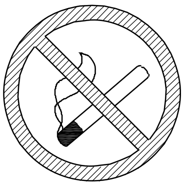
Safety signs fall into four separate categories. These can be recognised by their shape and colour. Sometimes they may be just a symbol; other signs may include letters or figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

The four basic categories of signs are as follows:

- prohibition signs (Fig 1 & Fig 5)
- mandatory signs (Fig 2 & Fig 6)
- warning signs (Fig 3 & Fig 7)
- information signs (Fig 4)

Prohibition signs

Fig 1



SHAPE	Circular.
COLOUR	Red border and cross bar. Black symbol on white background.
MEANING	Shows it must not be done.
Example	No smoking.

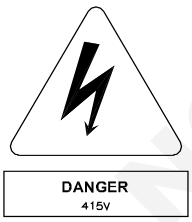
Mandatory signs

Fig 2

SHAPE	Circular.
COLOUR	White symbol on blue background
MEANING	Shows what must be done.
Example	Wear hand protection.

Warning signs

Fig 3



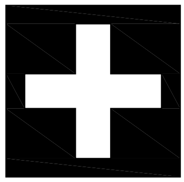
SHAPE	Triangular.
COLOUR	Yellow background with black border and symbol.
MEANING	Warns of hazard or danger.
Example	Caution, risk of electric shock.

Prohibition signs

Fig 5

Information signs

Fig 4



SHAPE	Square or oblong.
COLOUR	White symbols on green background.
MEANING	Indicates or gives information of safety provision.
Example	First aid point.

Mandatory signs

Fig 6

Warning signs

Fig 7

Fire - Types - Extinguishers

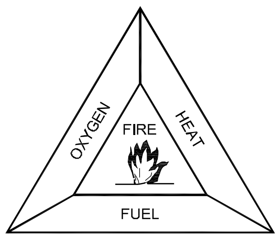
Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire break out and causes of fire in a workshop**
- **distinguish the different types of fire extinguishers**
- **state the classification of fires and basic ways for extingushing the fire**
- **determine the correct type of fire extinguisher to be used based on the class of fire**
- **describe the general procedure to be adopted in the event of fire**
- **state the method of operation of fire extinguisher and extinguishing of fire.**

Scan the QR Code to view the video for this exercise

Fire : Is it possible to prevent fire? Yes, fire can be prevented by eliminating anyone of the three factors that cauAses fire.

The following are the three factors that must be present in combination for a fire to continue to burn. (Fig 1)

Fig 1



Fuel: Any substance, liquid, solid or gas will burn, if there is oxygen and high enough temperatures.

Heat: Every fuel will begin to burn at a certain temperature. It varies and depends on the fuel. Solids and liquids give off vapour when heated, and it is this vapour which ignites.

Oxygen: Usually exists in sufficient quantity in air to keep a fire burning.

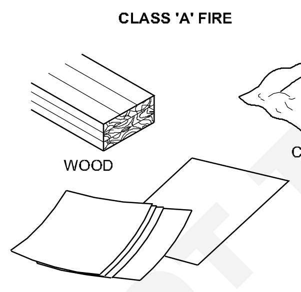
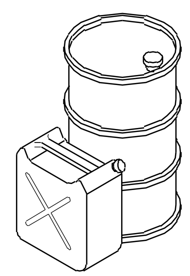
Extinguishing of fire: Isolating or removing any of these factors from the combination will extinguish the fire. There are three basic ways of achieving this.

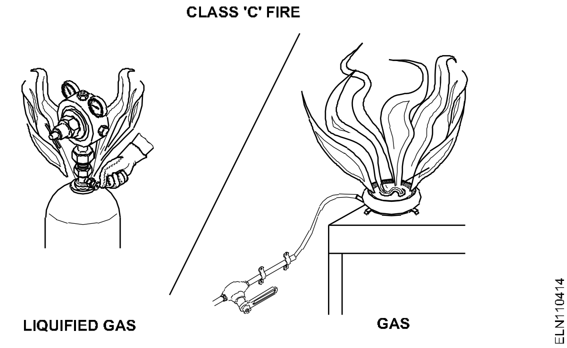
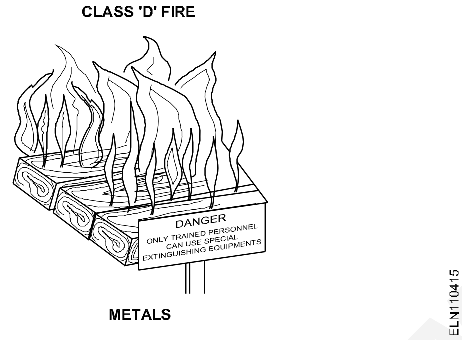
- **Starving** the fire of fuel removes this element.
- **Smothering** - ie. isolate the fire from the supply of oxygen by blanketing it with foam, sand etc.
- **Cooling** - use water to lower the temperature.

Removing any one of these factors will extinguish the fire.

Classification of fires: Fires are classified into four types in terms of the nature of fuel.

Different types of fires (Fig 2, Fig 3 Fig 4 & Fig 5) have to be dealt with in different ways and with different extinguishing agents.

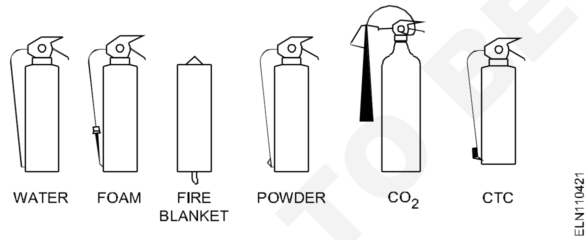
Fire Classification and Fuel	Extinguishing Method
Fig 2 	Most effective ie., cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
Fig 3 	**Should be smothered** :- The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire. Water should never be used on burning liquids. Foam, dry powder or CO_2 may be used on this type of fire.

Fire Classification and Fuel	Extinguishing Method
Fig 4 	Extreme caution is necessary in dealing with liquefied gases. There is a risk of explosion and sudden outbreak of fire in the entire vicinity. If an appliance fed from a cylinder catches fire - shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel. Dry powder extinguishers are used on this type of fire.
Fig 5 	Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire. The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires. Fire on electrical equipment. Halon, Carbon dioxide, dry powder and vapourising liquid (CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (eg. water) extinguishers must not be used on electrical equipment under any circumstances.

Types of Fire Extinguisher

Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 6)

Fig 6



Water-filled extinguishers: There are two methods of operation. (Fig 7)

- Gas cartridge type
- Stored pressure type

With both methods of operation the discharge can be interruted as required, conserving the contents and preventing unnecessary water damage.

Foam extinguishers (Fig 8):These may be of stored pressure or gas cartridge types.

Most suitable for

- flammable liquid fires
- running liquid fires

Must not be used on fires where electrical equipment is involved.

Fig 7

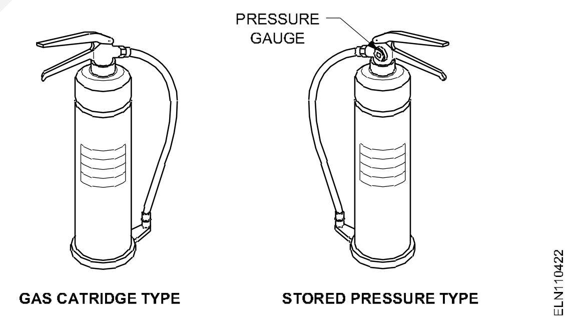
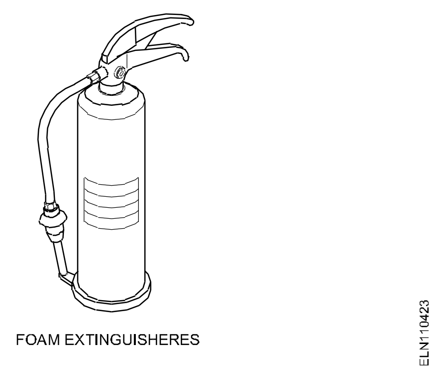
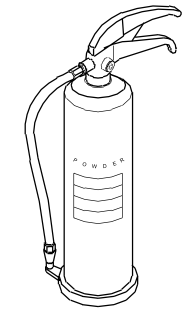


Fig 8



Dry powder extinguishers (Fig 9): Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type. Appearance and method of operation is the same as that of the water-filled one. The main distinguishing feature is the fork shaped nozzle. Powders have been developed to deal with class D fires.

Fig 9

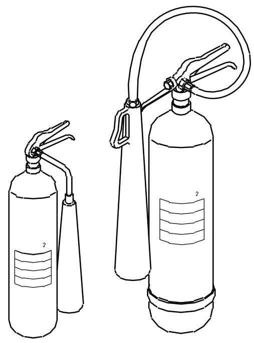


DRY POWDEER EXTINGUSHERS

ELN110424

Carbon dioxide (CO_2): This type is easily distinguished by the distinctively shaped discharge horn. (Fig 10).

Fig 10



CARBAN DIOXIDE(CO_2)

ELN110425

Suitable for Class B fires. Best suited where contamination by deposits must be avoided. Not generally effective in open air.

Always check the operating instructions on the container before use. Available with different gadgets of operation such as - plunger, lever, trigger etc.

The general procedure in the event of a fire:

- Raise an alarm.
- Turn off all machinery and power (gas and electricity).
- Close the doors and windows, but do not lock or bolt them. This will limit the oxygen fed to the fire and prevent its spreading.
- Try to deal with the fire if you can do so safely. Do not risk getting trapped.
- Anybody not involved in fighting the fire should leave calmly using the emergency exits and go to the designated assembly point.
- Analyze and identify the type of fire. Refer Table1.

Table 1

Class 'A'	Wood, paper, cloth, solid material
Class 'B'	Oil based fire (grease, gasoline, oil) liquifiable gases
Class 'C'	Gas and liquifiable gases
Class 'D'	Metals and electrical equipment

Fire extinguishers are manufactured for use from the distance.

Caution

- **While putting off fire, the fire may flare up**
- **Do not be panick belong as it put off promptly.**
- **If the fire doesn't respond well after you have used up the fire extinguisher move away yourself away from the fire point.**
- **Do not attempt to put out a fire where it is emitting toxic smoke leave it for the professionals.**
- **Remember that your life is more important than property. So don't place yourself or others at risk.**

In order to remember the simple operation of the extinguisher. Remember P.A.S.S. This will help you to use the fire extinguisher.

P for Pull

A for Aim

S for Squeeze

S for Sweep

Rescue operation - First aid treatment - Artificial respiration

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **explain how to rescue a person who is in contact with a live wire.**
- **state the first aid and its key aims.**
- **explain ABC of the first aid.**
- **brief how to give first aid treatment for a victim.**
- **explain how to treat a person affected due to electric shock/injury.**

The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that the electric current has been disconnected. If the victim is still in contact with the supply - break the contact either by switching off or by removing the plug or pulling the cable free.

If not, stand on some insulating material such as dry wood, rubber or plastic or newspaper and then pull his shirt sleeves. However, you have to insulate yourself and break the contact by pushing or pulling the person free. (Figs1 & 2)

Fig 1

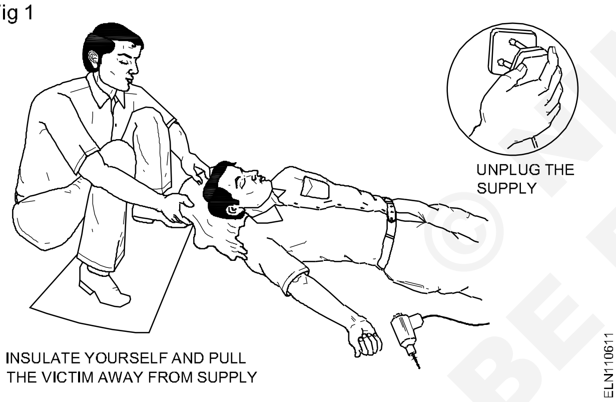
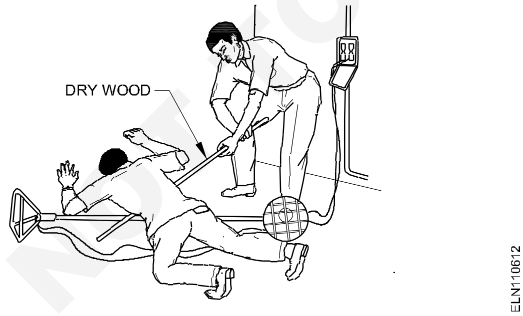


Fig 2



In any case avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

If the victim is at a height, efforts must be taken to prevent him from falling or to make him fall safe.

Electric burns on the victim may not cover a big area but may be deep seated. All you can do is to cover the area with a clean, sterile dressing and treat for shock. Get expert help as quickly as possible.

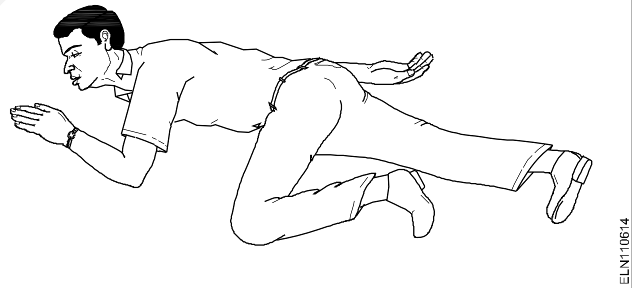
If the casualty is unconscious but is breathing, loosen the clothing about the neck, chest and waist (Fig 3) and place the casualty in the recovery position.

Fig 3

Keep a constant check on the breathing and pulse rate.

Keep the casualty warm and comfortable in the recover position. Send for help.(Fig 4)

Fig 4



Do not give an unconscious person anything to eat or drink.

Do not leave an unconscious person unattended.

If the casualty is not breathing - **Act at once to resuscitate the victim** - do not waste time.

Basic first-aid treatment

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life, prevent further deterioration or injury, plan to shift the victim to safer place, provide best possible comfort and finally help them to reach the medical centre/ hospital through all available means. It is an immediate life-saving procedure using all resources available within reach.

The key aims of first aid can be summarized in three key points:

- **Preserve life:** If the patient was breathing, a first aider would normally then place them in the recovery position, with the patient leant over on their side, which also has the effect of clearing the tongue from the pharynx. It also avoids a common cause of death in unconscious patients, which is choking on regurgitated stomach contents.
- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury.
- **Promote recovery:** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

Training

Basic principles, such as knowing to use an adhesive bandage or applying direct pressure on a bleed, are often acquired passively through life experiences. However, to provide effective, life-saving first aid interventions requires instruction and practical training.

ABC of first aid

ABC stands for **A**irway, **B**reathing and **C**irculation.

- **Airway:** Attention must first be brought to the airway to ensure it is clear. Obstruction (choking) is a life-threatening emergency.
- **Breathing:** Breathing if stops, the victim may die soon. Hence means of providing support for breathing is an important next steps. There are several methods practiced in first aid.
- **Circulation:** Blood circulation is vital to keep person alive. The first aiders now trained to go straight to chest compressions through CPR methods.

Not to get panic

Panic is one emotion that can make the situation more worse. People often make mistake because they get panic.

Call medical emergencies

If the situation demands, quickly call for medical assistance. Prompt approach may save the life.

Surroundings play vital role

Different surroundings require different approach. Hence first aider should study the surrounding carefully.

Do no harm

Most often over enthusiastically practiced first aid viz. administering water when the victim is unconscious, wiping clotted blood (which acts as plug to reduce bleeding), correcting fractures, mishandling injured parts etc., would leads to more complication.

Reassurance

Reassure the victim by speaking encouragingly with him.

Stop the bleeding

If the victim is bleeding, try to stop the bleeding by applying pressure over the injured part.

Golden hours

India have best of technology made available in hospitals to treat devastating medical problem viz. head injury, multiple trauma, heart attack, strokes etc, but patients often do poorly because they don't gain access to that technology in time.

The risk of dying from these conditions, is greatest in the first 30 minutes, often instantly. This period is referred to as **Golden period**.

Maintain the hygiene

Most important, the first aider need to wash hands and dry before giving any first aid treatment to the patient.

CPR (Cardio-Pulmonary Resuscitation) can be life-sustaining

CPR can be life sustaining. If one is trained in PR and the person is suffering from choking or finds difficulty in breathing, immediately begin CPR.

Call emergency service

The emergency number varies - 100 for Police & Fire, 108 for Ambulance.

Report your location

The first thing the emergency dispatcher will ask is where you are located, so the emergency services can get there as quickly as possible. Give the exact street address, if you're not sure of the exact address, give approximate information.

Give the dispatcher your phone number

This information is also imperative for the dispatcher to have, so that he or she is able to call back if necessary.

Important guideline for first aiders

Evaluate the situation

Are there things that might put the first aider at risk. When faced with accidents like fire, toxic smoke, gasses, an unstable building, live electrical wires or other dangerous scenario, the first aider should be very careful not to rush into a situation, which may prove to be fatal.

Remember A-B-Cs

The ABCs of first aid refer to the three critical things the first aiders need to look for.

- **A**irway - Does the person have an unobstructed airway?
- **B**reathing - Is the person breathing?
- **C**irculation - Does the person show a pulse at major pulse points (wrist, carotid artery, groin)

Call emergency services : Call for help or tell someone else to call for help as soon as possible. If alone at the accident scene, try to establish breathing before calling for help, and do not leave the victim alone unattended.

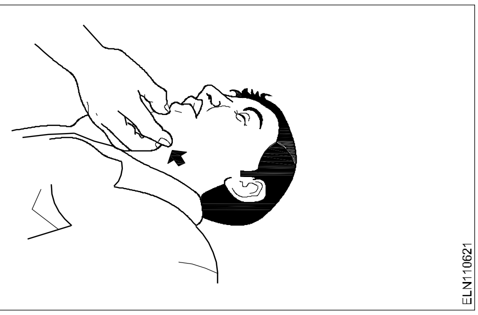
Determine responsiveness

If a person is unconscious, try to rouse them by gently shaking and speaking to them.

> **If the person remains unresponsive, carefully roll them on the side (recovery position) and open his airway.**

- Keep head and neck aligned.
- Carefully roll them onto their back while holding his head.
- Open the airway by lifting the chin (Fig 1).

Fig 1



Look, listen and feel for signs of breathing

Look for the victim's chest to raise and fall, listen for sounds of breathing.

- **Treat shock:** Shock may causes loss of blood flow from the body, frequently follows physical and occasionally psychological trauma.
- **Choking victim:** Choking can cause death or permanent brain damage within minutes.

Stay with the victim until help arrives

Try to be a calming presence for the victim until assistance can arrive.

Unconsciousness (COMA)

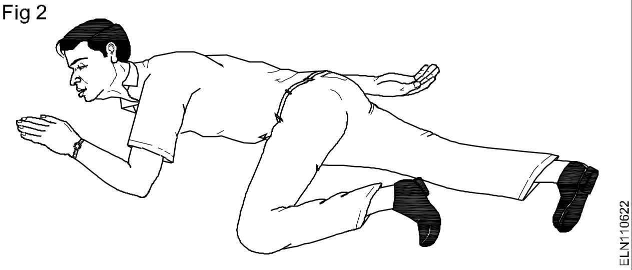
Unconscious also referred as Coma, is a serious life threatening condition, when a person lie totally senseless and do not respond to calls, external stimulus. But the basic heart, breathing, blood circulation may be still intact, or they may also be failing. If unattended it may lead to death.

First aid

- Call EMERGENCY number.
- Check the person's airway, breathing, and pulse frequently. If necessary, begin rescue breathing and CPR.
- If the person is breathing and lying on the back and after ruling out spinal injury, carefully roll the person onto the side, preferably left side.

  Bend the top leg so both hip and knee are at right angles. Gently tilt the head back to keep the airway open (Fig 2). If breathing or pulse stops at any time, roll the person on to his back and begin CPR.

Fig 2



- If there is a spinal injury, the victims position may have to be carefully assessed. If the person vomits, roll the entire body at one time to the side. Support the neck and back to keep the head and body in the same position while you roll.
- Keep the person warm until medical help arrives.
- If you see a person fainting, try to prevent a fall. Lay the person flat on the floor and raise the level of feet above and support.

First aid

Keep the patient warm and at mental rest. Assure of good air circulation and comfort. Call for help to shift the patient to safer place/ hospital.

- **Warmth:** Keep the victim warm but do not allow them to get overheated.
- **Air:** Maintain careful eye on the victim's airway.
- **Rest:** Keep the victim still and preferably sitting or lying down. If the victim is very giddy, lay them down with there legs raised to ensure that maximum blood and therefore maximum oxygen is sent to the brain.

Treatment of electric shock

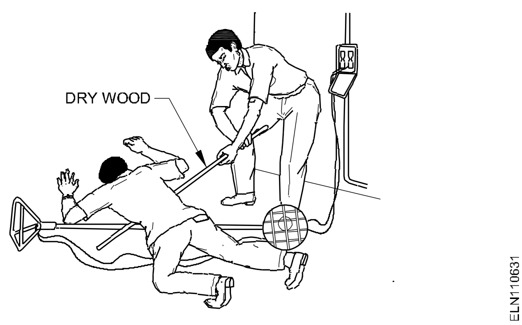
Prompt treatment is essential

If assistance is close at hand, send for medical aid, then carry on with emergency treatment.

If you are alone, proceed with treatment at once.

Switch off the supply, if this can be done without undue delay. Otherwise, remove the victim from contact with the live conductor, using dry non-conducting materials such as a wooden bar, rope, a scarf, the victim's coat-tails, any dry article of clothing, a belt, rolled-up newspaper, non-metallic hose, PVC tubing, bakelised paper, tube etc. (Fig 3)

Fig 3



Avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

Disposal of waste material

Objectives: At the end of this lesson you shall be able to
- **state about the waste material**
- **state the types of waste material and source of waste**
- **list out the waste material in workshop**
- **explain the methods of disposal of waste material.**

Scan the QR Code to view the video for this exercise

Waste

Waste are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or it is worthless, defective and of no use.

Waste can be broadly classified as follows

a Rural waste

b Urban waste

  i Solid waste

  II Liquid waste

a Rural waste

Rural waste is the waste from agricultural and dairy forms.

b Urban waste

It is the waste from house hold articles or from industries within municipal limit

It can be again classified into two types.

i Solid waste

Solid waste is the material is hard (from industries) such as newspaper, cans, bottles, broken glass, plastics container, polythene bags etc.

ii Liquid waste

It is the water based waste which is produced by the main activation sources of waste.

Sources of waste

i Industrial waste

It contains solid as well as liquid waste and is formed by the processing of various materials.

ii Domestic waste

It includes all rubbish, garbage, dust, sewage waste etc. It contains combustible and non-combustible materials. When these waste disposal off openly cause various harmful effects.

iii Agricultural waste

It includes the waste produced from the crops and cattle etc. Open disposal of thin waste create problems for health of man and other animals.

iv Ash produced by interval power plants.

v Hospital waste is most harmful waste off contains micro organisms which cause both communicable and non-communicable deseases.

List out the waste material in workshop (Fig 1)

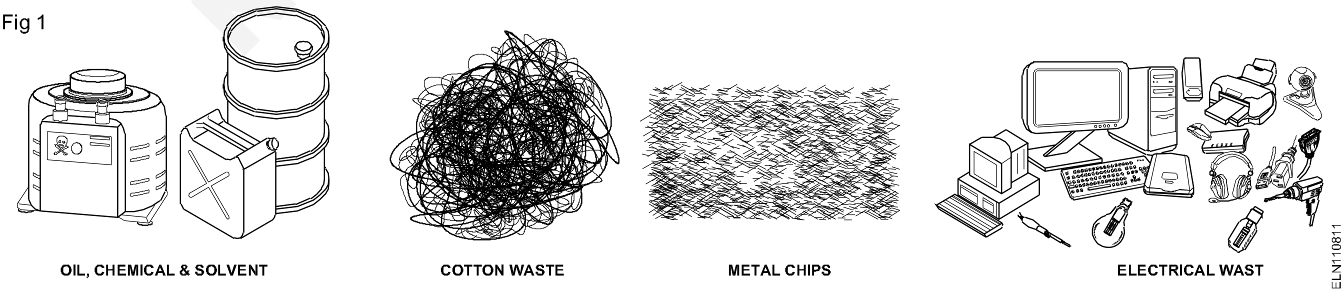
- Oily waste such as lubricating oil, coolant etc.
- Cotton waste.
- Metal chips of different materials.
- Electrical waste such as used and damaged accessories, wires, cables, pipes etc.

Methods of disposal of waste (Fig 2)

Disposal process : This is the final step of the waste management. From this disposal point or site the materials are selected steps as

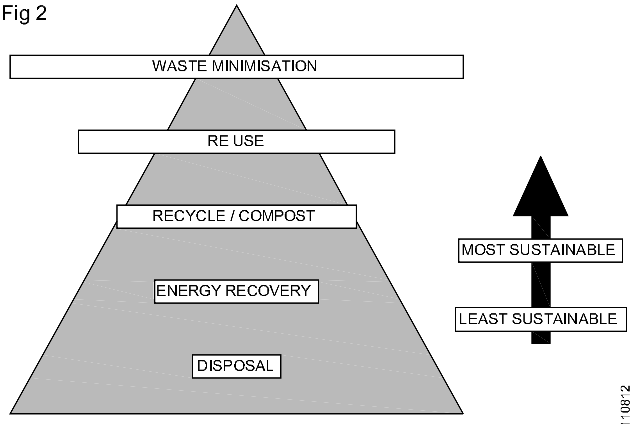
- Recycling
- Composing
- Landfill
- Incineration

Fig 1



- Waste compaction
- Reuse
- Animal Feed
- Fire Wood

Fig 2



METHOD OF WASTE DISPOSAL

Recycling

Recycling is one of the most well known method of managing waste. It is not expensive and can be easily done by you. If you carry out recycling, you will save a lot of energy, resources and thereby reduce pollution.

Composting

This is a natural process that is completely free of any hazardous by-products. This process involves breaking down the material into organic compounds that can be used as manure.

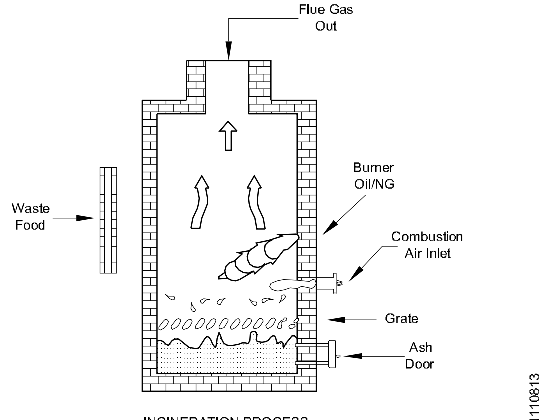
Landfill

In this process, the waste cannot be reused or recycled separated out and spread as a thin layer in some low-lying areas across the city.

Incineration (Fig 3)

It is the process of controlled combustion of garbage to reduce it to incombustible matter, ash, waste gas and heat. It is treated and released into the environment (Fig 3). This reduced 90% volume of waste, some time the heat generated used to produce electric power.

Fig 3



INCINERATION PROCESS

Waste compaction

The waste materials such as cans and plastic bottles compact into blocks and send for recycling. This process need space, thus making transportation and positioning difficult.

Reuse

The amount of waste disposal can be reduced by carefully considering the exact throwing away. Before discarding the item think for the possibility to wash and reuse them.

Animal Feed:

Vegetable peel and food scraps can be retained to feed small animals such as lamsters rabbit etc. Large meat bones will be greately reused by feeding dog.

Fire Wood:

A small amount of waste disposal can be reused when it comes to refurnishing have or replacing furniture. before dicarding the furniture, cut it into more meaningful process and use as fire wood.

Personal Protective Equipment (PPE)

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **state about Personal Protective Equipment (PPE) and its purpose**
- **explain the occupational health safety, hygien**
- **explain occupational hazards**
- **list the most common type of personal protective equipment for hazards**

Personal Protective Equipment (PPE)

The Devices, equipment, or clothing used or worn by the employees, as a last resort, to protect against hazards in the workplace. The primary approach in any safety effort is that the hazard to the workmen should be eliminated or controlled by engineering methods rather than protecting the workmen through the use of personal protective equipment (PPE).

In situations where it is not possible to introduce any effective engineering methods for controlling hazards, the workman shall use appropriate types of PPE.

The Factories Act, 1948 and several other labour legislations 1996 have provisions for effective use of appropriate types of PPE. Use of PPE is an important.

Ways to ensure workplace safety and use personal protective equipment (PPE) effectively.

- Workers to get up-to-date safety information from the regulatory agencies that oversees workplace safety in their specific area.
- To use all available text resources that may be in work area and for applicable safety information on how to use PPE best.
- When it comes to the most common types of personal protective equipment, like goggles, gloves or bodysuits, these items are much less effective if they are not worn at all times, or whenever a specific danger exists in a work process. Using PPE consistently will help to avoid some common kinds of industrial accidents.
- Personal protective equipment is not always enough to protect workers against workplace dangers. Knowing more about the overall context of your work activity can help to fully protect from anything that might threaten health and safety on the job.
- Inspection of gear thoroughly to make sure that it has the standard of quality and adequately protect the user should be continuously carried out.

Categories of PPEs

Depending upon the nature of hazard, the PPE is broadly divided into the following two categories:

1 **Non-respiratory:** Those used for protection against injury from outside the body, i.e. for protecting the head, eye, face, hand, arm, foot, leg and other body parts

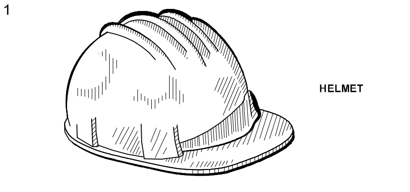
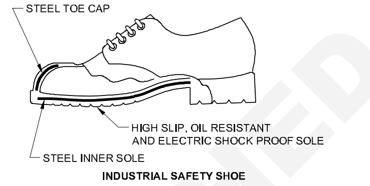
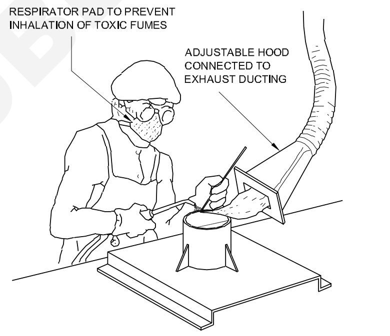
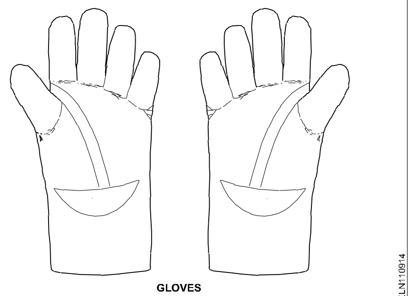
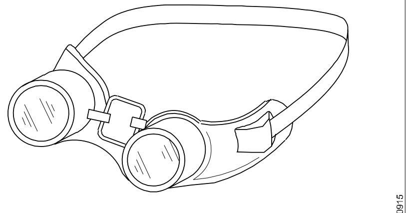
2 **Respiratory:** Those used for protection from harm due to inhalation of contaminated air.

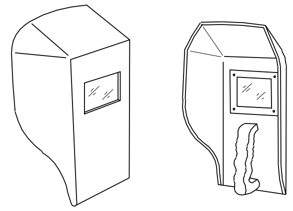
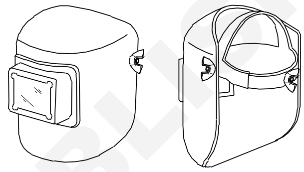
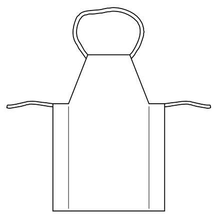
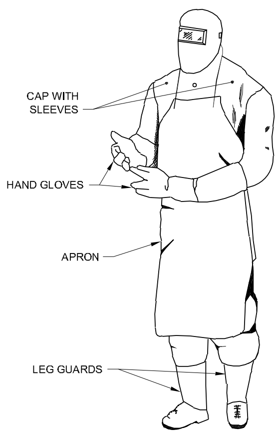
The guidelines on 'Personal Protective Equipment' is issued to facilitate the plant management in maintaining an effective programme with respect to protection of persons against hazards, which cannot be eliminated or controlled by engineering methods listed in table1.

Table1

No.	Title
PPE1	Helmet
PPE2	Safety footwear
PPE3	Respiratory protective equipment
PPE4	Arms and hands protection
PPE5	Eyes and face protection
PPE6	Protective clothing and coverall
PPE7	Ears protection
PPE8	Safety belt and harnesses

Personal protective equipments and their uses and hazards are as follows

Types of protection	Hazards	PPE to be used
Head Protection (Fig 1)	1. Falling objects 2. Striking against objects 3. Spatter	Fig 1  ELN110911
Foot protection (Fig 2)	1. Hot spatter 2. Falling objects 3. Working wet area	Fig 2  **leather leg guards**
Nose (Fig 3)	1. Dust particles 2. Fumes/ gases/ vapours	Fig 3  ELN110913
Hand protecion (Fig 4)	1. Heat burn due to direct contact 2. Blows sparks moderate heat 3. Electric shock	**Hand Gloves** Fig 4  ELN110914
Eye protection (Fig 5)	1. Flying dust particles 2. UV rays, IR rays heat and High amount of visible radiation	**Googgles** Fig 5  ELN110915

Types of protection	Hazards	PPE to be used
Face Protection (Fig 6, Fig 7)	1. Spark generated during Welding, grinding 2. Welding spatter striking 3. Face protection from UV rays	**Face Shield** **Head Shield with or without Ear Muff** **Helmets with screen for welders** Fig 6  HAND SCREEN ELN110916
Ear protection (Fig 7)	1. High noise level	**Head shield with Ear muff** Fig 7  WELDING HELMET ELN110917
Body protection (Fig 8, Fig 9)	1. Hot particles	Fig 8  APRON ELN110918 **Bodyguard** Fig 9  LEG GUARDS ELN110919

Proper use of PPEs

Having selected the proper type of PPE, it is essential that the workman wears it. Often the workman avoids using PPE.

Occupational health hazard and safety

Safety

Safety means freedom or protection from harm, danger, hazard, risk, accident, injury or damage.

Occupational health and safety

- Occupational health and safety is concerned with protecting the safety, health and welfare of people engaged in work or employment.
- The goal is to provide a safe work environment and to prevent hazards.
- It may also protect co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are affected by the workplace environment.

Need of occupational health and safety

- Health and safety of the employees is an important aspect of a company's smooth and successful functioning.
- Improving employee morale
- Reducing absenteeism
- Enhancing productivity
- Minimizing potential of work-related injuries and illnesses
- Increasing the quality of manufactured products and/ or rendered services.

Occupational (Industrial) hygiene

- Occupational hygiene is anticipation, recognition, evaluation and control of work place hazards (or) environmental factors (or) stresses
- Which may cause sickness, impaired health and well being (or) significant discomfort and inefficiency among workers.

Evaluation (Measurement & Assessment): Measuring or calculating the hazard by Instruments, Air sampling and Analysis, comparison with standards and taking judgement whether measured or calculated hazard is more or less than the permissible standard.

Control of workplace hazards: Measures like Engineering and Administrative controls, medical examination, use of Personal Protective Equipment (PPE), education, training and supervision

Types of occupational health hazards

- Physical Hazards
- Chemical Hazards
- Biological Hazards
- Physiological Hazards
- Mechanical Hazards
- Electrical Hazards
- Ergonomic Hazards.

1 Physical hazards

- Noise
- Heat and cold stress
- Illumination etc.,

2 Chemical hazards

- Inflammable
- Explosive

3 Biological hazards

- Bacteria
- Virus

4 Physiological

- Old age
- Sex
- Ill health
- Sickness
- Fatigue.

5 Psychological

- Wrong attitude
- Smoking
- Alcoholism
- Unskilled
- Emotional disturbances
  - voilence
  - bullying
  - sexual harassment

6 Mechanical

- Unguarded machinery
- No fencing

7 Electrical

- No earthing
- Short circuit
- No fuse or cut off device etc,

8 Ergonomic

- Poor manual handling technique
- Wrong layout of machinery
- Wrong design
- Poor housekeeping

Safety Slogan

A Safety rule breaker, is an accident maker

Guidelines for cleanliness of workshop and maintenance

Objectives: At the end of this lesson you shall be able to
- **state the necessity of cleaning of workshop**
- **list the benefits of shop floor cleaning and maintenance**
- **state the common cleaning procedure in workshop**
- **list the different methods of cleaning process**
- **state the concept of 5s techniques and their description**
- **list the benefits of 5s techniques.**

Scan the QR Code to view the video for this exercise

Cleaning process

Cleaning is the process of removal of unwanted matter, contaminants or pollutants from the environment or the prevention of soiling thus it should be - GREEN clean.

'Green-cleaning" means the need to clean up the cleaning process and protect themselves.

> **Cleaning is about removing pollution, not additing to it.**

Necessity of cleaning of workshop

A clean workplace ensures safety and health of employees and injuries can be prevented by taking action to ensure a clean, safe work environment.

Reasons for cleaning the workplace

- Cleaning of dry floors essentially to prevent slips and falls in the workplace.
- Disinfectants prevents the spread germs and illness, because it will stop germs in their tracks.
- Proper air filteration reduces the exposures of hazardous substances like dust and vapors.
- Cleaning of light fixtures improve lighting efficiency.
- Using green cleaning products which is safer for both employees and the environment.
- Proper disposal of waste and recyclable materials keeps work areas clean.

Benefits of a shop floor maintenance

- Productive can be improved.
- Improves operator's efficiencies.
- Improves the support operations such as replacement moves and finished goods.
- Reduction of scrap.
- Manufacturing process can be controlled effectively.
- Reduction of downtime due to better machine and tool manitoring.
- Better control of inventory process.

Common cleaning procedure

- Before starting to clean, read the product and equipment labels and usage instructions.
- Wear recommended Personal Potective Equipment (PPE) like rubber or surgical type gloves, goggles, dust mask or respirator, earplugs etc.
- Cleaning must be performed to prevent or remove soils, contaminants or pollutants.
- Select and use less toxic products and this system is known as **"Standard Operating Procedures" (SOPs)**.
- SOPs is the part of the over all operation and maintenance plan for bending.

Other different methods of cleaning are

- Sprinkling
- Spraying
- Power wash process
- Boiling under pressure
- Carbon dioxide cleaning
- Pre cleaning
- Main cleaning
- Rinsing
- Drying etc,

For improving the standardising the way to clean **Standard Operating Procedures (SOPs)** as a set of written guidelines must be provided to the cleaners which includes

1 Cleaning procedures
2 Chemical handling and tracking requirements
3 Communication protocols
4 Training and inspection programs
5 Reporting and record keeping procedures.

The above guidelines should be made available to all cleaning personel and occupants.

Recommended activities for green cleaning

- Provide easily understood directions to cleaning staff in written with local languages.

- Use the appropriate technology (coarse spray, automatic chemical dispensers etc).
- Provide directory for the proper rinsing and disposal of expended or empty solution containers.
- Reduce, minimize or eliminate the need for using cleaning chemicals if possible.

5 Steps (5s) - Concept

5s is a people-oriented and practice-oriented approach. 5s expects every one to participate in it. It becomes a basic for continuous improvement in the organisation.

The terms (5s) 5 steps are

Step 1: SEIRI (Sorting out)

Step 2: SEITON (Systematic arrangement)

Step 3: SEISO (Shine cleanliness)

Step 4: SEIKTSU (Stanardization)

Step 5: SHITSURE (Self discipline)

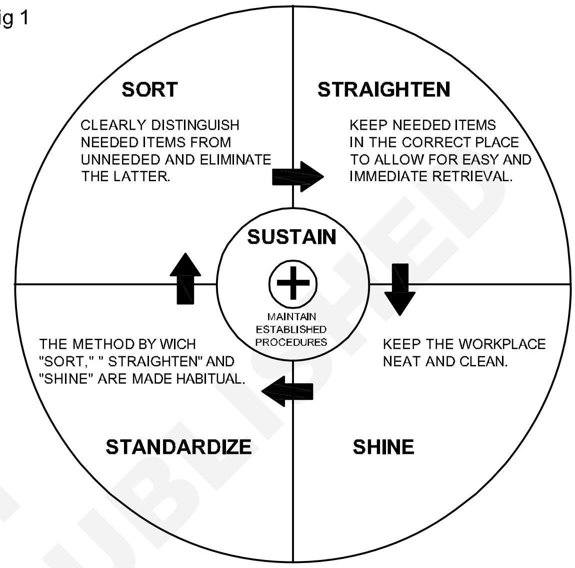
Fig 1 shows the 5s concept wheel.

The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items and sustaining the new order.

Benefits of 5s

- Work place becomes clearer and better organised.
- Working in working place becomes easier.
- Reduction in cost.
- People tend to be more disciplined.
- Delay is avoided.
- Less absenteeism.
- Better use of floor space.
- Less accidents.
- High productivity with quality etc.

Fig 1



5s WHEEL

Trade hand tools - specification - standards - NEC code 2011 - lifting of heavy loads

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **list the tools necessary for an electrician**
- **specify the tools and state the use of each tool.**

It is important that the electrician uses proper tools for his work. The accuracy of workmanship and speed of work depend upon the use of correct tools.

Listed below are the most commonly used tools by electrician.

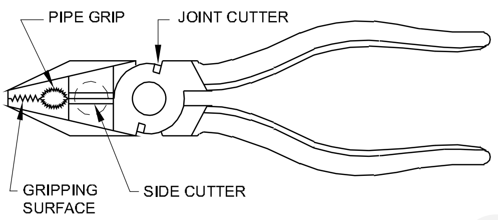
Pliers

The pliers used for electrical work will be of insulated grip.

1 **Combination pliers with pipe grip, side cutter and insulated handle**. BIS 3650 (Fig 1)

Size 150 mm, 200 mm etc.

Fig 1



COMBINATION SIDE CUTTING PLIERS
(ENGINEER'S PLIERS, COMBINATION PLIERS)

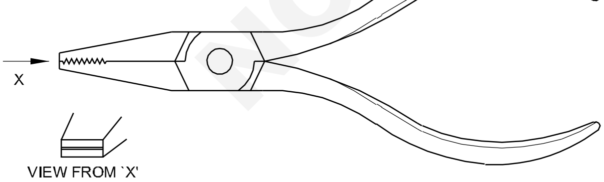
It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work.

2 **Flat nose pliers** BIS 3552 (Fig 2)

Size 100 mm, 150 mm, 200 mm etc.

Flat nose pliers are used for holding flat objects like thin plates etc.

Fig 2

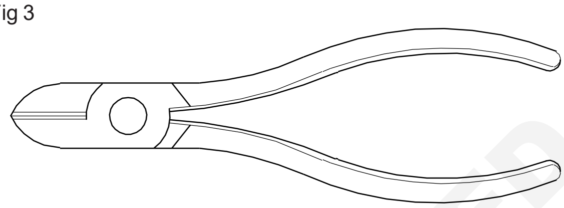


FLAT NOSE PLIERS

3 **Side cutting pliers** (Diagonal cutting pliers) BIS 4378 (Fig 3) Size 100 mm, 150 mm etc.

It is used for cutting copper and aluminium wires of smaller diameter (less than 4mm dia).

Fig 3

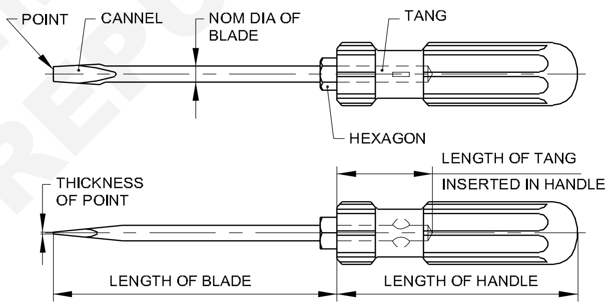


DIAGONAL CUTTING PLIERS/NIPPER

4 **Screwdriver BIS 844** (Fig 4)

The screwdrivers used for electrical works generally have plastic handles and the stem is covered with insulating sleeves. The size of the screw driver is specified by its blade length in mm and nominal screwdriver's point size (thickness of tip of blade) and by the diameter of the stem.

Fig 4



NOMENCLATURE FOR SCREWDRIVERS

eg. 150 mm x 0.6 mm x 4 mm

200 mm x 0.8 mm x 5.5 mm etc.

The handle of screwdrivers is either made of wood or cellulose acetate.

5 **Neon tester** BIS 5579 - 1985 (Fig 5)

It is specified with its working voltage range 100 to 250 volts but rated to 500 V.

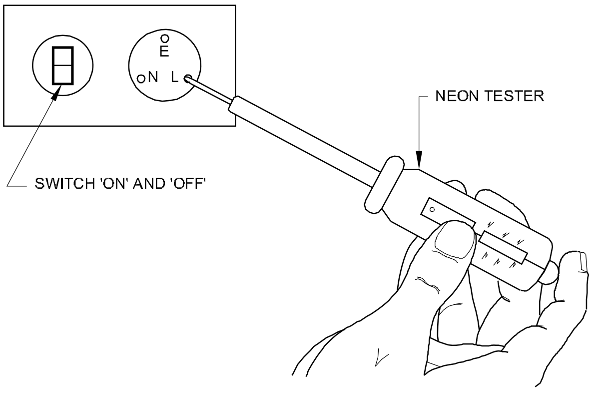
It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amps at the maximum voltage, a high value resistance is connected in series with one of the electrodes.

6 **Electrician's knife** (Double blade) (Fig 6)

The size of the knife is specified by its largest blade length eg. 50 mm, 75 mm.

It is used for skinning the insulation of cables and cleaning the wire surface. One of the blades which is sharp is used for skinning the cable.

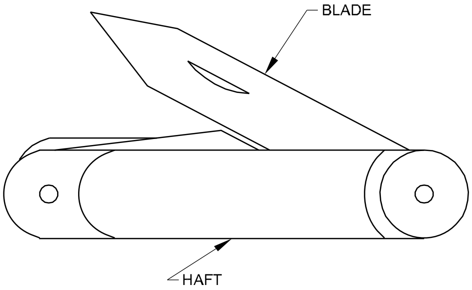
Fig 5



NEON TESTER

ELN11117

Fig 6



ELECTRICIAN'S KNIFE

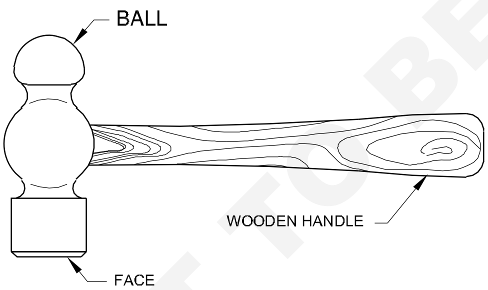
ELN11118

7 **Hammer ball pein (Fig 7)**

The size of the hammer is expressed in weight of the metal head. Eg.125 gms, 250 gms etc.

The hammer is made out of special steel and the striking face is tempered. Used for nailing, straightening, and bending work. The handle is made of hard wood.

Fig 7



BALL PEIN HAMMER

ELN11111A

8 **Try-square** (Engineer's square) (Fig 8) BIS 2103

This is specified by its blade length.

Eg. 50 mm x 35 mm

100 mm x 70 mm

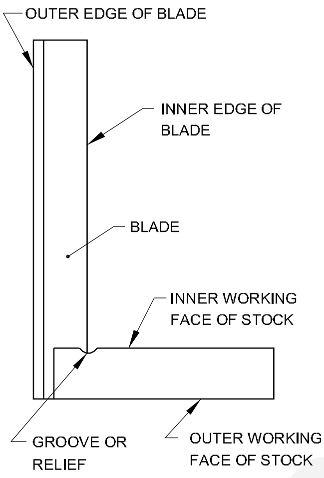
150 mm x 100 mm etc.

Do not use it as a hammer.

9 **Firmer chisel** (Fig 9)

It has a wooden handle and a cast steel blade of 150 mm length. Its size is measured according to the width of the blade eg. 6 mm, 12 mm, 18 mm, 25 mm. It is used for chipping, scraping and grooving in wood.

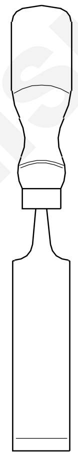
Fig 8



TRY-SQUARE

ELN11111B

Fig 9



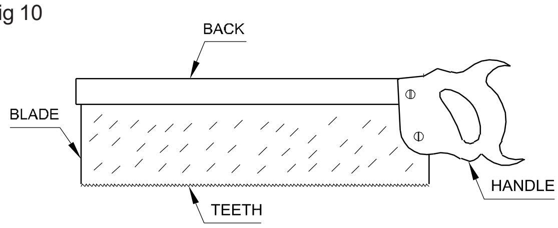
FIRMER CHISEL

ELN11111C

10 Tenon-saw (Fig 10) BIS 5123, BIS 5130, BIS 5031

Generally the length of a tenon-saw will be 250 or 300 mm. and has 8 to 12 teeth per 25.4 mm and the blade width is 10 cm. It is used for cutting thin, wooden accessories like wooden batten, casing capping, boards and round blocks.

Fig 10



TENON-SAW

ELN11111D

11 **Files** (Fig 11) BIS 1931

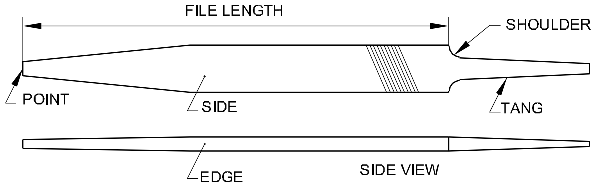
These are specified by their nominal length.

Eg.150 mm, 200 mm, 250 mm 300 mm etc.

These files have different numbers of teeth designed to cut only in the forward stroke. They are available in different lengths and sections (Eg.flat, half round, round, square, triangular), grades like rough, bastard second cut and smooth and cuts like single and double cut.

These files are used to remove fine chips of material from metals. The body of the file is made of cast steel and hardened except the tang.

Fig 11



FILE

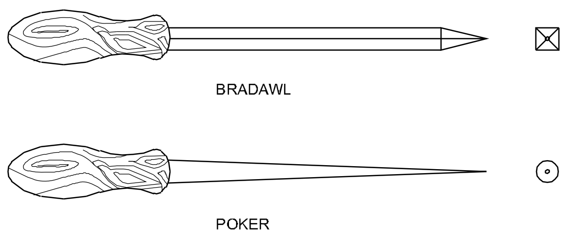
12 **Bradawl square pointed (or poker) (**Fig 12)

BIS 10375 - 1982

It is specified by its length and diameter eg. 150 mm x 6 mm.

It is a long sharp tool used for making pilot holes on wooden articles to fix screws.

Fig 12



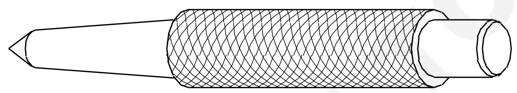
13 **Centre punch** (Fig 13) BIS 7177

The size is given by its length and diameter of the body.

Eg. 100 mm x 8 mm. The angle of the tip of the centre punch is 90°.

It is used for marking and punching pilot holes on metals. It is made of tool steel and the ends are hardened and tempered.

Fig 13

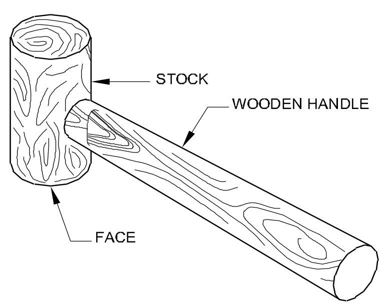


CENTRE PUNCH

14 **Mallet** (Fig 14)

The mallet is specified by the diameter of the head or by the weight.

Fig 14



MALLET

eg. 50 mm x 150 mm

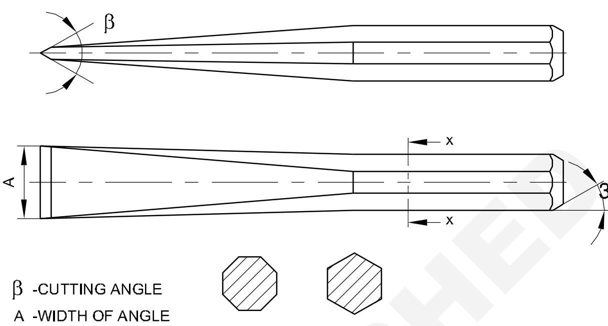
75 mm x 150 mm or 500gms, 1 Kg.

It is made out of hard wood or nylon. It is used for driving the firmer chisel, and for straightening and bending of thin metallic sheets. Also it is used in motor assembly work.

15 **Flat cold chisel** (Fig 15) BIS 402

Its size is given by the nominal width and length.

Fig 15



COLD CHISEL

ie. 14 mm x 100 mm

15 mm x 150 mm

20 mm x 150 mm

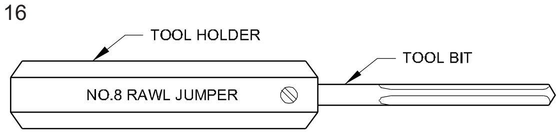
The body shape of a cold chisel may be round or hexagon.

The cold chisel is made out of high carbon steel. Its cutting edge angle varies from 35° to 45°. The cutting edge of the chisel is hardened and tempered. This chisel is used for making holes on wall etc.

16 **Rawl plug tool and bit** (Fig 16)

Its size depends upon the number. As the number increases, the thickness of the bit as well as the plug also decreases. Eg. Nos.8, 10, 12, 14 etc.

Fig 16



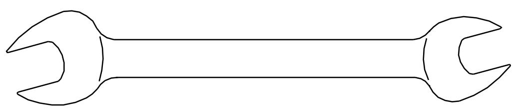
RAWL PLUG TOOL

A rawl plug tool has two parts, namely the tool bit and tool holder. The tool bit is made of tool steel and the holder is made of mild steel. It is used for making holes in bricks, concrete wall and ceiling. Rawl plugs are inserted in them to fix accessories.

17 **Spanner: double ended** (Fig 17) BIS 2028

The size of a spanner is indicated so as to fit on the nuts. They are available in many sizes and shapes.

Fig 17



DOUBLE ENDED OPEN JAW SPANNER

The sizes, indicated in double-ended spanners are

10-11 mm

12-13 mm

14-15 mm

16-17 mm

18-19 mm

20-22 mm.

For loosening and tightening of nuts and bolts, spanner sets are used. It is made out of cast steel. They are available in many sizes and may have single or double ends.

18 Hacksaw frame and blade

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours.

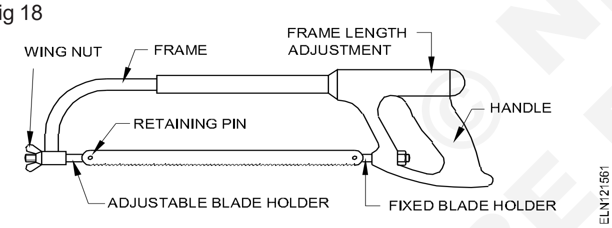
Types of hacksaw frames

Bold frame: Only a particular standard length of blade can be fitted.

Adjustable frame (flat)**:** Different standard lengths of blades can be fitted.

Adjustable frame tubular type (Fig 18)**:** This is the most commonly used type. It gives a better grip and control while sawing.

Fig 18



Hacksaw blades : The hacksaw blade is a thin, narrow, steel band with teeth and two pin holes at the ends. It is used along with a hacksaw frame. These blades are made of either low alloy steel (la) or high speed steel (hs) and are available in standard lengths of 250mm and 300mm.

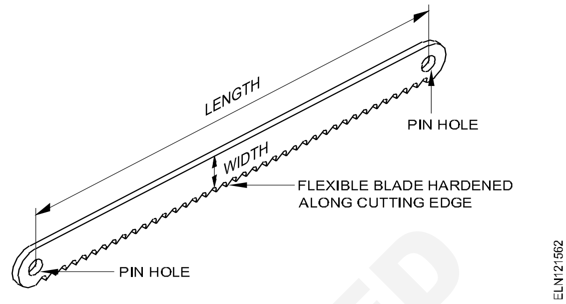
For proper working, it is necessary to have frames of rigid construction.

Types of hacksaw blades

All-hard blades: The width between the pin holes is hardened all allong the length of the blade.

Flexible blades: For these types of blades only the teeth are hardened. Because of their flexibility, these blades are useful for cutting along curved lines (Fig 19).

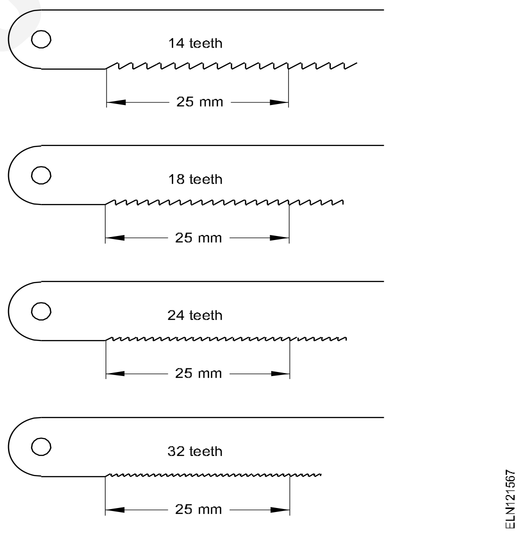
Fig 19



Saw blades for hacksaws are available with small and large cutting of teeth, depending on the type and size of material they are to cut. The size of the teeth is directly related to their pitch, which is specified by the number of teeth per 25mm of the cutting edge. Hacksaw blades are avaialable in pitches of: (Fig 20)

- 14 teeth per 25 mm • 18 teeth per 25 mm
- 24 teeth per 25 mm • 32 teeth per 25 mm.

Fig 20



Standard and standardisation

Objectives: At the end of this lesson you shall be able to
- **state what is meant by standardisation and standard**
- **state the names of various standard organisation**
- **read and interpret the basic concept of electrical code 2011**
- **state the types of injury caused by the improper lifting method**
- **describe the procedure to be followed for moving heavy equipments.**

Standardisation can be defined as the process of formulating and applying rules for an orderly approach to specific activity for the benefit of the user and the manufacturer, and in particular for the promotion of optimum overall economy taking due account of functional conditions and safety requirement.

It is based on the consolidated results of science, technique and experience. It determines not only the basis for the present but also for future development, and to keep pace with progress.

The materials/tools/equipment produced in any country should be of certain standard. To meet this requirement, the international organisation for standarization(ISO) is started and specifies the units of measurement, technology and symbols, products and processes, safety of persons and goods through a number of booklets coded with ISO number.

Standard can be defined as a formulation established verbally, in writing or by any other graphical method or by means of a model, sample or other physical means of representation to serve during a certain period of time for defining designating or specifying certain features of a unit or basis of measurement, physical object, an action, process, method, practice, capacity, function, duty, right of responsibility, a behaviour, an attitude a concept or a conception.

To sell Indian goods in the local and international market certain standardization methods are essential. The standard is specified by the **B**ureau of **I**ndian **S**tandard **BIS**(ISI) for various goods through their booklets. The BIS only certifies a good often the product meets the specification and passes necessary tests. The manufacturer allows to use the BIS(ISI) mark on the product only after BIS certification.

These are a number of organisation for standardisation throughout the world in different countries.

The standard organisation and the respective countries are given below:

BIS	- Bureau of Indian Standard (ISI) - India
ISO	- International standard Organisation
JIS	- Japanese Industrial Standard - Japan
BSI	- British Standards Institution BS(S) - Britain
DIN	- Deutche Industrie Normen - Germany
GOST	- Russian
ASA	- American standards association - America

Advantages of BIS(ISI) certification marks scheme:

A number of advantages accrue to different sectors of economy from the BIS(ISI) certification marks scheme.

To manufacturers

- Streamlining of production processes and introduction of quality control system.
- Independent audit of quality control system by BIS
- Reaping of production economics accruing from standardization
- Better image of products in the market, both internal and overseas
- Winning for whole-salers, retailers and stockists consumer confidence and goodwill
- Preference for ISI-marked products by organised purchasers, agencies of Central and State Governments, local bodies, public and private sector undertakings etc. Some organised purchasers offer even higher price for ISI-marked goods.
- Financial incentives offered by the Industrial Development Bank of India (IDBI) and nationalised banks.

To consumers

- Conformity with Indian Standards by an independent technical, National Organisation
- Help in choosing a standard product
- Free replacement of ISI-marked products in case of their being found to be of substandard quality
- Protection from exploitation and deception
- Assurance of safety against hazards to life and property

Introduction to National Electrical Code - 2011

National Electrical Code - 2011

National electrical code describes several indian standards deciding with the various aspects relating to electrical installation practice. It is there fore recommended that individual parts/ sections of the code should be read in conjunction with the relevant indian standards.

There are 8 parts and each part contains number of sections. Each section refers the description of the electrical item/ devices, equipment etc.

Here, 20 sections of the part - 1 are described which aspect it covers

In part 1, 20 sections are there. Each sections reference is given below.

Section 1 part 1/ section 1 of the code describes the scope of the NEC.

Section 2 covers definition of items with references.

Section 3 covers graphical symbols for diagrams, letter symbols and signs which may be referred for further details.

Section 4 covers of guidelines for preparation of diagrams, chart and tables in electro technology and for marking of conductors.

Section 5 covers units and systems of measurement in electro technology.

Section 6 covers standard values of AC and DC distribution voltage preferres values of current ratings and standard systems frequency.

Section 7 enumerates the fundamental principles of design and execution of electrical installation.

Section 8 covers guidelines for assesing the characteristics of buildings and the electrical installation there in.

Section 9 Covers the essential design and constructional requirement for electrical wiring installation.

Section 10 covers guidelines and general requirements associated with circuit calculators.

Section 11 covers requirements of installation work relating to building services that use electrical power.

Section 12 covers general criteria for selection of equipment.

Section 13 covers general principles of installation and guide lines on initial testing before commissioning.

Section 14 covers general requirements associated with earthing in electrical installations. Specific requirements for earthing in individual installations are covered in respective parts of the code.

Section 15 covers guidelines on the basic electrical aspects of lightning protective systems for buildings and the electrical installation forming part of the system.

Section 16 covers the protection requirements in low voltage electrical installation of buildings.

Section 17 covers causes for low power factor and guidelines for use of capacitors to improve the same in consumer installations.

Section 18 covers the aspects to be considered for selection of equipment from energy conservation point of view and guidence on energy audit.

Section 19 covers guidelines on safety procedures and practices in electrical work.

Section 20 gives frequently referred tables in electrical engineering work.

The above description is part 1 only you can refer remaining parts and section for other electrical installation, items devices and equipments.

Lifting and handling of loads

Many of the accidents reported involve injuries caused by lifting and carrying loads. A electrician may need to install motors, lay heavy cables, do wiring, which may involve a lot of lifting and carrying of loads. Wrong lifting techniques can result in injury.

A load need not necessarily be very heavy to cause injury. The wrong way of lifting may cause injury to the muscles and joints even though the load is not heavy.

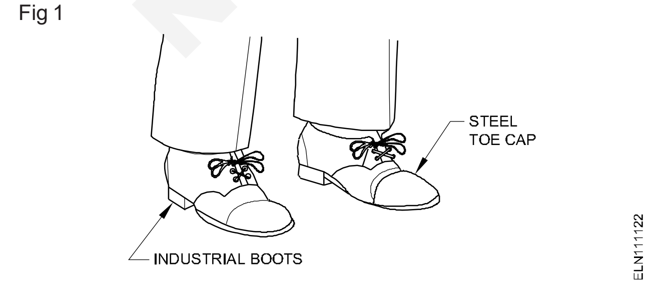
Further injuries during lifting and carrying may be caused by tripping over an object and falling or striking an object with a load.

Crushing of feet or hands

Feet or hands should be so positioned that they will not be trapped by the load. Timber wedges can be used when raising and lowering heavy loads to ensure fingers and hands are not caught and crushed.

Safety shoes with steel toe caps will protect the feet. (Fig 1)

Fig 1



Preparaing to lift : Load which seems light enough to carry at first will become progressively heavier, the farther you have to carry it.

The person who carries the load should always be able to see over or around it.

The weight that a person can lift will vary according to:

- Age
- Physique, and
- Condition

It will also depend on whether one is used to lifting and handling heavy loads.

What makes an object difficult to lift and carry?

1 Weight is not the only factor which makes it difficult to lift and carry.

2 The size and shape can make an object awkward to handle.

3 Loads high require the arms to be extended in front of the body, place more strain on the back and stomach.

4 The absence of hand holds or natural handling points can make it difficult to raise and carry the object.

Correct manual lifting techniques

1 Approach the load squarely, facing the direction of travel

2 The lift should start with the lifter in a balanced squatting position, with the legs slightly apart and the load to be lifted held close to the body.

3 Ensure that a safe firm hand grip is obtained. Before the weight is taken, the back should be straightened and held as near the vertical position as possible. (Fig 2)

4 To raise the load, first straighten the legs. This ensures that the lifting strain is being correctly transmitted and is being taken by the powerful thigh muscles and bones.

5 Look directly ahead, not down at the load while straightening up, and keep the back straight; this will ensure a smooth, natural movement without jerking or straining (Fig 3)

6 To complete the lift, raise the upper part of the body to the vertical position. When a load is near to an individual's maximum lifting capacity it will be necessary to lean back on the hips slightly (to counter balance the load) before straightening up. (Fig 4)

Keeping the load well near to the body, carry it to the place where it is to be set down. When turning, avoid twisting from the waist - turn the whole body in one movement.

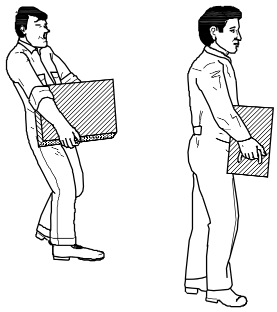
Fig 2

ELN111124

Fig 3

ELN111125

Fig 4



ELN111126

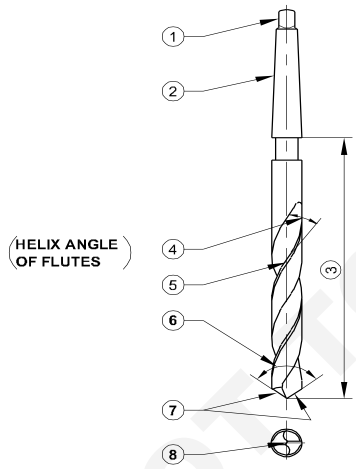
Drills and drilling machines

Objectives : At the end of this lesson you shall be able to
- **state the functions of drills**
- **name the parts of a drill**
- **name the drill bit holders**
- **state the uses of countersunking bits.**

Drill: Drilling is a process of making holes on workpieces by using a drill.

Parts of a drill (Fig 1)

Fig 1



ELN122111

- Tang (1)
- Shank (2)
- Body (3)
- Flute (4)
- Land (5)
- Point angle (6)
- Cutting lip (7)
- Chisel edge (8)

Tang: Tang is the part that fits into the slot of the drilling machine spindle.

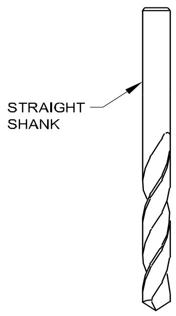
Shank: This is the driving end of the drill which is fitted on the machine. Shanks are of two types.

- Taper shank: for larger diameter drills.
- Straight shank: for smaller diameter drills.

The shank may be parallel or tapered.(Figs 2 & 3) Drills with parallel or straight shanks are made in small sizes, up to 12mm (1/2 in) diameter and the shank has the same diameter as the flutes.

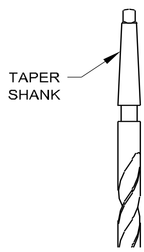
Taper shank drills are made in sizes from 3mm (1/8 in) diameter up to 50mm (2 in) diameter.

Fig 2



ELN122112

Fig 3



ELN122113

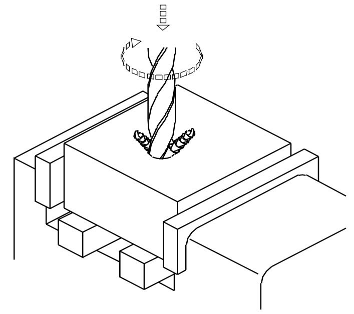
Body: The body is the portion between the point and shank.

Flutes: Flutes are the spiral grooves which run to the length of the drill.

The flutes help:

- to form the cutting edges
- to curl the chips and allow them to come out (Fig 4)

Fig 4



- the coolant to flow to the cutting edge.

Land/margin: Land/margin is the narrow strip which extends to the entire length of the flutes. The diameter of the drill is measured across the land/margin.

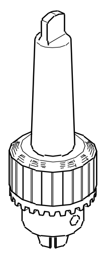
Body clearance: Body clearance is the part of the body which is reduced in diameter to cut down the friction between the drill and the hole being drilled.

Web: Web is the metal column which separates the flutes. It gradually increases in thickness towards the shank.

Drill bit holder

Drill chuck: Drill chuck is attached to the main spindle for straight shank basis. (Fig 5)

Fig 5



Sleeve: This is used to match bit tapers and the spindle taper holes. (Fig 6)

Socket: This is used when the main spindle length is too short, and the bit is changed frequently. (Fig 7)

Taper shank drills are held in taper sockets in the machine.(Fig 8)

Fig 6

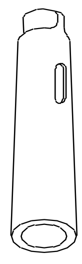


Fig 7

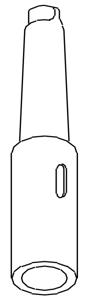
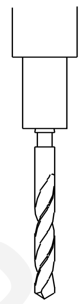


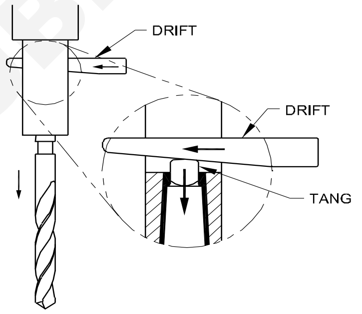
Fig 8



The tang on a taper shank drill enables easy removal of the drill from the socket at the end of the drilling work. This is done using a drift. (Fig 9) The tang also serves to prevent the drill from rotating in the socket.

Use of a coolant: A coolant is used to cool the cutting tool and the job.

Fig 9



Drilling machines

Objectives: At the end of this lesson you shall be able to
- **state the types of hand drilling machines and their uses**
- **state the parts of bench and pillar drilling machine**
- **explain the features of machine vice**

Making holes in sheet metal by using solid punches is a slow and inefficient process.

It is necessary to drill holes when working with heavy material.

The holes can be drilled by hand or by machine. When drilling by hand, a hand drilling machine (Fig 1) or the electric hand drilling machine (Fig 2) is used.

Twist drills are used as a cutting tool for drilling holes. The hand drill is used for drilling holes up to 6.5 mm diameter.

The portable electric hand drilling machine is a very popular and useful power tool. It comes in different sizes and capacities.

The handle shown in Fig 2 is called a pistol grip handle.

The parts of an electric hand machine are shown in Fig 2.

Precautions to be observed : Make sure the holes are properly located and punched with a centre punch.

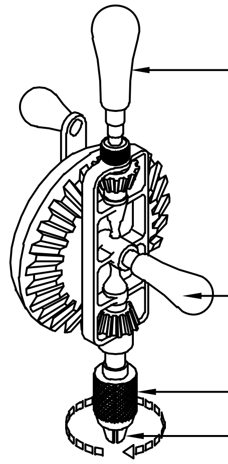
Be sure the drill is properly centred in the chuck by turning (rotating).

Be sure the work is mounted properly in a holding device such as a vice or `G' clamp.

Check the centering of the drill after the point has just started in the metal. Relocate the hole with a centre punch, if necessary. Feed the drill with a light, even pressure.

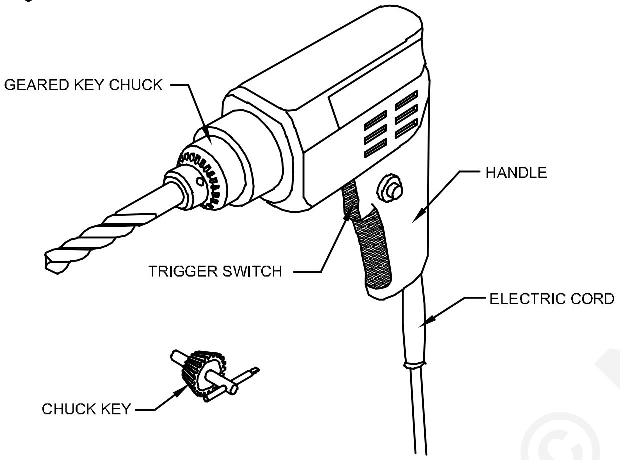
Types of Electric Drilling Machines: Some of the electric drilling machines are listed here.

Fig 1



HAND DRILLING MACHINE

Fig 2



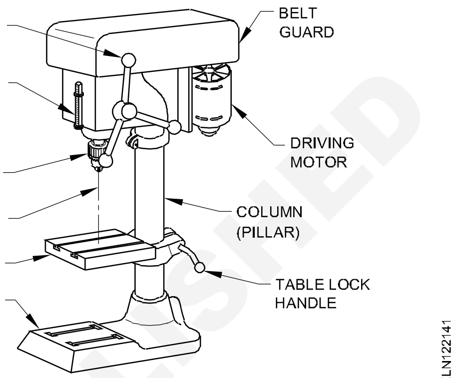
ELECTRIC - HAND DRILLING MACHINE

- The sensitive bench dilling mchine
- The pillar drilling machine
- The radial arm drilling machine. (Radial drilling machine)

(As you are not likely to use the column and radial type of drilling machines now, only the sensitive and pillar type machines are explained here.)

Sensitive bench driling machine: The simplest type of sensitive bench drilling machine is shown in the (figure 3) with its various parts marked. This machine is used for light duty work. (Fig 3)

Fig 3



This machine is capable of drilling holes up to 12.5mm diameter. The drills are fitted in the chuck or directly in the tapered hole of the machine spindle.

The pillar drilling machine: This is an enlarged version of the sensitive bench drilling machine. These drilling machines are mounted on the floor and are driven by more powerful electric motors. They are used for heavy duty work. Pillar drilling machines are available in different sizes. Large machines are provided with a rack and pinion mechanism for moving the table for setting the work.

Fundamental of electricity - conductors - insulators - wire size measurement - crimping

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **define electricity and atom**
- **explain about the atomic structure**
- **define the fundamental terms and definition of electricity**
- **state the conductors, insulators, wires - size measurement methods.**

Introduction: Electricity is one of the today's most useful sources of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

Electricity in motion is called electric current. Whereas the electricity that does not move is called static electricity.

Examples of static electricity

- Shock received from door knobs of a carpeted room.
- Attraction of tiny paper bits to the comb.

Structure of matter: Electricity is related to some of the most basic building blocks of matter that are atoms (electrons and protons). All matter is made of these electrical building blocks, and, therefore, all matter is said to be 'electrical'.

Atom: Matter is defined as anything that has mass and occupies space. A matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into simpler parts by chemical means. The simplest parts of a molecule are called atoms.

Basically, an atom contains three types of sub-atomic particles that are of relevance to electricity. They are the electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus, of the atom, and the electrons travel around the nucleus in orbits.

Atomic structure

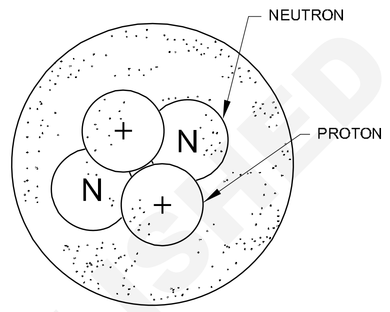
The Nucleus: The nucleus is the central part of the atom. It contains the protons and neutrons in equlal numbrs shown in Fig 1.

Protons: The proton has a positive electrical charge. (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy.

Electron: It is a small particle revolving round the nucleus of an atom (as shown in Fig 2). It has a negative electric charge. The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

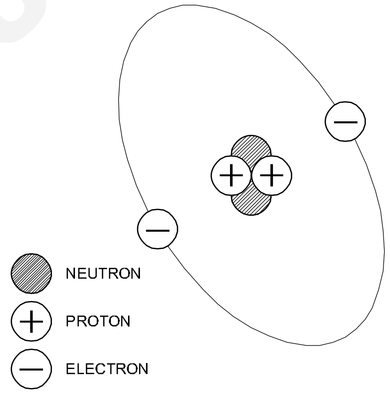
Neutron: A neutron is actually a particle by itself, and is electrically neutral. Since neutrons are electrically neutral, they are not too important to the electrical nature of atoms.

Fig 1



NUCLEUS OF AN ATOM

Fig 2



Energy shells

In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major shell layers are identified by numbers or by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each shell. Fig 3 illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a copper atom which has 29 electrons would have four shells with a number of electrons in each shell as shown in Fig 4.

Fig 3

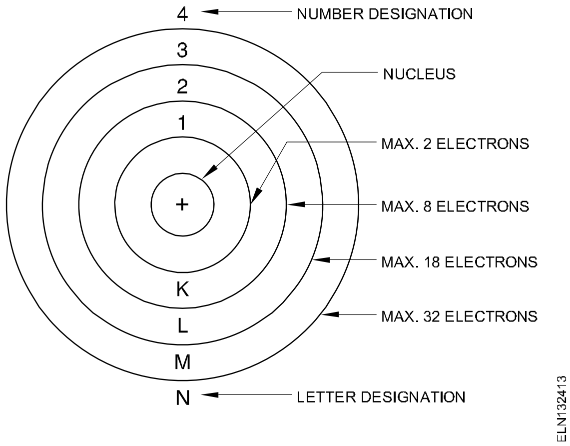
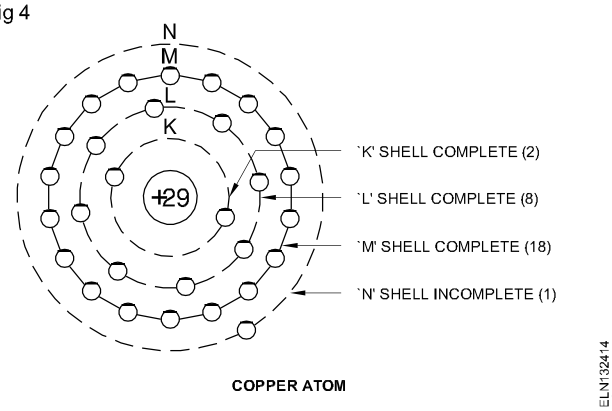


Fig 4



COPPER ATOM

Similarly an aluminium atom which has 13 electrons has 3 shells as shown in Fig 5.

Electron distribution: The chemical and electrical behaviour of atoms depends on how completely the various shells and sub-shells are filled.

Atoms that are chemically active have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

Conductors, insulators and semiconductors

Conductors: A conductor is a material that has many valance electrons permitting electrons to move through it easily. Generally, conductors have many valence shells of one, two or three electrons. Most metals are conductors.

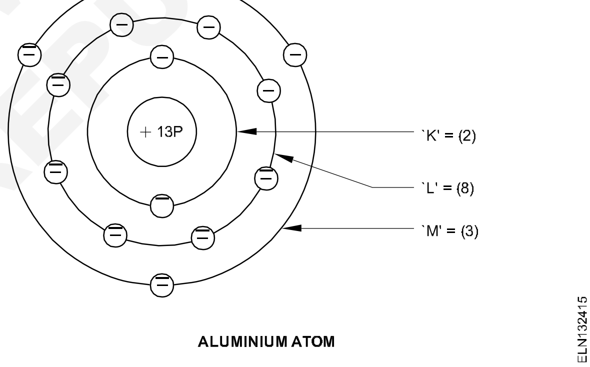
Some common good conductors are Copper, Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, are conductors, where as silver and gold are very good conductors

Insulators: An insulator is a material that has few, if any, free electrons and resists the flow of electrons. Generally, insulators have full valence shells of five, six or seven electrons. Some common insulators are air, glass, rubber, plastic, paper, porcelain, PVC, fibre, mica etc.

Semiconductors: A semiconductor is a material that has some of the characteristics of both the conductor and insulator. Semiconductors have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

Fig 5



ALUMINIUM ATOM

Simple electrical circuit and its elements

Objectives: At the end of this lesson you shall be able to
- **describe a simple electric circuit**
- **explain the current, its units and method of measurement (ammeter)**
- **explain the emf, potential difference, their units and method of measurement (voltmeter)**
- **explain resistance and its unit, and quantity of electricity.**

Simple electric circuit

A simple electrical circuit is one in which the current flows from the source to a load and reaches back the source to complete the path.

A simple electrical circuit is shown in Fig 1

Electric current

Fig 2 shows a simple circuit which consists of a battery as the energy source and a lamp as the resistance. In this circuit, when the switch is closed, the lamp glows because of the electric current flows from the +ve terminal of the source (battery) via the lamp and reaches back the –ve terminal of the source.

Flow of electric current is nothing but the flow of free electrons. Actually the electrons flow is from the negative terminal of the battery to the lamp and reaches back to the positive terminal of the battery.

However direction of current flow is taken conventionally from the +ve terminal of the battery to the lamp and back to the –ve terminal of the battery. Hence, we can conclude that conventional flow of current is opposite to the direction of the flow of electrons. Throughout the Trade Theory book, the current flow is taken from the +ve terminal of source to the load and then back to the –ve terminal of the source.

Fig 1

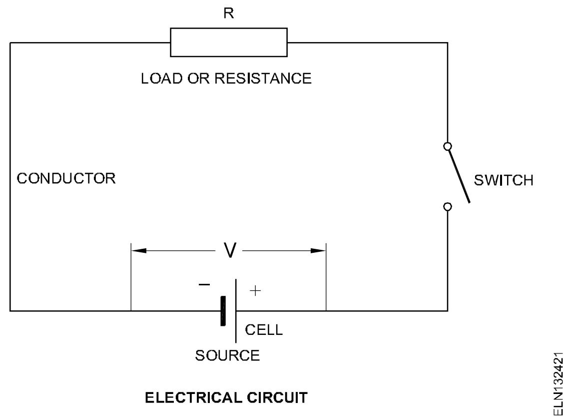
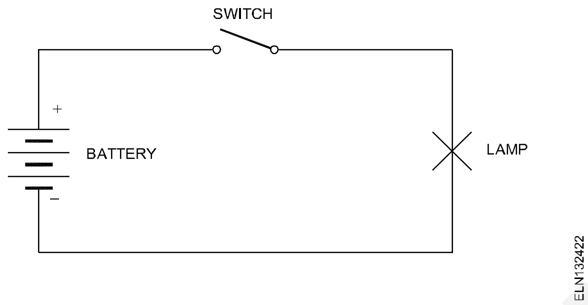


Fig 2



Ampere

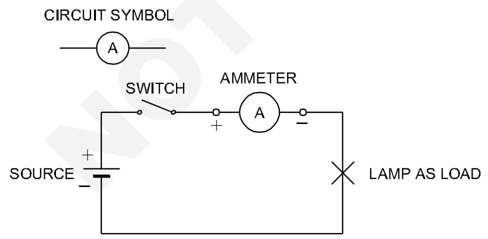
The unit of current (abbreviated as I) is an ampere (symbol A). If 6.24 x 10^{18} electrons pass through a conductor per second having one ohm resistance with a potential difference of one volt causes one ampere current has passed through the conductor.

Ammeter

We know the electrons cannot be seen and no human being can count the electrons. As such an instrument called ammeter is used to measure the current in a circuit.

As an ammeter measures the flow of current in amperes it should be connected in series with the resistance (Load) as shown in Fig 3.

Fig 3

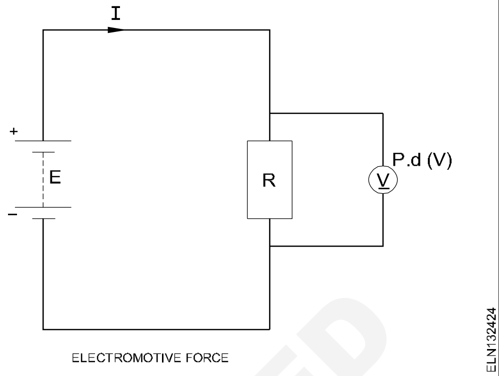


Electro Motive Force (EMF)

In order to move the electrons in a circuit- that is to make the current to flow, a source of electrical energy is required. In a torch light, the battery is the source of electrical energy.

Within the battery the negative terminal contains an excess of electrons whereas the positive terminal has a deficit of electrons. The battery is said to have an electromotive force (emf) which is available to drive the free electrons in the closed path of the electrical circuit. The difference in the distribution of electrons between the two terminals of the battery produces this emf.

Fig 4



In Simple,

Electromotive force (EMF) is the electrical force, which is initially available in elecrical source, cause to move the free electrons in a conductor

Its unit is 'Volt'

It is denoted by letter 'E'

It cannot be measured by any meter. It can be only calculated by using the formula

E = Potential Difference (P.D) + V. drop

= p.d + V.drop

E = V + IR

Electromotive force is essential to drive the electrons in circuit

System International (SI) unit of electromotive force is Volts (symbol 'E')

Potential Difference (PD)

The difference of volatge and pressure across two points in a circuit is called a potential difference (p.d) and is measured in volts.

In a circuit, when a current flows, there will be a potential difference across the terminals of the resistor/load. In the circuit shown in Fig 4, when the switch is in open conidition, the voltage across the terminals of the cell is called electromotive force (E) whereas when the switch is in the closed position, the voltage across the cell is called potential difference (p.d) which wil be lesser in value than the electromotive force earlier measured. This is due to the fact that the internal resistance of the cell drops a fer volts when the cell supplies current to the load.

The force which causes current to flow in the circuit is called emf. Its symbol is E and its unit is Volts (V). It can be calculated as

EMF = voltage at the terminal of source of supply + voltage drop in the source of supply

or emf = V_T + IR

Terminal voltage (p.d)

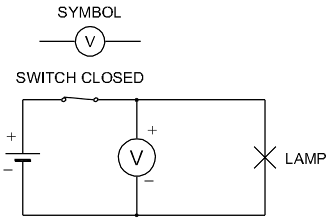
It is the voltage available at the terminal of the source of supply. Its symbol is V_T. Its unit is also the volt and is also measured by a voltmeter. It is given by the emf minus the voltage drop in the source of supply, i.e.

V_T = EMF - IR

Hence EMF is always greater than p.d [E.M.F>p.d]

Voltmeter : Electrical voltage is measured with a voltmeter.The voltmeter connection is across or it is a parallel connection (Fig 5).

Fig 5



Resistance (R) : The resistance is the property of opposition to the flow of the current offered by the circuit elements like resistance of the conductor or load is limit the flow of current.

> **In absence of resistance in a circuit, the current will reach an abnormal high value endangering the circuit itself.**

Ohm : The unit of electrical resistance (abbreviated as R) is ohm (symbol Ω).

Meter to measure resistance

Ohmic value of a medium resistance is measured by an ohmmeter or a Wheatstone bridge.

International Ohm : It is defined as that resistance offered to an unvarying current (DC) by a column of mercury at the temperature of melting ice (i.e. 0°C), 14.4521 g in mass, of constant cross-sectional area (1 sq. mm) and 106.3 cm in length.

International ampere

One international ampere may be defined as that unvarying current (DC) which when passed through a solution of silver nitrate in water, deposits silver at the rate of 1.118 mg per second at the cathode.

Internation volt

It is defined as that potential difference which when applied to a conductor whose resistance is one international ohm produces a current of one international ampere. Its value is equal to 1.00049V.

Conductance

The property of a conductor which conducts the flow of current through it is called conductance. In other words, conductance is the reciprocal of resistance. Its symbol is G (G = 1/R) and its unit is mho represented by ℧. Good conductors have large conductances and insulators have small conductances. Thus if a wire has a resistance of R Ω, its conductance will be 1/R

Quantity of electricity

As the current is measured in terms of the rate of flow of electricity, another unit is necessary to denote the quantity of electricity (Q) passing through any part of the circuit in a certain time. This unit is called the coulomb (C). It is denoted by the letter Q. Thus

Quantity of electricity = current in amperes (I) x time in seconds (t)

or Q = I x t

Coulomb

It is the quantity of electricity transferred by a current of one ampere in one second. Another name for the above unit is the ampere-second. A larger unit of the quantity of electricity is the ampere-hour (A.h)

Types of electrical supply

Objectives: At the end of this lesson you shall be able to
- **explain the difference types of electrical supply**
- **differentiate between alternating current and direct current**
- **explain the method of identification of polarity in DC source**
- **state the effect of electric current**

Type of electrical supply (Voltage)

There are two types of electrical supply in use for various technical requirements. The alternating current supply (AC) and the direct current supply (DC).

__ DC is represented by this symbol.

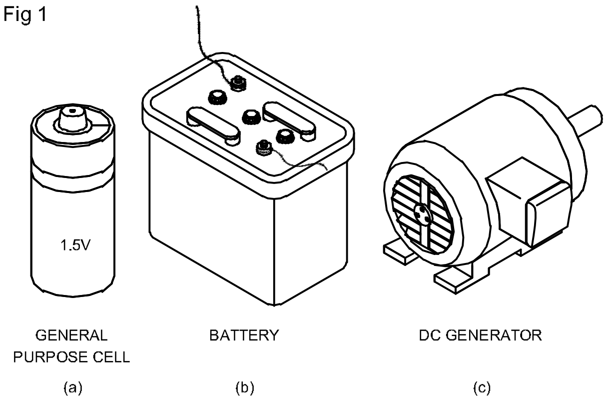
~ AC is represented by this symbol.

DC Supply

The most common sources of DC supply are the cells/ batteries (Figs 1a and 1b) and DC generators (dynamos). (Fig 1C)

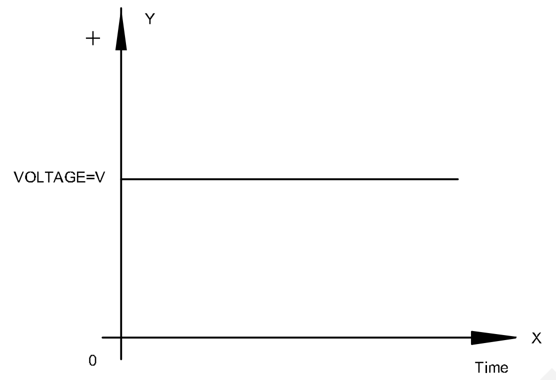
Direct voltage is of constant magnitude (amplitude). It remains at the same amplitude from the moment of switching on to the moment of switching off. The polarity of the voltage source does not change. (Fig 2)

Fig 1



VARIOUS DC SOURCES

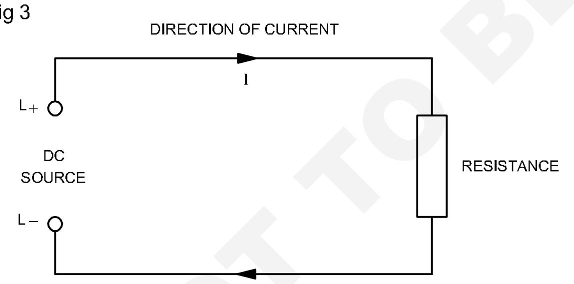
Fig 2



LINEAR VOLTAGE CHARCTERISTIC

The polarity of direct voltage (commonly known as DC voltage) is positive (+ve) and negative (–ve). The direction of conventional flow of current is taken as from the positive to the negative terminal outside the source. (Fig 3)

Fig 3



Thus direct current remains at the same value from the moment of switching on to the moment of switching off. (Direct current in common usage is known as DC current.)

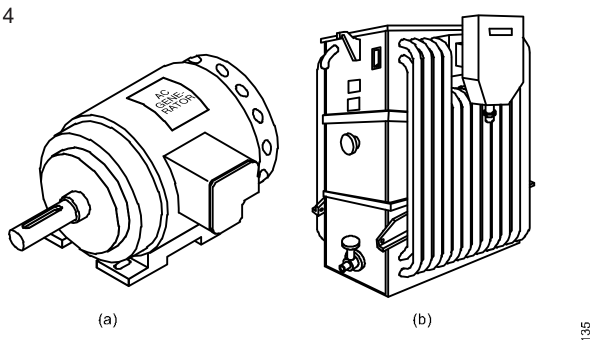
AC Supply

The source of AC supply is AC generators (alternators). (Fig 4a) The supply from a transformer (Fig 4b) is also AC.

Alternating voltage

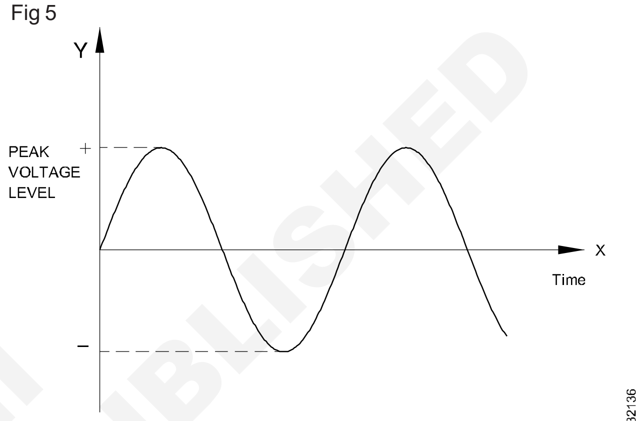
AC supply sources change their polarity constantly, and consequently the direction of voltage also magnitude. The voltage supplied to our homes by power plants is alternating. Fig 5 shows a sinusoidal alternating voltage over time (wave-form).

Fig 4



VARIOUS AC SOURCES

Fig 5



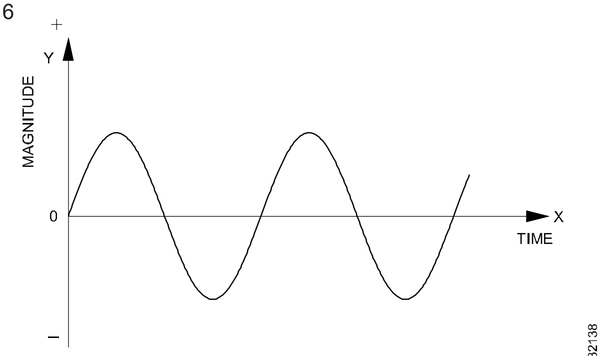
AC VOLTAGE

AC supply is expressed by the effective value of the voltage, and the number of times it changes in one second is known as frequency. Frequency is represented by 'F' and its unit is in Hertz(Hz).

AC supply terminals are marked as phase/line(L) and neutral(N).

Current is caused in an electric circuit due to the application of voltage. If an alternating voltage is applied to an electrical circuit, an alternating current (commonly known as AC current) will flow. (Fig 6)

Fig 6



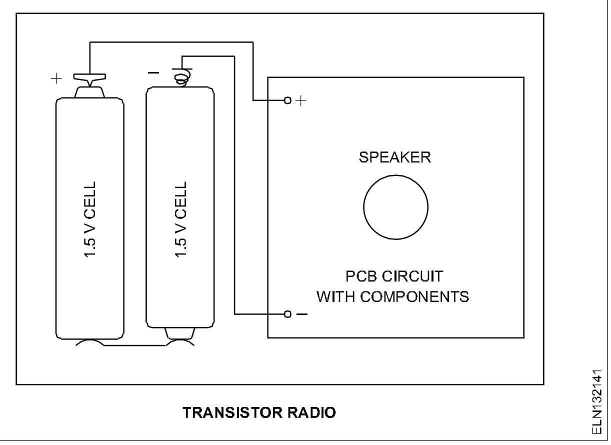
ALTERNATING CURRENT

Polarity test in DC

Polarity

The polarity of a DC supply source should be identified as positive or negative. We can also use the term to indicate how an electric device is to be connected to the supply. For example, when putting new cells in a transistor radio we must put the cells correctly such that the positive terminal of one cell connects to the positive terminal of the radio and the negative terminal of the other cell connects to the negative terminal of the radio as shown in Fig 7.

Fig 7



Importance of the polarity

Direct current supply has fixed polarity, positive and negative marked as + and –. Electric devices which have positive and negative identifications on their terminals are said to be polarised. When connecting such devices to a source of voltage (such as a battery or DC supply)

We must observe the correct polarity markings. That is the positive terminal of the device must be connected to the positive terminal of the source, and the negative to the negative. If the polarity is not observed correctly (that is, if +ve is connected to –ve) the device will not function and may be damaged.

Effects of electric current

When an electric current flows through a circuit, is judged by its effects, which are given below.

1 Chemical effect

When an electric current is passed through a conducting liquid (i.e. acidulated water) called an electrolyte, it is decomposed into its constituents due to chemical action. The practical application of this effect is utilized in electroplating, block making, battery charging, metal refinery, etc.

2 Heating effect

When an electric potential is applied to a conductor, the flow of electrons is opposed by the resistance of the conductor and thus some heat is produced. The heat produced may be greater or lesser according to the circumstances, but some heat is always produced. The application of this effect is in the use of electric presses, heaters, electric lamps, etc.

3 Magnetic effect

When a magnetic compass is placed under a current carrying wire, it is deflected. It shows that there is some relation between the current and magnetism. The wire carrying current does not become magnet but produces a magnetic field in the space. If this wire is wound on an iron core (i.e. bar), it becomes an electro-magnet. This effect of electric current is applied in electric bills, motors, fans, electric instruments, etc.

4 Gas ionization effect

When electrons pass through a certain gase sealed in a glass tube, it becomes ionised and starts emitting light rays, such as in fluorescent tubes, mercury vapour lamps, sodium vapour lamps, neon lamps, etc.

5 Special rays effect

Special rays like X-rays and laser rays can also be developed by means of an electric current.

6 Shock effect

The flow of current through the human body may cause a severe shock or even death in many cases. If this current is controlled to a specific value, this effect of current can be used to give light shocks to the brain for the treatment of mental patients.

Conducting materials and their comparison

Objectives: At the end of this lesson you shall be able to
- **differentiate between conducting and insulating materials**
- **state the electrical properties of conducting materials**
- **state the characteristics of copper and aluminium conductors**
- **state the types and propertites of insulating materials.**
- **describe the method of measurement of wire size using SWG**
- **explain the method of measure wire size by outside micrometer**

Conductors and insulators

Material with high electron mobility (many free electrons) are called conductor.

Materials that contain many free electrons and are capable of carrying an electric current are known as conductors.

Examples - silver, copper, aluminium and most other metals.

Materials with low electron mobility (few (or) no free electron) are called insulators

Materials that have only a few electrons and are incapable of allowing the current to pass through them are known as insulators.

Examples - wood, rubber, PVC, porcelain, mica, dry paper and fibreglass.

Copper and aluminium

In electrical work, mostly copper and aluminium are used for conductors. Though silver is a better conductor than copper, it is not used for general work due to higher cost.

Copper used in electrical work is made with a very high degree of purity, say 99.9 percent.

Characteristics of copper

1 It has the best conductivity next to silver.

2 It has the largest current density per unit area compared to other metals. Hence the volume required to carry a given current is less for a given length.

3 It can be drawn into thin wires and sheets.

4 It has a high resistance to atmospheric corrosion: hence, it can serve for a long time.

5 It can be joined without any special provision to prevent electrolytic action.

6 It is durable and has a high scrap value.

Next to copper, aluminium is the metal used for electrical conductors.

Characteristics of aluminium

1 It has good conductivity, next to copper. When compared to copper, it has 60.6 percent conductivity. Hence, for the same current capacity, the cross-section for the aluminium wire should be larger than that for the copper wire.

2 It is lighter in weight.

3 It can be drawn into thin wires and sheets. But loses its tensile strength on reduction of the cross-sectional area.

4 A lot of precautions needs to be followed while joining aluminium conductors.

5 The melting point of aluminium is low, hence it may get damaged at points of loose connection due to heat developed.

6 It is cheaper than copper.

Table 1 shows the properties of copper compared with those of aluminium.

Table 1

Chararacteristics of conductor materials

Sl. No.	Properties	Copper (Cu)	Aluminium (Al)
1	Colour	Reddish	White brown
2	Electrical conductivity in MHO/metre	56	35
3	Resistivity at 20°C in ohm/metre (Cross-sectional area in 1 mm^2)	0.01786	0.0287
4	Melting point	1083°C	660°C
5	Density in kg/cm^3	8.93	2.7
6	Temperature coefficient of resistance at 20°C per °C	0.00393	0.00403
7	Coefficient of linear expansion at 20°C per °C	17×10^{-6}	23×10^{-6}
8	Tensile strength in Nw/mm^2	220	70

Properties of insulating materials

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. They are entirely different from each other and measured in different ways.

Insulation resistance

Megohmmeter (Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megohms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Dielectric strength

It is the measure of how much potential difference the insulation layer can withstand without breaking down. The potential difference that causes a breakdown is called the breakdown voltage of the insulation.

Every electrical device is protected by some kind of insulation. The desirable characteristics of insulation materials are:

- high dielectric strength
- resistance to temperature
- flexibility
- mechanical strength.

No single material has all the characteristics required for every application. Therefore, many kinds of insulating materials have been developed.

Measurement of wire sizes - standard wire gauge - outside micrometer

Necessity of measuring the wire sizes

A proper estimate involves determination of current in different loads, correct selection of the type of cable, size of the cable and the required quantity. Any error will result in defective wiring, fire accidents and bring unhappiness to both the house owner and the electrician.

A sound knowledge about the area of the cross-section of the core, the diameter of the single strand of the conductor and the number of conductors in each core of the stranded conductor is essential for a wireman to be successful in his carreer.

Table 1 - Conversion table SWG to mm/inch

SWG No.	mm	inch
0	8.23	0.324
1	7.62	0.300
2	7.01	0.276
3	6.40	0.252
4	5.89	0.234
5	5.38	0.212
6	4.88	0.192
7	4.47	0.176
8	4.06	0.160
9	3.66	0.144
10	3.25	0.128
11	2.95	0.116
12	2.64	0.104
13	2.34	0.092
14	2.03	0.080
15	1.83	0.072
16	1.63	0.064
17	1.42	0.056
18	1.22	0.048
19	1.02	0.040
20	0.91	0.036
21	0.81	0.032
22	0.71	0.028
23	0.61	0.024
24	0.56	0.022
25	0.51	0.020
26	0.46	0.018
27	0.42	0.0164
28	0.38	0.0148
29	0.34	0.0136
30	0.31	0.0124
31	0.29	0.0116
32	0.27	0.0108
33	0.25	0.0100
34	0.23	0.0092
35	0.21	0.0084
36	0.19	0.0076

To measure the size of conductors, a electrician can use normally a standard wire gauge or an outside micrometer for more accurate results.

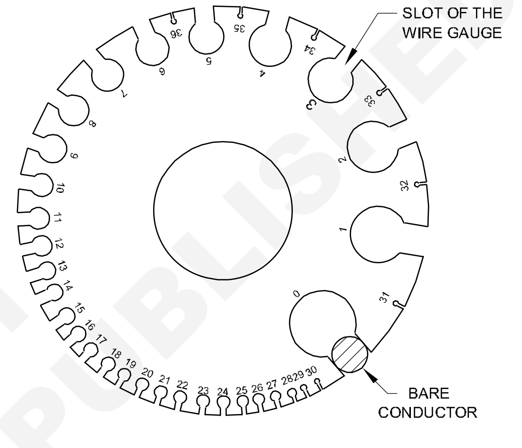
Standard Wire Gauge (SWG)

The size of the conductor is given by the standard wire gauge number. According to the standards each number has an assigned diameter in inch or mm. This is given in Table 1. The standard wire gauge, shown in Figure 1 could measure the wire size in SWG numbers from 0 to 36. It should be noted that the higher the number of wire gauge the smaller is the diameter of the wire.

For example, SWG No. 0 (zero) is equal to 0.324 inch or 8.23 mm in diameter whereas SWG No.36 is equal to 0.0076 inch or 0.19 mm in diameter.

While measuring the wire, the wire should be cleaned and then inserted into the slot of the wire gauge to determine the SWG number.

Fig 1

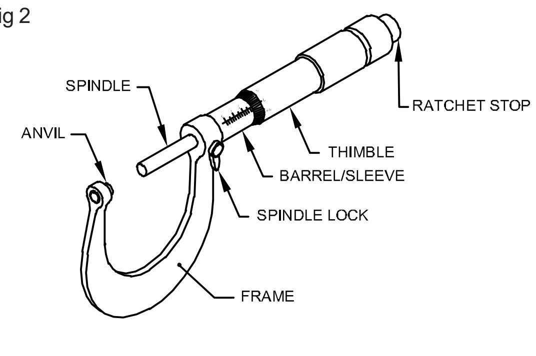


STANDARD WIRE GAUGE

Measurement of wire size by outside mirometers : A micrometer is a precision instrument used to measure a job, generally within an accuracy of 0.01 mm.

Micrometers used to take the outside measurements are known as outside micrometers. (Fig 2)

Fig 2



OUTSIDE MICROMETER - PARTS

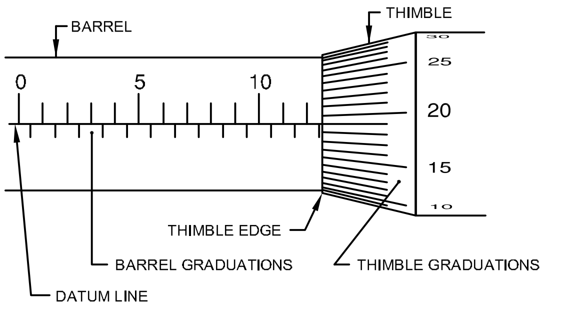
Principle of the micrometer : The micrometer works on the principle of screw and nut. The longitudinal movement of the spindle during one rotation is equal to the pitch of the screw. The movement of the spindle to the distance of the pitch or its fractions can be accurately measured on the barrel and thimble.

Graduations : In metric micrometers the pitch of the spindle thread is 0.5 mm.

Thereby, in one rotation of the thimble, the spindle advances by 0.5 mm.

In a 0-25 mm outside micrometer, on the barrel a 25 mm long datum line is marked. (Fig 3) This line is further graduated in millimetres and half millimetres (ie. 1 mm & 0.5 mm). The graduations are numbered as 0, 5, 10, 15, 20 & 25 mm on the barrel.

Fig 3



GRADUATIONS MARKINGS ON OUTSIDE DIAMETER

The circumference of the bevel edge of the thimble is graduated into 50 divisions and marked 0-5-10-15... 45-50 in a clockwise direction.

The distance moved by the spindle during one rotation of the thimble is 0.5 mm.

Movement of one division of the thimble

= 0.5 x 1/50 = 0.01 mm.

This value is called the least count of the micrometer.

The accuracy or least count of a metric outside micrometer is 0.01 mm.

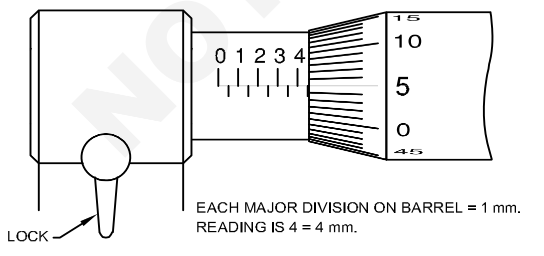
Outside micrometers are available in ranges of 0 to 25 mm, 25 to 50 mm, and so on. For electrician, to read the size of the wire 0 to 25 mm is only suitable.

Reading micrometer measurements

How to read a measurement with an outside micrometer?

a Read on the barrel scale, the number of whole millimetres that are completely visible from the bevel edge of the thimble. It reads 4 mm. (Fig 4)

Fig 4

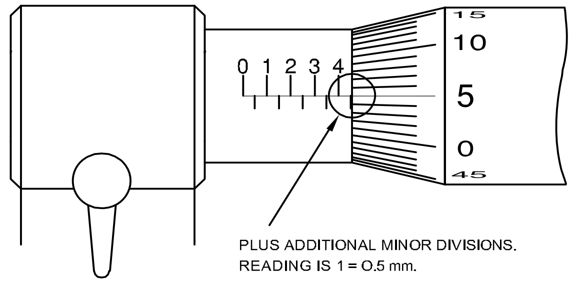


READING MICROMETER MEASUREMENT

b Add to this any half millimetre that is completely visible from the bevel edge of the thimble and away from the whole millimetre reading.

The figure reads one division (Fig 5) mm after the 4 mm mark. Hence 0.5 mm to be added to the previous reading.

Fig 5



THIMBLE READING ON MICROMETER

c Add the thimble reading to the two earlier readings.

The figure shows the 5th division of the thimble is coinciding with the datum line of the barrel. Therefore, the reading of the thimble is 5 x 0.01 mm = 0.05 mm. (Fig 5)

The total reading of the micrometer.

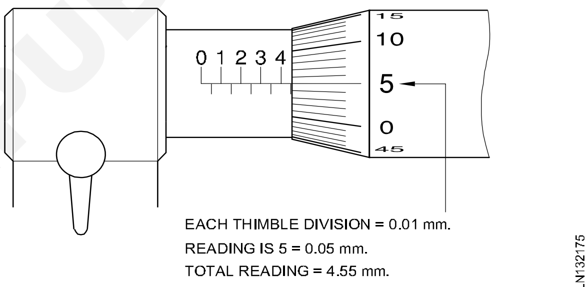
a 4.00 mm

b 0.50 mm

c 0.05 mm.

Total reading = 4.55 mm (Fig 6)

Fig 6



Precautions to be followed while using a micrometer

Before using the micrometer for measurement, it is necessary to ascertain that there is no error in the micrometer. To find the error, close the jaws of the measuring surfaces using the ratchet. Read the micrometer. If the thimble zero is coincident with the datum line of the barrel, error is zero. If it reads higher value, the error is +ve; if it reads lesser value the difference between zero and the read value is -ve error.

If there is minus error it should be added to the total reading and if there is plus error the value should be subtracted from the total reading.

The faces of the anvil and spindle must be free from dust, dirt and grease.

While reading the micrometer, the spindle must be locked with the reading.

Do not drop or handle the micrometer roughly.

Skinning of cables

Objective: At the end of this lesson you shall be able to
- **state the method of skinning of cable.**

While, using aluminium cables proper care is to be taken regarding the following.

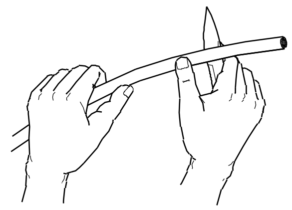
- Handling
- Skinning of the cables
- Connecting the cable ends

Handling: Remember that aluminium conductors when compared to copper conductors have less tensile strength and less resistance to fatigue. As such, bending or twisting of aluminium conductors while laying the cables should be avoided as far as possible.

Skinning of cables: While skinning the insulation from the cables, knicks and scratches should be avoided. As shown in Fig 1, the insulation should not be ringed as there is a danger of nicking the aluminium conductor while ringing the insulation with a knife.

Using the knife as shown in Fig 2 at an angle of 20° to the axis of the core will avoid knicking of the conductor.

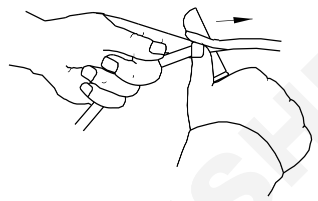
Fig 1



WRONG METHOD

ELN132181

Fig 2



RIGHT METHOD

ELN132182

Cable end termination - crimping tool

Objectives: At the end of this lesson you shall be able to:
- **state the necessity of proper termination**
- **list the different types of terminations**
- **describe the parts and their functions of crimping tool**
- **state the advantages of crimping termination**

Necessity of termination

Cables are terminated at electrical appliances, accessories and equipment etc. for providing electrical connections. All terminations must be made to provide good electrical continuity, and made in such a manner as to prevent contact with other metallic parts and other cables.

Loose terminations will lead to overheating of cables, plugs and other connecting points due to higher resistance at those terminations. Fires may also be started due to the excess heat. Wrong termination like excess or extended conductor touching metallic part of the equipment may lead to giving shock to the person who comes in contact with the equipment.

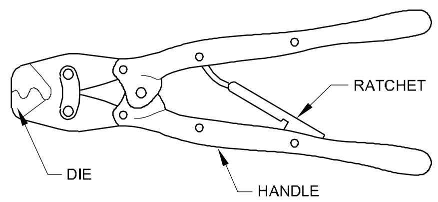
To conclude, we can state that wrong termination will lead to overheating of terminating points and cables, short circuits and earth leakage.

Types of termination

Crimp connection: In this type of connection the conductor is inserted into a crimp terminal and is then crimped with a crimping tool (Fig 1).

It is important to choose a crimp terminal that matches the conductor diameter and the dimensions of the connecting screw terminal. (Figs 2 & 3)

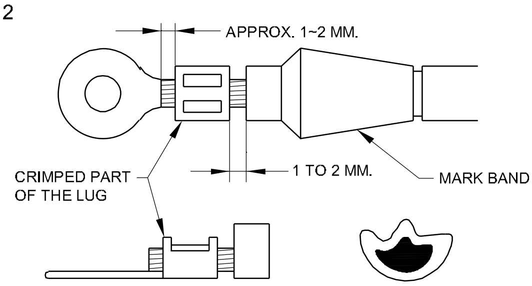
Fig 1



CRIMPING TOOL

ELN132191

Fig 2

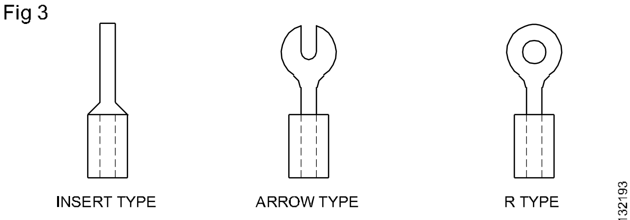


CRIMP TERMINAL CONNECTION

ELN132192

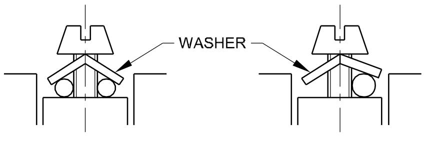
Insert screw setting: The conductor is inserted between the terminal block and the special form of washer (Fig 4), and then the screw is tightened.

Fig 3



VARIOUS KINDS OF CRIMP TERMINALS

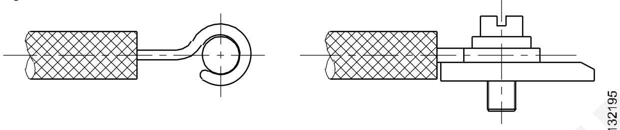
Fig 4



INSERT AND SCREW SETTING

Screw on terminals with loop/ring conductor: A loop is formed clockwise in the bare portion of the conductor to match the size of the screw diameter. Then the loop is inserted to the screw and tightened. (Fig 5) In the case of a stranded conductor, soldering of the loop is essential to prevent strands getting fray.

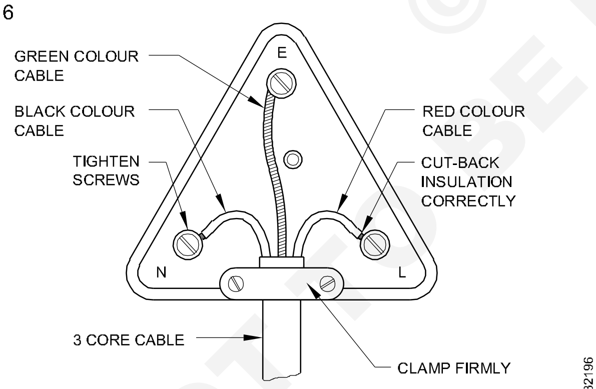
Fig 5



RING MAKE-UP SCREW SETTING

While connecting the plug and socket for extension of the cable, Line (L), the Neutral (N) and Earth (E) terminals must be properly identified by markings on them .(Fig 6)

Fig 6



INSIDE VIEW OF A 3-PIN PLUG

Crimping and crimping tool

The ends of cables can be prepared for termination with lugs by the soldering process or by mechanical means - compression or crimp fitting.

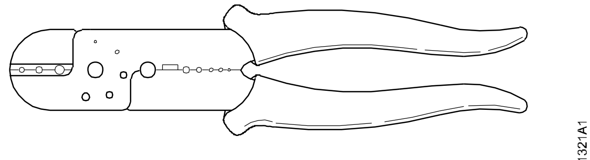
In crimp compression fitting, a ring-tongued terminal (lug) is to be compressed to the bared end of an insulated multi-strand cable. The process is called crimping and the tool used is called crimping pliers or crimping tool.

The principal purpose of the pressure is to establish and maintain suitable low contact resistance between the contact surfaces of the conductor. Improper crimping will create increased contact resistance and will cause overheating while carrying electrical load.

Crimping tools

The crimping pliers illustrated in Fig 7 is of a type which crimps from 0.5 to 6 mm cables.

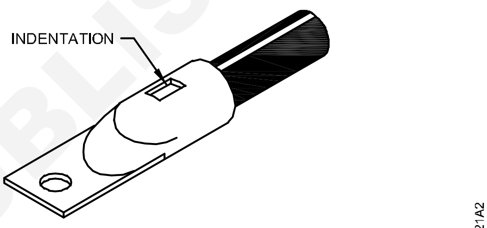
Fig 7



HAND CRIMPING PLIERS

The tool is operated by squeezing the handles. The jaws move together, grip and then crimp the fitting. Using the crimping tool that matches the specific crimp lug will give the correct crimping force for a properly executed crimp. Properly executed crimp will indent the top of the lug and the indentation will hold the conductor securely as shown in Fig 8.

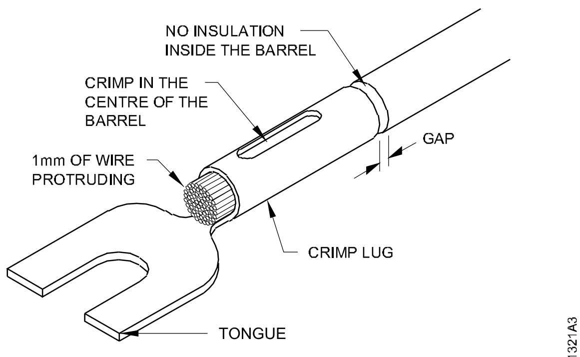
Fig 8



CORRECT EXECUTED CRIMPING

If the terminal has too deep a crimp, the strength of the joint is reduced. With too shallow a crimp, the electrical contact has a high resistance. Selection of the correct crimping tool is essential. A properly crimped terminal is shown in Fig 9.

Fig 9

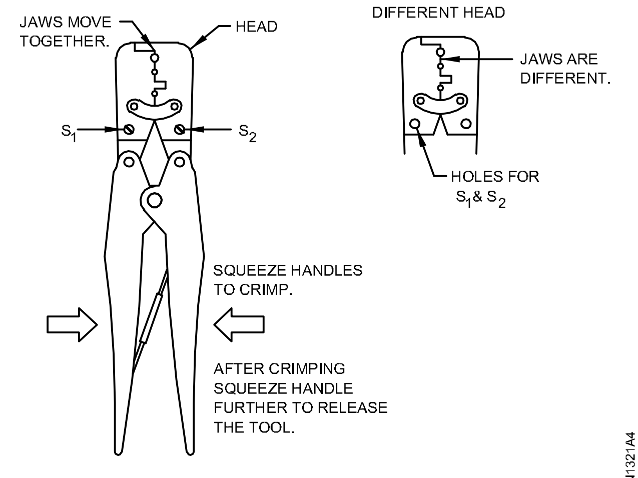


A PROPERLY CRIMPED TERMINAL

Fig 10 shows another type of crimping tool which crimps from 26 to 10 SWG.

The head and jaws, may be removed, by unscrewing the screws S_1 and S_2. A head with different shaped jaws may then be secured to the tool. The shape of the jaws determines the shape of the crimp (indent). Some crimp sections are shown in Fig 11.

Fig 10

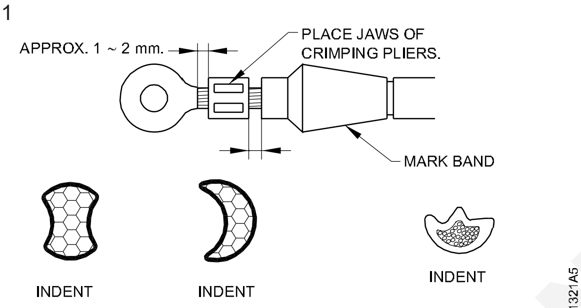


PARTS OF CRIMPING TOOLS

Safety

When using this type of crimping tool care must be taken not to trap the finger.

Fig 11



CRIMPED SECTION

Terminal types

It is important to consider both the mechanical and electrical requirements when selecting a lug connector.

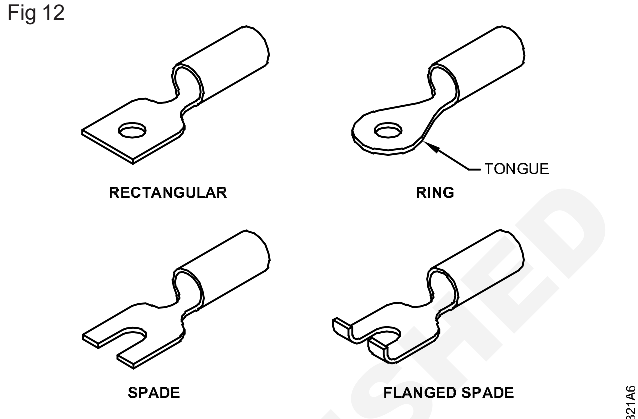
The factors are:

- the type of tongue, i.e. rectangular, ring, spade, etc.
- the mechanical size, i.e. tongue size and thickness, hole size etc. for the cable selected
- the electrical considerations such as the current carrying capacity, that may also determine some of the mechanical dimensions.

The electrical and mechanical requirements for the lug and the base material of the lug are decided by the cable material, and the place of connection will determine the minimum tongue size and the barrel size. The most commonly used base materials are copper and brass. Nickel, aluminium and steel are also used, but less frequently.

Fig 12 shows some lug connectors normally used in practice terminals. They are ring, rectangular, spade, flanged spade etc.

Fig 12



LUG CONNECTORS

Precautions for crimping tool application

Do not handle the job/tool roughly e.g. drop, hammer, etc. which may harm the tool.

Do not alter the crimping tool, e.g. alter the shape of the die etc.

Do not let metal chips adhere to the working position of the tool, particularly on the lower surface of replaceable die on the crimping part.

If a pin, spring, etc. is found damaged in the crimping tool, repair it immediately.

Apply oxide inhibiting grease to the aluminium conductor end just before crimping.

Advantages of crimping terminations

1 A properly made crimp is better in electrical conductivity and mechanical strength.

2 Less costly.

3 When the same size cables are to be terminated through lug connectors, the crimping process is faster than soldering.

Cable insulation - voltage grading

Objectives: At the end of this lesson you shall be able to
- **list out the factors for selection of cables**
- **state voltage grading.**

Selection of cables

The current carrying capacity of a particular area of cross-section cable depends upon the following factors.

- Type of conductors (metal)
- Type of insulation
- Cable run in conduit or in open surface
- Single or three phase circuit
- Type of protection - coarse or close excess current protection
- Ambient temperature

- Number of cables in bunches
- Length of circuit (permissible voltage drop) - this will be discussed at a later stage.

Depending upon the above factors the current rating of cables may vary to a great extent.

Classification of voltage grading

Voltage is classified as

1 Low voltage (L.V): Normally not exceeding 250V (i.e.) from 0 to 250 volts.

2 Medium voltage (M.V): Exceeding 250V but not exceeding 650V from 250 to 650 volts

3 High voltage (H.V): Exceeding 650V but not exceeding 33000V.(650-33000 volts)

4 Extra high voltage: All voltages above 33000V comes under this category.

TABLE

Various types of electrical cables

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
A.Wiring cable 1 PVC insulated a) non-sheathed single core	250/440,650/ 1100	1.5 to 50	Domestic/industrial wiring in conduits. Domestic/industrial wiring in batten.	694 part II
b) PVC sheathed				
i) single core	-do-	-do-	-do-	
ii) flat twin-core	-do-	1.5 to 16	Domestic wiring for power plug.	
iii) flat twin-core ECC and 3-core	250/440	1.5 to 50	Domestic/industrial wiring on batten.	
iv) circular 2,3 or 4 core	650/1100V	1.5 to 300	Sub-main/industrial.	
c)non-sheathed single core and twisted twin flexible copper	250/400 650/1100	4 to 5	Temporary wiring interconnections, household applicances.	694 part I 694 part I&II
d)PVC sheathed circular twin, 3 and 4 core flexible copper	-do-	-do-		
e)Single extrusion	-do-	1.5 to 50	Domestic wiring on batten	694 part I,II
2 Polythene insulated and PVC sheathed with aluminium conductor a) single core flat & circular twin core	250/440	1.5 to 50	Domestic wiring on batten	1596
b) flat twin with ECC & circular	-do-	1.5 to 10	-do-	1596
3 Lead alloy sheathed i) single core ii) 2,3 and 4-core circular iii) twin & 3 core flat (ECC) 250/440	250/440 650/1100	Aluminium Copper 1.5 to 50 1.5 to 50 70 to 625 64.5 to 645 1.5 to 16 1.5 to 16 corrosive atmosphere.	Industrial wiring in damp	434 part I,II

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
4 TRS sheathed i) single core ii) 2,3 and 4-core circular iii) Twin & 3 core flat (ECC) e) TRS sheathed flexible f) Fire resisting asbestos sheathed g) Poly Phropene sheathed flexible	 -do- -do- 250/440 650/1100 -do- -do-	 1.5 to 50 0.5 to 50 1.5to625,64.5-645 1.5 to 16 1.5 to 16	 Wiring residential on batten,industrial wiring Residential batten Welding cables in fire hazards. Training cable for lifts and other mobile equipments	 434 part I,II -do- -do- -do-
5 Weather-proof cables a)VIR insulated cotton, braided and treated with weather resistance compound b)PVC insulated PVC sheathed c)Polythene insulated, taped braided and compounded	250/440 650/1100 -do- -do-	1.50 to 50 -do- -do-	 Service connection and other outdoor application.	 434 part I,II 3035 part I 3035 part II
6 Power cables heavy duty 1.1kV grade PVC insulated PVC sheathed cable a)Unarmoured/armoured i) Single core ii) Twin core iii) Three-core iv) Three and a half core v) Four core	 650/1100 650/1100 -do- -do- -do-	 1.5 to 1000 1.5 to 500 1.5 to 400 16 to 400 1.5 to 50	 Armoured cable in singlecore not available. Unarmoured power cables are used only in protected places. Use of copper is banned for such applications	 1554 Part I/76
7 Paper insulated, lead, covered, single core, unarmoured. a) Twin-core, armoured b) Three and three and half, armoured.	1.1kV -do- -do- -do-	6 to 625 6 to 625 -do- -do- -do- -do- -do- -do-	Dry places, heavy duty, hazardous applications underground. Dry places for cotton braided, otherwise metal sheathed.	692-73 693-1965
8 Varnished cambric insulated	-do-			

N.B. 1 Where material of core is not mentioned, it is aluminium.
2 ECC - Earth continuity conductor.

Wire joints - Types - Soldering methods

Objective: At the end of this lesson you shall be able to
- **state the different types of wire joints and their uses**
- **state the necessity of soldering and types of soldering**
- **state the purpose and types of fluxes**
- **explain the different method of soldering and techniques of soldering**
- **explain the type of solder and flux used for soldering aluminium conductor.**

Scan the QR Code to view the video for this exercise

Definition of joint: A joint in an electrical conductor means connecting/tying or interlaying together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

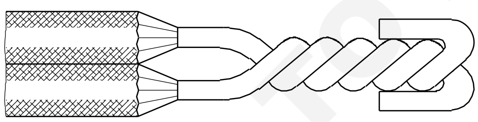
Types of joints: In electrical work, different types of joints are used, based on the requirement. The service to be performed by a joint determines the type to be used.

Some of the commonly used joints are listed below.

- Pig-tail or rat-tail
- twisted joints
- Married joint
- Tee joint
- Britannia straight joint
- Britannia tee joint
- Western union joint
- Scarfed joint
- Tap joint in single stranded conductor

Pig-tail/Rat-tail/Twisted joint: (Fig 1) This joint is suitable for pieces where there is no mechanical stress on the conductors, as found in the junction box or conduit accessories box. However, the joint should maintain good electrical conductivity.

Fig 1



RAT TAIL JOINT

ELN132511

Married joint: (Fig 2) A married joint is used in places where appreciable electrical conductivity is required, along with compactness.

Fig 2

MARRIED JOINT

ELN132512

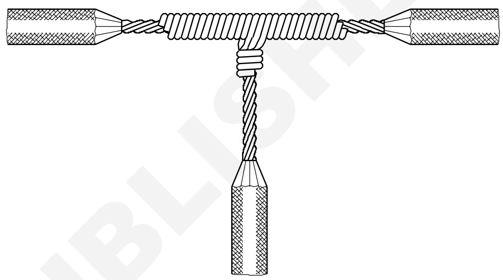
As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3)**:** This joint could be used in overhead distribution lines where the electrical energy is to be tapped for service connections.

Britannia joint: (Fig 4) This joint is used in overhead lines where considerable tensile strength is required.

It is also used both for inside and outside wiring where single conductors of diameter 4 mm or more are used.

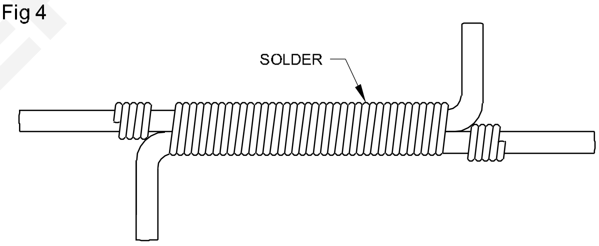
Fig 3



TEE JOINT

ELN132513

Fig 4

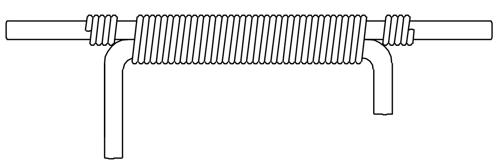


BRITANNIA JOINT

ELN132514

Britannia tee joint: This joint (shown in Fig 5) is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

Fig 5



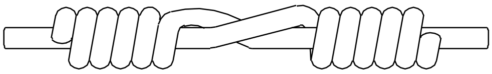
BRITANNIA TEE JOINT

ELN132515

Western union joint (Fig 6)**:** This joint is used in overhead lines for extending the length of wire where the joint is subjected to considerable tensile stress.

Scarfed joint (Fig 7)**:** This joint is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring.

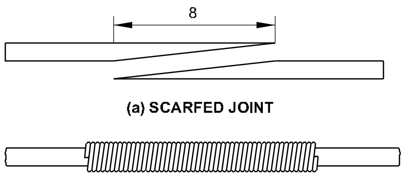
Fig 6



WESTERN UNION JOINT

ELN132516

Fig 7



(a) SCARFED JOINT

(b) SCARFED JOINT

ELN132517

Tap joints in single stranded conductors of diameter 2 mm or less : By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

The following types of taps are commonly used.

– Plain

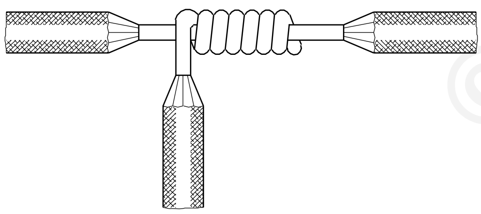
– Aerial

– Knotted

– Cross - Double - Duplex

Plain tap joint: (Fig 8) This joint is the most frequently used, and is quickly made. Soldering makes the joint more reliable.

Fig 8

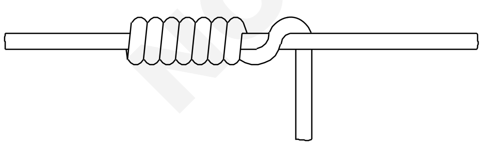


PLAIN TAP JOINT

ELN132518

Aerial tap joint : (Fig 9) This joint is intended for wires subjected to considerable movement, and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap joint except that it has a long or easy twist to permit the movement of the tap wire over the main wire.

Fig 9



AERIAL TAP JOINT

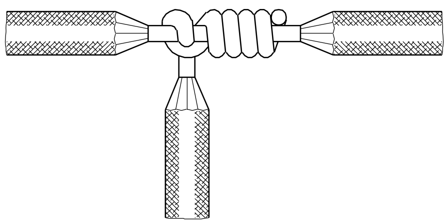
ELN132519

Knotted tap joint : (Fig 10) A knotted tap joint is designed to take considerable tensile stress.

Soldering - types of solders, flux and methods of soldering

Soldering: Soldering is the process of joining two metal plates or conductors without melting them, with an alloy called solder whose melting point is lower than that of the

Fig 10



KNOTTED TAP JOINT

ELN13251A

metals to be soldered. The molten solder is added to the two surfaces to be joined so that they are linked by a thin film of the solder which has penetrated into the surfaces.

Necessity of soldering: Wire and cable joints should have the same electrical conductivity and mechanical strength as that of the parent conductor. This cannot be achieved by a mere mechanical joint. As such cable joints are soldered to have good mechanical strength, electrical conductivity and also to avoid corrosion.

Solders : The following are the general proportions of tin and lead used in the solders.

Designation	Composition	Working temp.	Uses
Electrician's solder	Tin-60% Lead-40%	185°C. or 365°F.	Tinning and soldering electrical joints etc.

Solder used for copper: The metal alloy used as a bonding agent in soldering is called a solder. The solders used for soft soldering consist of an alloy (mixture) of mostly tin and lead.

Factors influencing the choice of a solder

The factors that influence the choice of a solder are:

- melting point
- solidification range
- strength
- hardness
- sealability
- price.

Flux: Flux is a substance used to dissolve oxides on the surface of conductors and to protect against de-oxidisation during the soldering process.

General properties of flux : The purpose of the flux is to

- dissolve oxides, sulphides etc. thereby making the soldering surface free of oxides and dirt
- prevent re-oxidation during the soldering operation thereby making the solder adhere to the surface to be soldered.
- facilitate the flow of the solder through surface tension so as to make the solder flow into the surface to be soldered.

The type of solder often determines the flux to be used for soldering.

The following table lists the fluxes used for soldering.

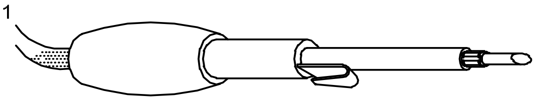
Table

Sl. No.	Suitable flux	Metals/job - used for	Type of solder
1	Sal ammonia rosin (Not fully acid-free)	Copper, brass, tin plate, gun-metal: for clean and finer soldering work.	Coarse solder
2	Rosin	Joining electrical conductors	Electrician's solder
3	Tallow - (turpentine, acid free)	For joining electrical conductors, for soldering.	Electrician's fine solder

Soldering methods

Soldering with a soldering iron: The most common method of soldering is with a soldering iron as shown in Fig 1. This is widely used for most kinds of soft soldering work.

Fig 1



SOLDERING IRON

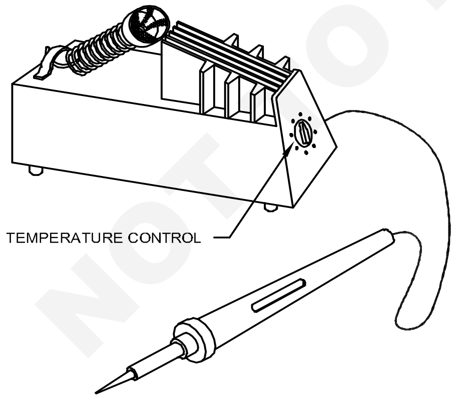
ELN132521

This tool is simple and inexpensive. Soldering irons are available in a wide range of sizes and models.

Temperature controlled soldering

For soldering miniature components on printed circuit boards, a temperature-controlled soldering iron is used as shown in Fig 2. The electrical supply given to the soldering iron is of low voltage, and is completely isolated from the main supply. Low voltage does not endanger the life of the user and will also not spoil the sensitive electronic components. Controlled temperature makes the job easy for the user.

Fig 2



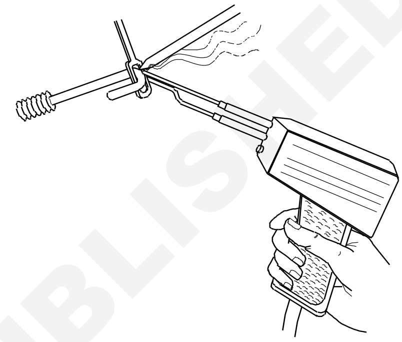
TEMPERATURE CONTROLLED SOLDERING IRON

ELN132522

Soldering with a soldering gun: This method, shown in Fig 3, is used for individual soldering, e.g. for servicing and repair work.

The principle of this method is that an electric current flows through a wire coil heating it. The temperature is difficult to check, and overheating can easily occur. This is the disadvantage.

Fig 3



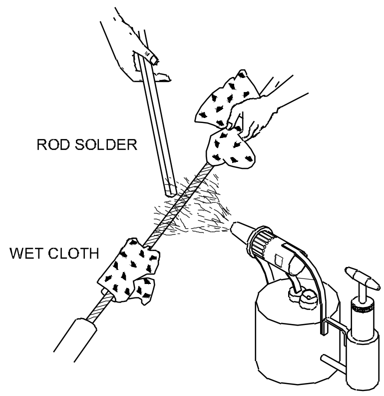
SOLDERING WITH A SOLDERING GUN

ELN132523

Soldering with a flame: Soldering with a flame is used when the heat capacity of a soldering iron is insufficient.

This method, shown in Fig 4, permits rapid heating and is used primarily for larger jobs, such as piping and cable work, vehicle body repairs and some applications in the building trade.

Fig 4



SOLDERING WITH BLOWLAMP

ELN132524

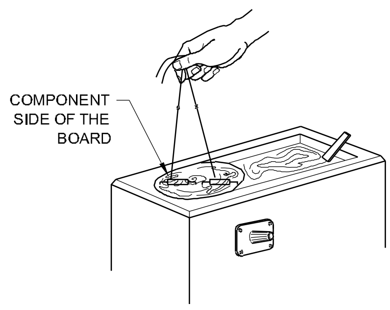
This method requires skilful management of the flame.

Dip soldering: This method, shown in Fig 5, is used for quantity production and for tinning work similar to component soldering on Printed Circuit Boards (P.C.B.). Components to be soldered or tinned are dipped into a bath of molten solder, which is heated electrically.

The temperature can be controlled very accurately.

Machine soldering: This method is used for quantity production, and is based on the principle that molten solder or a mixture of oil and molten solder is set in rapid motion, thus breaking up the oxide film. The solder comes into direct contact with the component ends to be soldered.

Fig 5



DIP SOLDERING

Techniques of soldering : Soldering involves the following main operations.

- Tinning the soldering iron
- Cleaning the parts to be soldered
- Applying the solder

Tinning the soldering iron: To make the solder adhere to the tip of the soldering iron, the surface of the tip must be coated with the solder, and this operation is known as tinning.

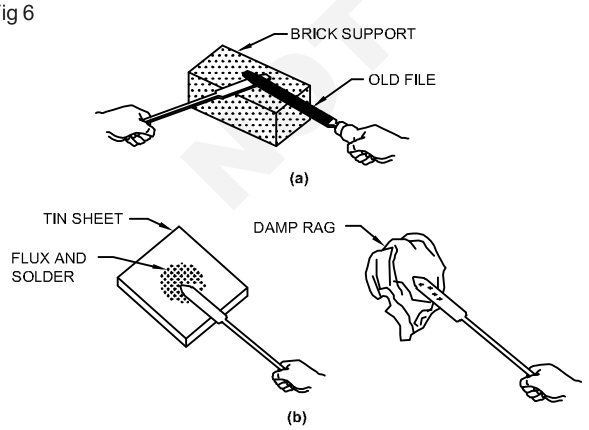
First the tip is cleaned with a cloth and heated either directly or indirectly. The tip is then filed to remove the scales, and is wiped again with a cloth.

The right temperature for tinning could be judged by the change of colour of the tip when heated. If the surface of the copper tip tarnishes immediately, the temperature is high and needs to be cooled slightly by withdrawing the source of heat temporarily. A correctly heated tip tarnishes slowly.

After the soldering iron tip attains the correct temperature, place a small quantity of solder and the flux on a tin plate and rub the bit on the mixture. The solder should stick to the surface of the tip evenly. Wipe out the superfluous solder with a clean damp cloth.

The whole process of tinning is shown in Figures 6a and 6b.

Fig 6



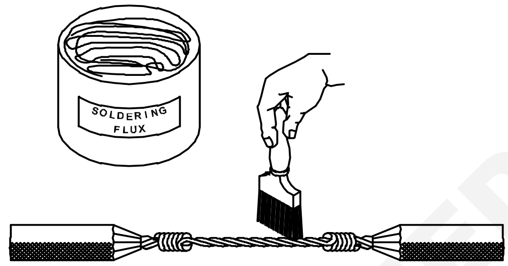
TINNING PROCESS

The surface should present a bright silvery appearance when properly tinned.

Cleaning the surface to be soldered: The parts to be soldered should be well cleaned for perfect soldering. The scales, dirt, oil and grease should be completely removed either by wiping or by rubbing with a sandpaper. Immediately after cleaning, the flux should be applied on the surface to avoid oxidization.

Applying the flux: The rosin which is recommended as a flux may be sprinkled over the surface to be soldered or may be applied with a brush as shown in the Fig 7.

Fig 7



APPLYING SOLDERING FLUX

Applying the solder: The quantity of the solder to be applied depends upon the size of the job. For small jobs like printed circuit boards soldering or soldering joints in wires of diameter 2 mm or lower, an electric soldering iron is used whereas for soldering joints of large sized cables, pot and ladle are used.

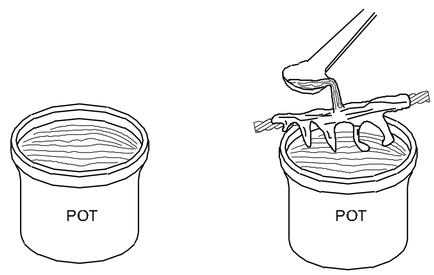
Soldering precautions: Remove the iron as soon as the solder has flowed over the surfaces.

Excessive heating may damage:

- the wire and its insulation
- the component being soldered
- the adjoining components.

Soldering with pot and ladle (Fig 8): For larger sized jobs like underground cable jointing, a melting pot and ladle are used. The solder is kept in the pot and heated either by a blowlamp or by charcoal. Initially the surface to be soldered is cleaned and a coat of flux is given.

Fig 8



POT AND LADLE METHOD OF SOLDERING

Then the surface to be soldered is heated by pouring molten solder over it in quick succession. The dripping solder is collected in a clean tray. After several pourings, the surface attains the same temperature as that of the molten solder. The flux is again applied and the solder is slowly poured on the surface as it forms an even layer. Superfluous solder collected in the tray is re-melted in the pot.

Soldering of aluminium cables: Soldering aluminium conductors is more difficult than soldering copper conductors owing to the highly tenacious, refractory and stable nature of the oxide film which forms immediately on any aluminium exposed to air.

This oxide film does not allow the solder to wet the surface to be soldered, and also prevents the solder from entering the interior surface by capillary action. Hence special solders and fluxes are used for aluminium soldering.

Solder: A special soft solder having a small percentage of zinc is used for joining aluminium conductors. (Soft solders are alloys which have a melting point below 300^0C.) IS 5479-1985 gives details of the chemical composition of soft solders and their grades used for soldering aluminium conductors. Details are given in Table 1.

The object of this small zinc content which is a common feature of aluminium solders is to fecilitate the alloying of the solder with an aluminium surface. A typical composition of solder with 51% lead, 31% tin, 9 % zinc and 9% cadmium with the brand name `ALCA P' solder is available in the market for soldering aluminium conductors. In addition a special solder by name Ker-al-lite is also available for soldering aluminium conductors.

Flux: In soldering aluminium conductors, organic fluxes of reaction type, free from chlorides and suitable for soft soldering are used.

The composition of the organic fluxes decomposes at approximately 250°C to effect the removal of the oxide film and also to assist in the spreading of the molten solder to enable tinning the de-oxidised surface immediately.

The major disadvantage of organic flux is that it tends to char at a temp. above 360°C. The charring, thus caused, renders the flux ineffective and gives rise to the danger of creating voids in the joint due to charred flux residues. For this reason, it is essential that the temp. of this solder during the operation is maintained well within 360°C. The commercial name of fluxes used for joining aluminium conductors are Kynal Flux and Eyre No.7.

Procedure of soldering aluminium cables : The procedure of soldering aluminium cables to standard copper lugs employing Kynal's flux and Ker-al-lite special solder is explained below.

Strip the cable in preparation for jointing in the usual manner.

Spread out the strands so as to effect a general loosening and slight displacement of the wires, and clean the surface preferably with a wire brush.

Apply a small quantity of flux by brushing well into the fanned-out ends of the conductor and baste (moisten) the fluxed conductor with a full ladle of molten solder.

Apply more flux and baste again with the molten solder. Continue to make repeated alternate applications of flux and solder until the wires exhibit a brightly tinned surface free from dull spots.

After the final basting, wipe off the surplus metal from the strands with a clean and dry piece of cloth.

Flux the lug inner surface and fill it with the molten solder.

Insert the tinned end of the cable inside the lug and hold both the cable and the lug firmly without shaking.

Allow the lug to cool and baste the surface quickly with the molten solder to remove the excess solder.

Wipe the lug surface with a clean cloth.

Apply a coating of graphite conducting grease on the lug before using.

Precautions to be followed while soldering aluminium

All surfaces must be scrupulously clean.

When a joint is being made between stranded conductors, the strands must be `stepped' to increase the surface area.

The surface must be fluxed before the heat is applied.

Safety

During the jointing operation copious fumes are given off when the flux is heated. These fumes contain small quantities of fluorine, and it is, therefore, advisable not to inhale them.

As smoking during the jointing operation results in the inhaling of toxic fumes, smoking during soldering should be avoided.

Table 1

Grade	% of alloying elements			Melting temp. in °C	Flux type	Applications
	Zinc	**Lead**	**Tin**			
SnPb53Zn	1.75–2.25	52–54	45.71–45.21	170–215	Organic	Conductors of electrical cables
SnPb58Zn	1.75–2.25	57–59	40.66–40.6	175–220		-do-

Under ground (UG) cables - construction - materials - types - joints - testing

Objectives: At the end of this lesson you shall be able to
- **define UG cable**
- **explain the construction of UG cables**
- **list and state the insulating materials used in cables**
- **list out and state the types of UG cables used for 3 phase service**
- **state the types of cable joints and laying methods**
- **expalin the faults and testing procedures of cables.**

Under Ground (UG) cables

"A cable so prepared that it can withstand pressure and can be installed below the ground level and normally two or more conductors are placed in an UG cablewith separate insulation on each conductor"

Electric power can be transmitted (or) distributed either by over-head lines system or by underground cable system. The underground cable system have several advantage, such

Advantages

- Less chance to damage through storms or lightning.
- Low maintenance cost.
- Less chances of fault.

Disadvantages

However, their major draw back / disadvantages are

- Initial cost of UG cable system is heavy.
- The cost of joints are more.
- Introduce insulation problems at high voltages compared with O.H lines.

For these reasons UG cables are employed where it is impracticable to use O.H lines like (i) thickly populated areas, where municipal authorities prohibit O.H lines for the reason of safety.

ii Around plants

iii In Substations,

iv Where maintenance conditions do not permit the use of O.H construction.

General construction of UG cables

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Necessity requirements for cables

In general, a cable must fulfill the following necessary requirements.

i The conductor used in cables should be tinned stranded copper or aluminum of high conductivity. (Strands of cable gives flexibility and carry more current).

ii The size of the conductor should be selected, so that the cable carries the desired load current without overheating and limits the voltage drop to a permissible value.

iii The cable must have proper thickness of insulation to ensure the safety and reliability for the designed voltage.

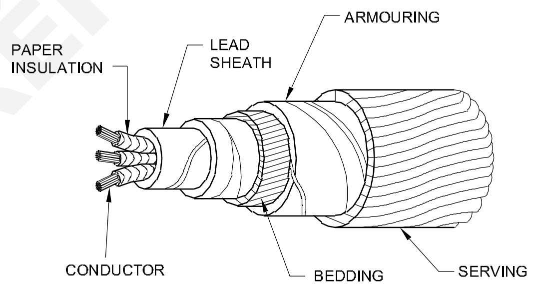
iv The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.

v The materials used in cables should be with complete chemical and physical stability throughout.

Construction of Cables

Fig 1 shows the general construction of a 3-core cable. The various parts are:

Fig 1



CONSTRUCTION OF CORE CABLE

ELN132811

i Cores or conductors: A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instance, the 3-conductor cable shown in Fig 1 is used for 3-phase service. The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable and having high conductivity.

ii Insulation: Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound. Petrolium jelly is applied to the layers of the cambric to prevent damage.

iii Metallic sheath: In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalies) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig 1. The metallic sheath is usually a lead or lead alloy.

iv Paper Belt: Layer of imprignated paper tape is wound round the grouped insulated cores. The gap in the cores is filled with fibrous insulating material (jute etc.)

v Bedding: Over the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape. The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armouring.

vi Armouring: Over the bedding, armouring is provided which consists of one or two layers of galvanized steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in the case of some cables.

vii Serving: In order to protect armouring from atmospheric conditions, a layer of fibrous material (like jute) similar to bedding is provided over the armouring. This is known as serving.

It may not be out of place to mention here that bedding, armouring and serving are only applied to the cables for the protection of conductor insulation and to protect the metallic sheath from mechanical injury.

The principal insulating materials used in cables are

i Rubber

ii Vulcanized India rubber

iii Impregnated paper

iv Varnished cambric and

v Polyvinyl chloride.

Classification of cables

Cables for underground service may be classified in two ways according to (i) the type of insulating material used in their manufacture (ii) the voltage for which they are manufactured. However, the later method of classification is generally preferred as

i Low-tension (L.T) cables – upto 1100 V

ii High-tension (H.T) cables – upto 11,000 V

iii Super-tension (S.T cables – from 22 KV to 33 KV

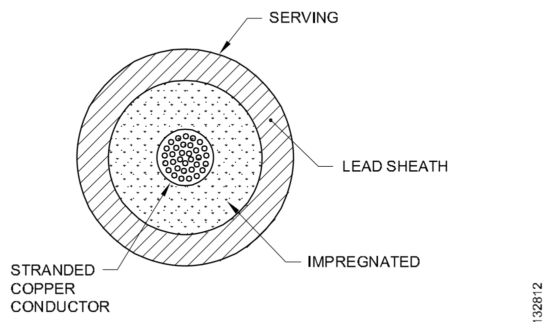
iv Extra high-tension (E.H.T) cables – from 33 to 66 KV

v Extra super voltage cables – beyond 132 KV

A cable may have one or more than one core depending upon the type of service for which it is intended. It may be (i) single-core (ii) two-core (iii) three-core (iv) four-core etc. For a 3-phase service, either 3-single core cables or three-core cable can be used depending upon the operating voltage and load demand.

Single core low tension cable: Fig 2 shows the constructional details of a single-core low tension cable. The cable has ordinary construction because the stresses developed in the cable for low voltages (upto 6600 V) are generally small. It consists of one circular core of tinned stranded copper (or aluminium) insulated by layers of impregnated paper.

Fig 2



SINGLE CORE L.T. CABLE

Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cables or three single core cables may be used. For voltages upto 66 KV, 3-core cable (i.e. multi-core construction) is preferred due to economic reasons. The following types of cables are generally used for 3-phase service.

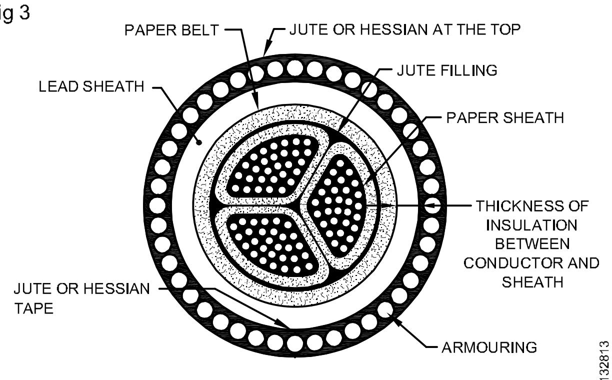
1 Belted cables – upto 11 KV

2 Screened cables – from 22 KV to 66 KV

3 Pressure cables – beyond 66 KV

1 Belted cables : These cables are used for voltages upto 11 KV but in extraordinary cases their use extended upto 22KV. (Fig 3)

Fig 3



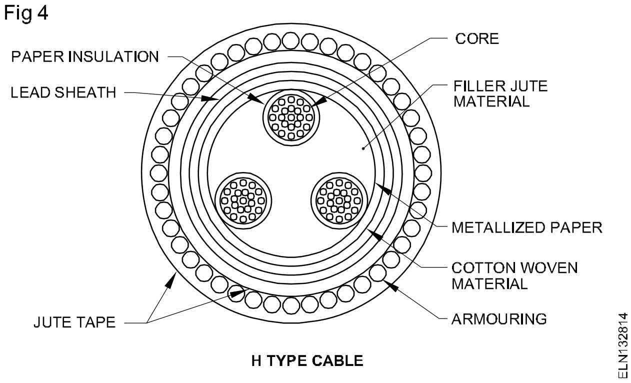
BELTED TYPE CABLE

2 Screened cable

These cables are meant for use upto 33 KV but in particular cases their use may be extended to operating voltages upto 66 KV. Two principal types of screened cables are H-type cable and S.L. type cables.

i **H-type cables** : This type of cable was first designed by H. Horchstadter and hence the name. Fig 4 shows the constructional details of a typical 3-core, H-type cable. Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil.

Fig 4



H TYPE CABLE

Advantages:

- The posibility of air pockets or volds in the dielectric is eleminated
- The metalic screen increase the heat dissipating power of the cable

(ii) **S.L. type cables** Fig 5 shows the constructional details of 3-core S.L **(separate lead)** type cable. It is basically H-type cable but the screen round each core insulation is covered by its own lead sheath. There is no overall lead sheath but only armouring and serving are provided.

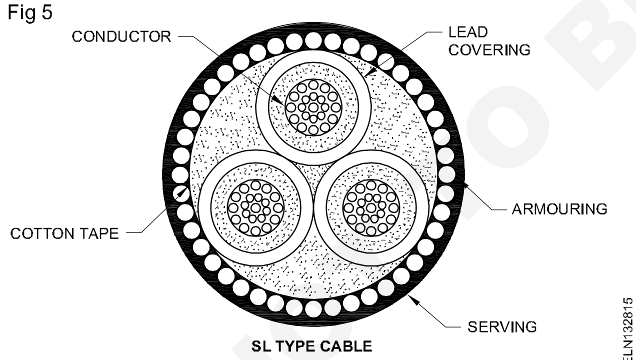
The S.L type cables have two main advantages over H-type cables.

a The separate sheaths minimize the possibility of core-to-core breakdown.

b Bending of cables become easy due to the elimination of overall lead sheath.

The disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of H-cable

Fig 5



SL TYPE CABLE

3 Pressure cables

For voltages beyond 66 KV, solid type cables are unreliable because there is a danger of breakdown of insulation due to the presence of voids. When the operating voltages are greater than 66 KV, pressure cables are used. Two types of pressure cables viz oil filled cables and gas pressure cables are commonly used.

i **Oil filled cables.** In such type of cables, channels of ducts are provided in the cable for oil circulation. The oil under pressure (it is the same oil used for impregnation) is kept constantly supplied to the channel by means of external reservoirs placed at suitable distances (say 500 m) along the route of the cable.

Oil under pressure compresses the layers of paper insulation and is forced into any voids that may have formed between the layers. Due to the elimination of voids, oil-filled cables can be used for higher voltages, the range being from 66 KV upto 230 KV.

Oil-filled cables are of three types viz.

i Single-core conductor channel

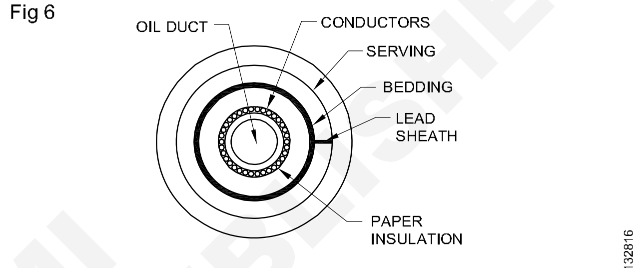
ii Single-core sheath channel and

iii Three-core filler-space channels.

i Single-core Conductor channel

Fig 6 shows the constructional details of a single-core conductor channel, oil-filled cable.

Fig 6

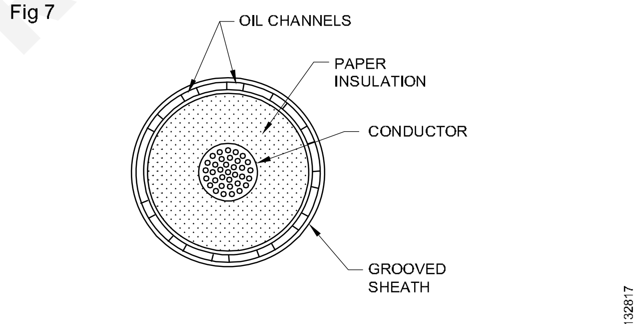


SINGLE - CORE CONDUCTOR CHANNEL OIL - FILLED CABLE

ii Single-core sheath channel (Fig 7)

In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated. However, oil ducts are provided in the metallic sheath.

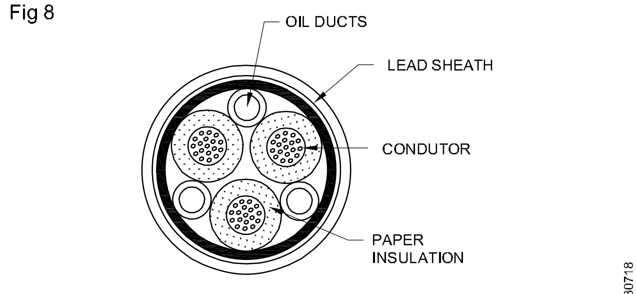
Fig 7



OIL - FILLED CABLES

iii 3-core oil-filled cable (Fig 8): The oil ducts are located in the filler space. These channels are composed of perforated metal-ribbon tubing and are at earth potential.

Fig 8



THREE CORE OIL FILLED CABLES

Advantages

a Formation of voids and ionization are avoided.

b Allowable temperature range and dielectric strength are increased.

c If there is leakage, the defect in the lead sheath is at once indicated and the possibility of earth faults is decreased.

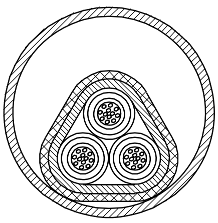
Disadvantages

a High initial cost and complicated system of laying

ii **Gas pressure cables**. The voltage required to set up ionization inside a void increases as the pressure is increased. Therefore, if ordinary cable is subjected to a sufficiently high pressure, the ionization can be altogether eliminated. At the same time, the increased pressure produces radial compression which tends to close any voids. This is the underlying principle of gas pressure cables.

Fig 9 shows the section of external pressure cable designed by Hockstadter, Vogal and Bowden. The construction of the cable is similar to that an ordinary solid type except that it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance but the main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape. The cable is laid is a gas-tight steel pipe.

Fig 9



EXTERNAL PRESSURE CABLE

The pipe is filled with dry nitrogen gas at a pressure of 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids that may have formed between the layers of paper insulation.

Advantages:

a Cables can carry more load current

b Operate at higher voltages than a normal cable.

c Maintenance cost is small and the nitrogen gas helps in quenching any flame.

Disadvantages:

The overall cost is very high.

Further the cables are also classified according to their insulation system as under:

PVC insulated cables	(Poly vinyl chloride)
MI cables	(Mineral insulation)
PILC cables	(Paper insulated lead covered)
XLPE cables	(Cross linked poly ethylene)
PILCDTA cables	(Paper insulated lead covered double tape armoured)

UG cables laying method

The reliability of the underground cable (UG) installation depends upon the proper laying and attachment of fittings (i.e) cable and boxes, joints, branch connectors etc.

Methods of laying of UG cables

The following are the methods of laying underground cables

1 Laying direct in ground

2 Laying in ducts

3 Laying on racks in air.

4 Laying on racks inside a cable tunnel.

5 Laying along buildings or structures.

Precautions while handling cables

1 Prevent the cable from dragging on the floor.

2 Prevent kinking of the cable.

3 After laying the cable in the ducts it should be immediately covered or suspended.

Cable jointing methods: This process consists of the following steps.

a Exact measurement of the cable for insulation removal.

b Removal of insulation.

c Replacing of the original insulation with high grade tapes and sleeves.

d Dressing the cable ends and conductor joints through sleeves/split sleeves.

e Providing separators between cables.

f Fixing a cast iron or any other protective shell around the joint and filling the joint boxes with molten bitumen compound.

g Plumbing metallic sleeves or brass glands to the lead sheath of the cable to prevent moisture from entering the joint in case of cast iron joint boxes or tape insulation in case of cast resin kit joint boxes.

Straight through joints

The emphasis should be laid on quality and selection of proper cable, cable accessories, proper jointing techniques.

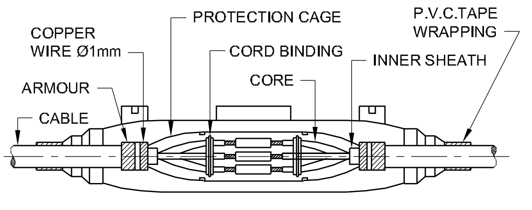
For PILC cable: For paper insulated lead sheathed cables, straight joints are made either by using sleeve joints or crimping joints up to voltage grade 11 KV. Above 11 KV, compound filled copper or brass sleeves, along with cast iron, fibre glass protection boxes are used.

Fig 10 shows such a joint.

Tee joint: These joints are to be restricted up to 11 KV.

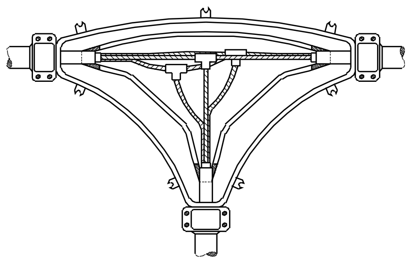
These joints are made either using cast resin kits or C.I. boxes with or without sleeves for PILC cables and cast resin kits for PVC and XLPE cables. (Fig 11)

Fig 10



STRAIGHT THROUGH JOINTS FOR CABLES 3.3 KV GRADE

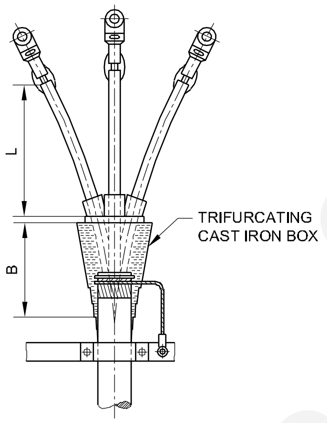
Fig 11



TEE JOINT OF 11 kV PAPER INSULATED CABLE

Tri-furcating end connections: In order to connect UG cables to the air break switches etc. tri-furcating boxes are used. They can be either cast resin type up to 1.1 KV or cast iron type for 11 KV and above. This type of box is shown in Fig 12.

Fig 12



TERMINATION FOR PVC CABLE

Method of preparing and filling compounds

- Hot pouring
- Cold pouring

Hot pouring compounds: A bituminous compound of melting temperature 90°C and pouring temperature 180°C - 190°C is used for hot pouring.

Cold pouring compound: Cold pouring is used by using cast resin system for PVC cable jointing. This has been developed for application up to 11 KV grade cables. The compound consists of a resin base and a polyamino hardener. The two component liquids are mixed at the site in accordance with the recommendation of the manufacturer.

Types of cable faults and testing procedure

The common faults which are likely to occur in cables are:

1 **Ground fault.** The insulation of the cable may breakdown causing a flow of current from the core of the cable to the lead sheath or to the earth. This is called "Ground Fault".

2 **Short circuit fault.** If the insulation between two conductors is faulty, a current flows between them. This is called a "short circuit fault".

Methods for locating ground and short circuit faults.

The methods used localizing the ground and short circuit faults differ from those used for localizing open circuit faults.

In the case of multi core cables it is advisable, first of all, to measure the insulation resistance of each core to earth and also between cores. This enables us to sort out the core that is earthed in-case of ground fault; and to sort out the cores that are shorted in case of a short circuit fault. Loop tests are used for location of ground short circuit faults. These tests can only be used if a sound cable runs along with the faulty cable or cables.

The loop tests work on the principle of a Wheatstone bridge. The advantage of these tests is that their setup is such that the resistance of fault is connected in the battery circuit and therefore does not effect the result. However, if the fault resistance is high, the sensitivity is adversely affected. In this section only two types of tests viz., Murray and Varley loop tests are being described.

Murray Loop Test. The connection for this test are shown in Fig 13a relates to the ground fault and Fig 13b relates to the short circuit fault.

In both cases, the loop circuit formed by the cable conductors is essentially a wheatstone bridge consisting of resistances P, Q, R and X. G is a galvanometer for indication of balance,

The resistors P, Q forming the ratio arms may be decade resistance boxes or slide wires.

Under balance conditions :

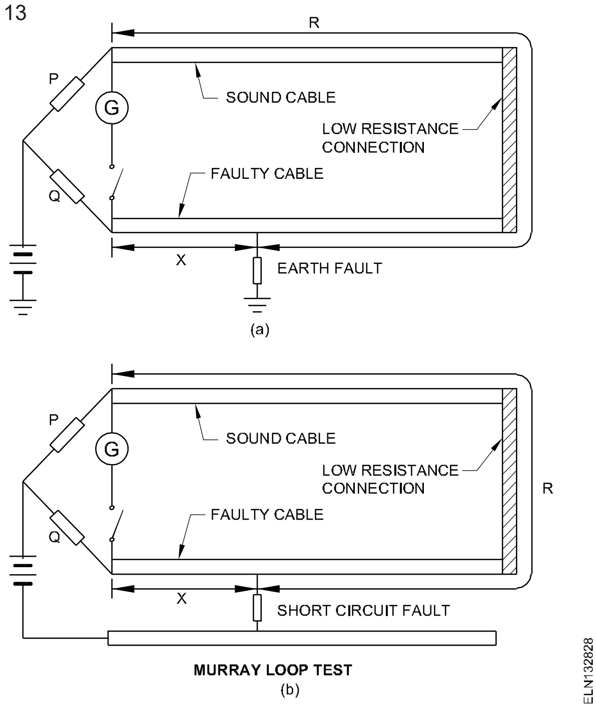
$$\frac{X}{R} = \frac{Q}{P} \text{ or } \frac{X}{R+X} = \frac{Q}{P+Q}$$

$$\therefore X = \frac{Q}{P+Q}(R+X)$$

Where (R+X) is total loop resistance formed by the sound cable and the faulty cable. When the conductors have the same cross-sectional area and the same resistivity, the resistance are proportional to lengths. If l_1 represents the length of the fault from the test end and 'l' is the length of each cable. Then

$$l_1 = \frac{Q}{P+Q} \cdot 2l$$

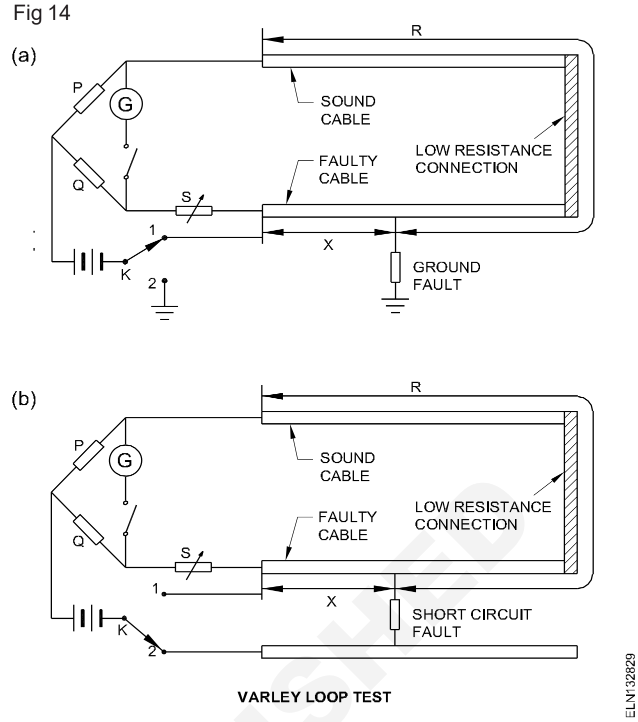
Fig 13



MURRAY LOOP TEST

(b)

Fig 14



VARLEY LOOP TEST

The above relation shows that the position of the fault may be located when the length of the cable is known. Also, the fault resistance does not alter the balance condition because its resistance enter the battery circuit hence effects only the sensitivity of the bridge circuit. However, if the magnitude of the fault resistance is high, difficulty may be experienced in obtaining the balance condition on account of decrease in sensitivity and hence accurate determination of the position of the fault may not be possible.

In such a case, the resistance of the fault may be reduced by applying a high direct or alternating voltage, in consistence with the insulation rating of the cable, on the line so as to carbonize the insulation at the point of the fault.

Varley loop test. In this test we can determine experimentally the total loop resistance instead of calculating it from the known lengths of the cable and its resistance per unit length. The necessary connections for the ground fault are shown in Fig 14a and for the short circuit fault in Fig 14b. The treatment of the problem, in both cases, is identical.

A single pole double throw switch A is used in this circuit. Switch K is first thrown to position 'I' and the resistance 'S' is varied and balance obtained.

Measurement of resistance

Let the value of S for balance be S. The four arms of the Wheatstone bridge are P, Q, R + X, S_1 at balance:

$$\frac{R+X}{S_1} = \frac{P}{Q}$$

This determines R + X i.e. the total loop resistance as P, Q and S_1 are known.

The switch K is then thrown to position '2' and the bridge is rebalanced. Let the new value of S for balance be S_2. The four arms of the bridge now are P, Q, R, X + S_2.

At balance

$$\frac{R}{X+S_2} = \frac{P}{Q}$$

$$\frac{R+X+S_2}{X+S_2} = \frac{P+Q}{Q} \text{ or } X = \frac{(R+X)Q - S_2 P}{P+Q}$$

Hence, X is known from the known value of P, Q, S_2 from this equation and R+X (the total resistance of 2 cables) as determined from Eqn. knowing the value of X, the position of the fault is determined.

Now

$$\frac{X}{R+X} = \frac{l_1}{2l} \text{ or } l_1 = \frac{X}{R+X} 2l$$

Where

l_1= length of fault from the test end and

l = total length of conductor.

Equations for murrary loop test and varley loop test are valid only when the cable sections are uniform throughout the loop. Corrections must be applied in case the cross-sections of faulty and sound cables are different or when the cross-section of the faulty cable is not uniform over its entire length.

Since temperature affects the value of resistance, corrections must be applied on this account if the temperatures of the two cables are different. Corrections may also have to be applied in case the cables have a large number of joints.

Ohm's law - simple electrical circuits and problems

Objectives: At the end of this lesson you shall be able to
- **state Ohm's law**
- **apply Ohm's law in an electric circuit.**
- **define electrical power and energy and calculate related problems.**

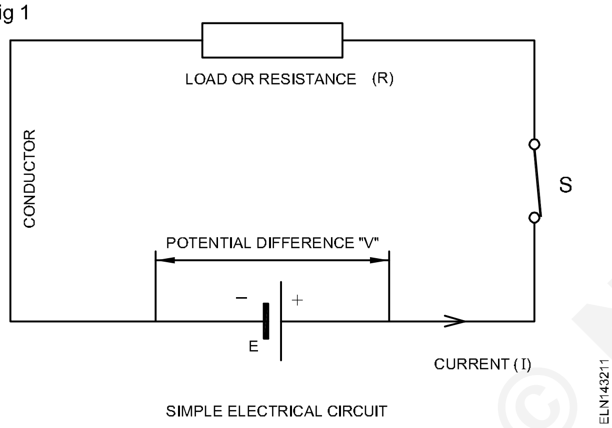
Scan the QR Code to view the video for this exercise

Simple electric circuit

In the simple electric circuit shown in Fig 1, the current completes its path from the positive terminal of the battery via the switch and the load back to the negative terminal of the battery.

The circuit shown in Fig 1 is a closed circuit. In order to make a circuit to function normally the following three factors are essential.

Fig 1



SIMPLE ELECTRICAL CIRCUIT

- Electromotive force (EMF) to drive the electrons through the circuit.
- Current (I), the flow of electrons.
- Resistance (R) - the opposition to limit the flow of electrons.

Ohm's law

Ohm's law states that in any electrical closed circuit, the current (I) is directly proportional to the voltage (V), and it is inversely proportional to the resistance 'R' at constant temperature.

$$I \propto \frac{V}{R}$$

It means I = V/R

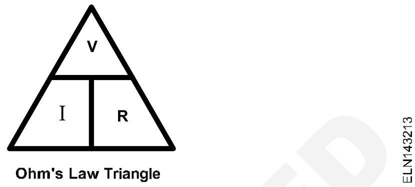
V = Voltage applied to the circuit in 'Volt'

I = Current flowing through the circuit in 'Amp'

R = Resistance of the circuit in Ohm (Ω)

The above relationship can be referred to in a **triangle** as shown in Fig 2. In this triangle whatever the value you want to find out, place the thumb on it then the position of the other factors will give you the required value.

Fig 2



Ohm's Law Triangle

For example for finding 'V' close the value V then, readable

$$I = \frac{V}{R}$$

values are IR so, V = IR

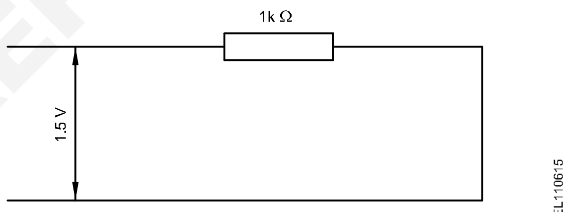
R = V/I

I = V/R

Example 1

How much current (I) flows in the circuit shown in Fig 3.

Fig 3



Given:

Voltage (V) = 1.5 Volts

Resistance (R) = 1 kOhm

= 1000 Ohms

$$I = \frac{V}{R}$$

Solution:

$$I = \frac{1.5\ V}{1000\ Ohms} = 0.0015\ amp$$

Electrical Power (P) & Energy (E) : The product of voltage (V) and current (I) is called electrical power. Electrical power (P) = Voltage x Current P=V x I

The unit of Electrical power is 'Watt' It is denoted by the letter 'P' It is measured by Watt meter. The following formulae can also be derived from formula of power (P) as

i P = V X I

= IR x I

P = I^2R

ii P = V X I

$$= V \times \frac{V}{R}$$

$$P = \frac{V^2}{R}$$

Electrical Energy (E)

The product of power (P) and time (t) is called as electrical energy (E)

Electrical Energy (E) = Power x time

E = P x t

= (V x I) x t

E = V x I x t

The unit of electrical energy is "Watt hour" (Wh)

The commercial unit of Electrical energy is "Kilo watt hour" (KWH) or unit

B.O.T (Board of Trade) unit / KWH/Unit

One B.O.T (Board of Trade) unit is defined as that one thousand watt lamp is used for one hour time, it consumes energy of one kilowatt hour (1kWH). It is also called as **"unit"**

Energy = 1000W x 1Hr = 1000WH (or) 1kWH

Example - 1

How much electrical energy is consumed in an electric iron rated as 750W/250V used for 90 Minutes

Given:

Power (P) = 750W

Voltage (V) = 250V

Time = 90min (or) 1.5Hr

Find:

Electrical Energy (E) = ?

Solution:

Electrical Energy (E) = P x t

=750 w x 1.5Hr

= 1125 WH (or)

E = 1.125 kWH

Work, Power and Energy

Work is said to be done, when a force (F) displaces a body from one distance (s) to another (or)

Work done = Force x distance moved

w.d = F x S

It is generally denoted as "W"

The unit of work done is

i In Foot Pound Second (F.P.S) System is "Foot Pound (lb.ft)"

ii In Centimetre Gram Second (C.G.S) System "Gram Centimetre (gm.cm)"

or

1 gm.cm = 1 dyne

1 dyne = 10^7 ergs

The smallest unit of work done is **"Erg"**

iii In Metre - Kilogram - Second (M.K.S.) System is "Kilogram Metre (Kg-M)'

1 Kilogram = 9.81Newton

iv In system of international unit (S.I. Unit) is 'Joule'

1 Joule = 1 Newton Metre (Nw-M)

Power (P)

The rate of doing work is called as Power (P)

Power (P) = work done / time taken

$$P = \frac{F \times S}{t}$$

It's unit is Lb.ft/sec in FPS system

gm-cm/sec is in C.G.S. System

(or)

Dyne/sec

(or)

Kg-M/sec in M.K.S System (or) NW - M/ sec

(1kg = 9.81 Newton)

Joule/sec in (S.I)

1 Joule/Sec = 1 watt

Electrical Power = VI Watt

The unit of Mechanical power is "Horse Power" (H.P)

Horse Power (HP) further classified into two:

They are:-

Indicated Horse Power - (IHP)

Brake Horse Power - (BHP)

Indicated Horse Power (IHP)

The power developed inside the engine (or) pump (or) motor is called Indicated Horse Power (IHP)

Brake Horse Power (BHP)

The useful Horse Power which is available at the shaft of the engine/motor/pump is called Brake Horse Power (BHP)

So, IHP is always greater than

BHP due to friction losses

IHP > BHP

The relation between Mechanical and Electrical Power (ie) 1 HP (British) = 746 Watt

1 HP (Metric) = 735.5 Watt

One HP (Metric)

The amount of Mechanical Power required to move/displace a body/substance by force of 75 Kg to one metre distance in one second is called as one HP (metric)

HP (Metric) = 75kg - M/Sec

One HP (British)

The amount of Mechanical power required to move/displace a body/substance of force 550lb to one foot (ft) distance in one second is called as one HP (British)

1 HP (British) = 550 lb.ft/sec

Energy

The capacity for doing work is called as electrical Energy

(or)

The product of power and time is known as Electrical energy

(ie) Energy = Power x time

= VI x t

S.I unit of energy is "Joule"

(ie) Energy = (Joule/sec) x sec

$$= \frac{\text{Joulle}}{\text{Sec}} \times \text{Sec} = \text{joule}$$

(ie) The S.I of unit of work done and energy is same (Joule)

The energy can be divided into two main categories (ie)

(i) Potential Energy (eg. Loaded gun, energy (stored in spring etc)

(ii) Kinetic Energy (eg. Moving of car, raining etc).

Example

In a house, the following electrical loads are daily used:-

(i) 5 Nos of 40W Tube Lights used for 5 hours/day

(ii) 4 Nos of 80W fans used for 8 hours/day

(iii) 1 No of 120W T.V. receiver used for 5 hours/day

(iv) 4 No of 60W lamps used for 4 hours/day

Calculate the total energy consumed in unit's per day and also the cost of electric bill for the month of January If the cost of energy is 1.50/unit

Given

Load details per day

Electric Device		Power		Numbers		Time in hours
(i) Tube light	-	40W	-	5	-	5 hr/day
(ii) Fans	-	80W	-	4	-	8 hr/day
(iii) T.V.	-	120W	-	1	-	6 hr/day
(iv) Lamps	-	60W	-	4	-	4 hr/day

cost of energy - Rs.1.50/unit

Find:

(i) Energy consumption in unit per day = ?

(ii) Cost of energy for the month of January = ?

Solution

Energy consumption/day

1. Tube light = 40W x 5 x 5 hr /day

$$= \frac{1000 \text{ wh}}{1000} = 1\text{Kwh/day}$$

2. Fans = 80W x 4x8 hr/day

$$= \frac{2560}{1000} = 2.56\text{Kwh/day}$$

3. T.V. = 120W x 1x6 hr/day

$$= \frac{720 \text{ wh}}{1000} = 0.72\text{Kwh/day}$$

4. Lamp = 60W x 4x4 hr/day

$$= \frac{960}{1000} = \text{Kwh} = \frac{0.96 \text{ kwh/day}}{5.24 \text{ kwh/day}}$$

(i) Total energy consumption in unit per day = 5.24 unit

(ii) Total energy consumption for the month of January (i.e 31 days) = 5.24 x 31 = 162.44 units

Cost of energy = Rs. 1.50/unit

Total electric bill for the month of January = 162.44 x 1.50 = Rs.243.66

Electricity Bill for the month = Rs. 244/-

Kirchhoff's law and its applications

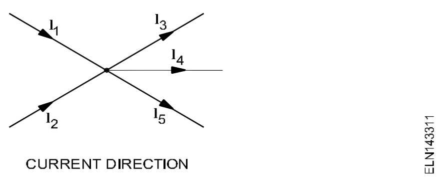
Objectives: At the end of this lesson you shall be able to
- **state Kirchhoff's first law**
- **apply Kirchhoff's first law to find the circuit current**
- **state Kirchhoff's second law and apply the same to find the voltage drop in branches**
- **solve problems by applying Kirchhoff's laws.**

Kirchoff's laws are used in determinig the equivalent resistance of a complex network and the current flowing in the various conductors.

Kirchhoff's laws

Kirchhoff's first law: At each junction of currents, the sum of the incoming currents is equal to the sum of the outgoing currents. (Fig 1) (or) The algebric sum of all branch currents meeting at a point/node is zero

Fig 1



If all inflowing currents have positive signs and all outflowing currents have negative signs, then we can state that

$I_1 + I_2 = I_3 + I_4 + I_5$

$+ I_1 + I_2 - I_3 - I_4 - I_5 = 0$

In the above example the sum of all the currents flowing at the junction (node) is equal to zero.

$\Sigma I = 0$

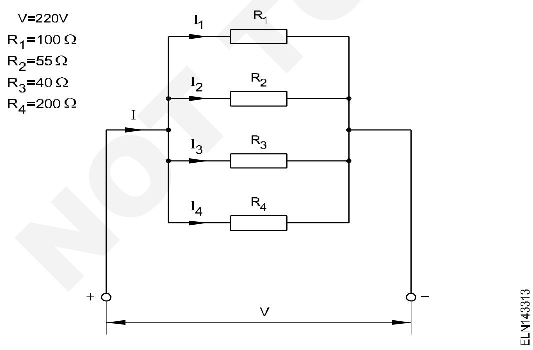
$I = I_1 + I_2 + I_3 + ...$

Example: Apply Kirchhoff's First Law to find the current shown in circuit.. (Fig 2)

Find current

I, I_1, I_2, I_3, I_4

Fig 2



Solution

$$I_1 = \frac{V}{R_1} = \frac{220\ V}{100\ ohms} = 2.2A$$

$$I_2 = \frac{V}{R_2} = \frac{220\ V}{55\ ohms} = 4A$$

$$I_3 = \frac{V}{R_3} = \frac{220\ V}{40\ ohms} = 5.5A$$

$$I_4 = \frac{V}{R_4} = \frac{220\ V}{200\ ohms} = 1.1A$$

$$I = I_1 + I_2 + I_3 + I_4$$
$$= 2.2A + 4A + 5.5A + 1.1A = 12.8A$$

Checking the calculation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{100} + \frac{1}{55} + \frac{1}{40} + \frac{1}{200}$$

$$= \frac{22 + 40 + 55 + 11}{2200} = \frac{128}{2200} = \frac{16}{275}$$

$$\frac{1}{R_{TOT}} = \frac{16}{275}$$

$$R_{TOT} = 17.19\ ohms$$

$$I = \frac{V}{R_{TOT}} = \frac{220V}{17.19\ ohms} = 12.798\ A$$

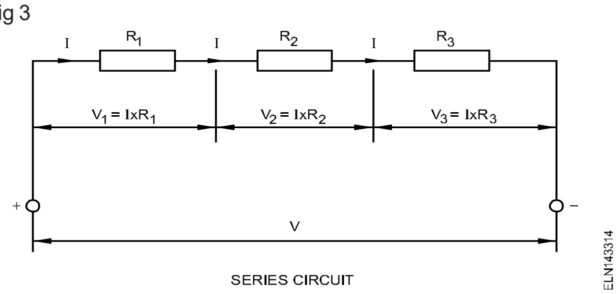
Kirchhoff's second law : In closed circuits, the applied terminal voltage V is equal to the sum of the voltage drops $V_1 + V_2$ and so forth. (Fig 3)

If all the generated voltages are taken as positive, and all the consumed voltages are taken as negative, then it can be stated that:

in each closed circuit the sum of all voltages is equal to zero.

$\Sigma V = 0$

Fig 3



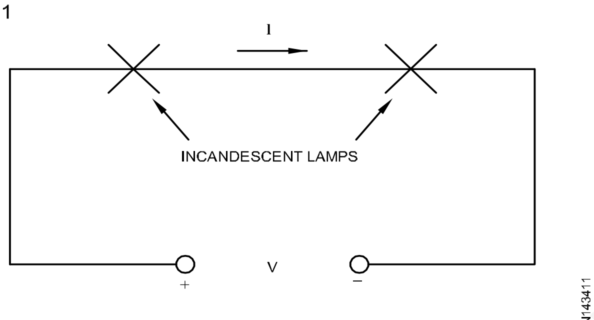
DC series and parallel circuits

Objectives: At the end of this lesson you shall be able to
- **state the characteristics of series circuit and determine the current and voltage across each resistors**
- **determine the total voltage sources in series circuit**
- **state the relation between EMF potential difference and terminal voltage.**

The series circuit

If more than one resistors are connected one by one like a chain and if the current has only one path is called as series circuit. It is possible to connect two incandescent lamps in the way shown in Fig 1. This connection is called a series connection, in which the same current flows in the two lamps.

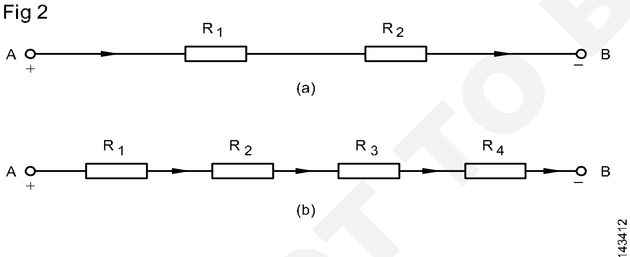
Fig 1



SERIES CIRCUIT WITH LAMPS

The lamps are replaced by resistors in Fig 2. Fig 2 (a) shows two resistors are connected in series between point A and point B. Fig 2(b) shows four resistors are in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

Fig 2



SERIES CIRCUIT WITH RESISTORS

Current in series circuits

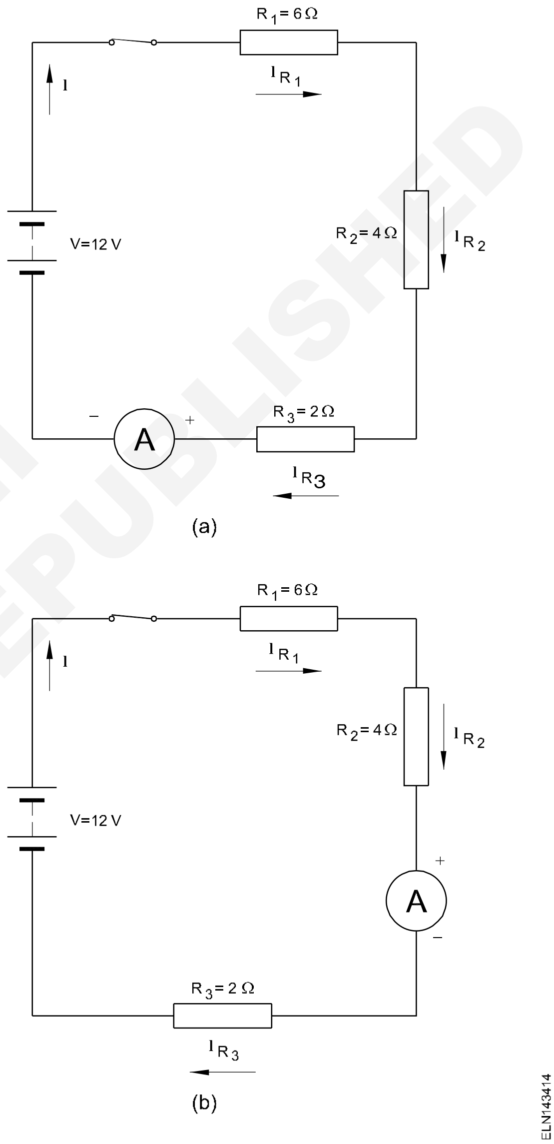
The current will be the same at any point of the series circuit. This can be verified by measuring the current in any two points of a given circuit as shown in Figs 3a and 3b. The ammeters will show the same reading.

The current relationship in a series circuit is

$I = I_{R1} = I_{R2} = I_{R3}$. (Refer Fig 3a & 3b)

We can conclude that there is only one path for the current to flow in a series circuit. Hence, the current is the same throughout the circuit.

Fig 3



The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$R = R_1 + R_2 + R_3 + ...R_n$

where R is the total resistance

$R_1, R_2, R_3,.......R_n$ are the resistors connected in series.

When a circuit has more than one resistor of the same value in series, the total resistance is $R = r \times N$

where 'r' is the value of each resistor and N is the number of resistors in series.

Voltage in series circuits

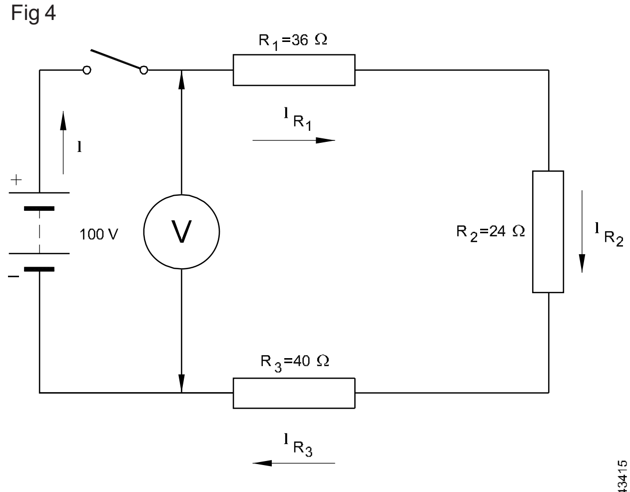
In DC circuit voltage divides up across the load resistors, depending upon the value of the resistor so that the sum of the individual load voltages equals the source voltage.

As the source voltage divides/drops across the series resistance depending upon the value of the resistances

$$V = V_{R1} + V_{R2} + V_{R3} + ...V_{RH}$$

the total voltage of a series circuit must be measured across the voltage source, as shown in Fig 4.

Fig 4



MEASURIING THE TOTAL VOLTAGE OF SERIES CIRCUIT

When Ohm's law is applied to the complete circuit having an applied voltage V, and total resistance R, we have the current in the circuit as

$$I = \frac{V}{R}$$

Application of Ohm's law to DC series circuits

Applying to Ohm's law to the series circuit, the relation between various currents could be stated as below

$$I = I_{R1} = I_{R2} = I_{R3}$$

This could be stated as $\frac{V}{R} = \frac{V_{R1}}{R_1} = \frac{V_{R2}}{R_2} = \frac{V_{R3}}{R_3}$

You can use any of the above formulae to calculate current in a series circuit.

$$V = V_{R1} + V_{R2} + V_{R3}$$

$$\text{i.e.} IR = R_1 I_{R1} + R_2 I_{R2} + R_3 I_{R3}$$

and Total resistance $R = R_1 + R_2 + R_3$.

Use of series connection

1 Cells in torch light, car batteries, etc.

2 Cluster of mini-lamps used for decoration purposes.

3 Fuse in circuit.

4 Overload coil in motor starters.

5 Multiplier resistance of a voltmeter.

Definitions

Electromotive force (emf)

We have seen that the electromotive force (emf) of a cell is the open circuit voltage, and the potential difference (PD) is the voltage across the cell when it delivers a current. The potential difference is always less than the emf.

Potential difference

PD = emf – voltage drop in the cell

Potential difference can also be called by another term, the terminal voltage, as explained below.

Terminal voltage

It is the voltage available at the terminal of the source of supply. Its symbol is V_T. Its unit is also the volt. It is given by the emf minus the voltage drop in the source of supply,

i.e. $V_T = \text{emf} - IR$

where I is the current and R the resistance of the source.

Voltage drop (IR drop)

The voltage lost by resistance in a circuit is called the Voltage drop or IR drop.

DC parallel circuit

Objectives: At the end of this lesson you shall be able to
- **explain a parallel circuit**
- **determine the voltages in a parallel circuit**
- **determine the current in a parallel circuit**
- **determine the total resistances in a parallel circuit**
- **state the application of a parallel circuit.**

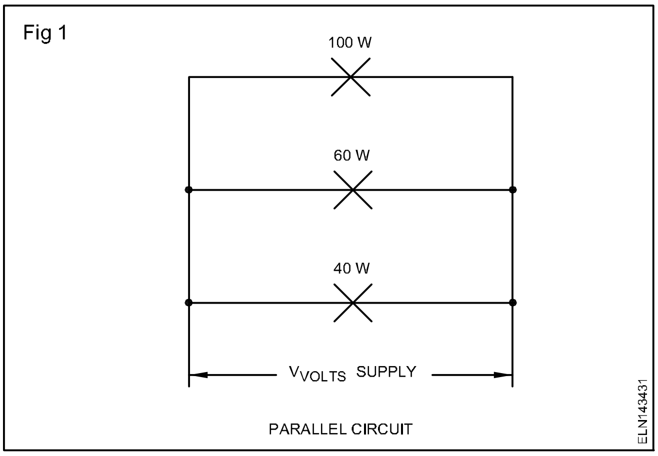
In an electrical circuit, if the current has more than one paths and equal voltage in each branch is called parallel circuit.

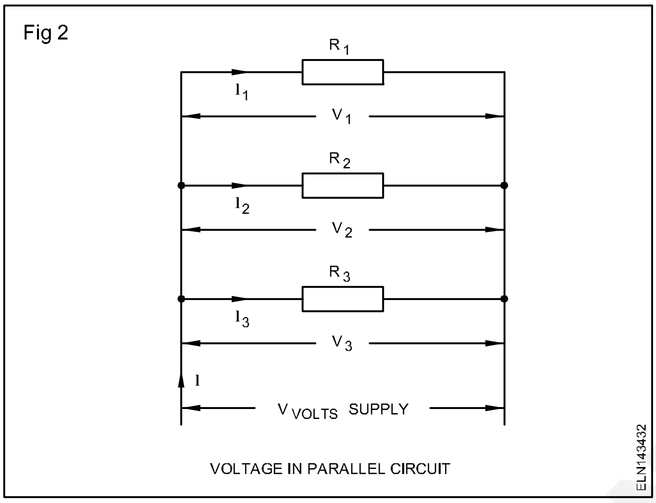
It is possible to connect three incandescent lamps as shown in Fig 1. This connection is called parallel connection in which, the same source voltage is applied across all the three lamps.

Voltage in parallel circuit

The lamps in Fig 1 are replaced by resistors in Fig 2. Again the voltage applied across the resistors is the same and also equal to the supply voltage.

We can conclude that the voltage across the parallel circuit is the same as the supply voltage.





Mathematically it could be expressed as $V = V_1 = V_2 = V_3$.

Current in parallel circuit

Again referring to Fig 2 and applying Ohm's law, the individual branch currents in the parallel circuit could be determined.

Current in resistor $R_1 = I_1 = \frac{V_1}{R_1} = \frac{V}{R_1}$.

Current in resistor $R_2 = I_2 = \frac{V_2}{R_2} = \frac{V}{R_2}$.

Current in resistor $R_3 = I_3 = \frac{V_3}{R_3} = \frac{V}{R_3}$

as $V_1 = V_2 = V_3$.

Refer to Fig 2 in which the branch currents I_1, I_2 and I_3 are shown to flow into resistance branches R_1, R_2 and R_3 respectively.

The total current I in the parallel circuit is the sum of the individual branch currents.

Mathematically it could be expressed as $I = I_1 + I_2 + I_3 + ... I_n$.

Resistance in parallel circuit

In a parallel circuit, individual branch resistances offer opposition to the current flow though the voltage across the branches will be same.

Let the total resistance in the parallel circuit be R ohms.

By the application of Ohm's law

we can write

$$R = \frac{V}{I} \text{ ohms or } I = \frac{V}{R} \text{ amps.}$$

where

R is the total resistance of the parallel circuit in ohms

V is the applied source voltage in volts, and

I is the total current in the parallel circuit in amperes.

We have also seen

$I = I_1 + I_2 + I_3$

or $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

As V is the same throughout the equation and dividing the above equation by V, we can write

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The above equation reveals that in a parallel circuit, the reciprocal of the total resistance is equal to the sum of the reciprocals of the individual branch resistances.

Applications of parallel circuits

The electric system used in homes consists of many parallel circuits.

An automobile electric system uses parallel circuits for lights, horn, motor, radio etc. Each of these devices operates independent of the others.

Individual television circuits are quite complex. However, the complex circuits are connected in parallel to the main power source. That is why the audio section of television receivers can still work when the video (picture) is inoperative.

Open and short circuit in series and parallel network

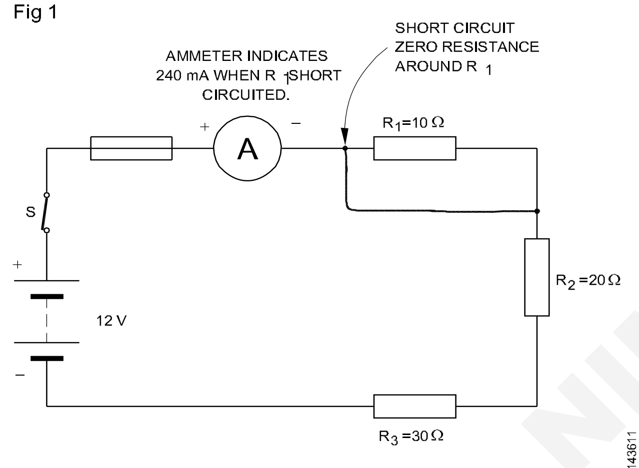
Objectives: At the end of this lesson you shall be able to
- **state about short circuit in series circuit and its effect in series circuit**
- **state the effect of an open circuit in series circuit and its causes**
- **state the effect of shorts and open in parallel circuit.**

Short circuits

A short circuit is a path of zero or very low resistance compared to the normal circuit resistance.

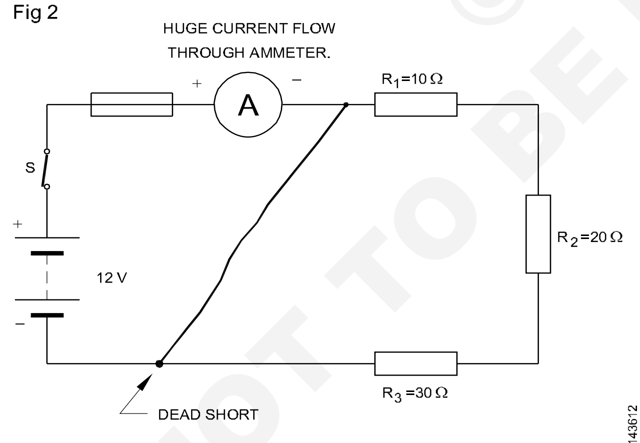
In a series circuit, short circuits may be partial or full (dead short) as shown in Fig 1 and Fig 2 respectively.

Fig 1



PARTIAL SHORT AT R 1

Fig 2



DEAD SHORT ACROSS CIRCUIT

Short circuits cause an increase in current that may or damage the series circuit.

Effects due to short circuit

Excess current due to short circuit can damage the circuit components, power sources, or burn the insulation of connecting wires. Fire is also caused due to intense heat generated in the conductors.

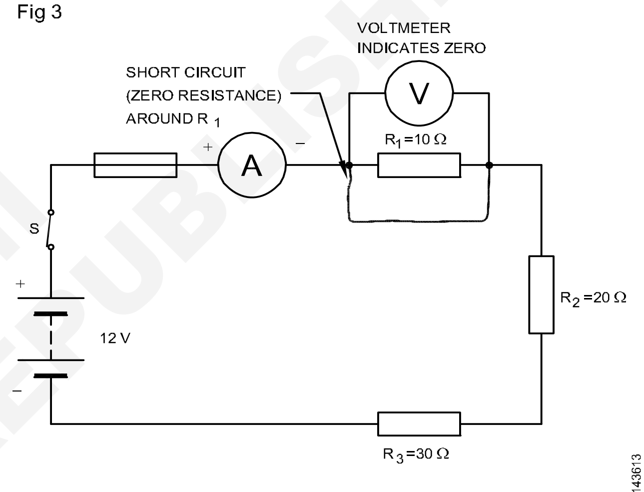
Protection against dangers of short circuit

Dangers of short circuit can be prevented by means of fuses and circuit breakers in series with the circuit.

Detecting short circuit

When the ammeter in the circuit indicates excessive current then it indicates a short circuit in the circuit. The location of short in a circuit can be detected by connecting a voltmeter across each of the elements (resistors) and circuit source. If the voltmeter indicates zero volts or reduced voltage across the element, it is short circuited as shown in Fig 3.

Fig 3



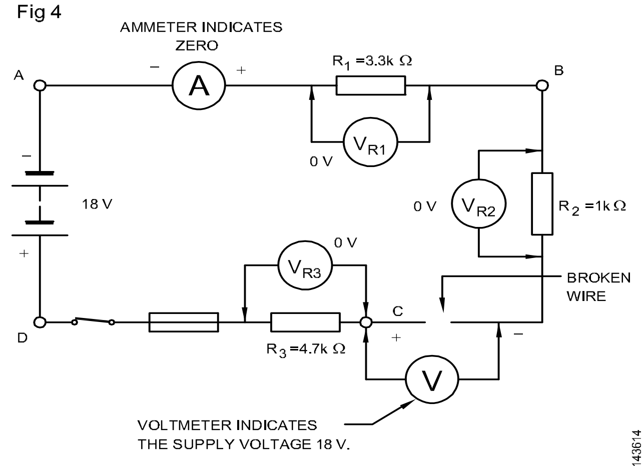
SHORT CIRCUIT IN ONE RESISTANCE

Open circuit in series circuit

An open circuit results whenever a circuit is broken or is incomplete, and there is no continuity in the circuit.

In a series circuit, open circuit means that there is no path for the current, and no current flows through the circuit. Any ammeter in the circuit will indicate no current as shown in Fig 4.

Fig 4



OPEN CIRCUIT IN SERIES CIRCUIT

Causes for open circuit in series circuit

Open circuits, normally, happen due to improper contacts of switches, burnt out fuses, breakage in connection wires and burnt out resistors etc.

Effect of open in series circuit

a No current flows in the circuit.

b No device in the circuit will function.

c Total supply voltage/ source voltage appear across the open.

Determination the location of break in the circuit has occurred

Use a voltmeter on a range that can accommodate the supply voltage; connect it across each connecting wire in turn. If one of the wires is open as shown in Fig 4, the full supply voltage is indicated on the voltmeter. In the absence of a current, there is no voltage drop across any of the resistors. Therefore, the voltmeter must be reading full supply voltage across the open. part of the circuit

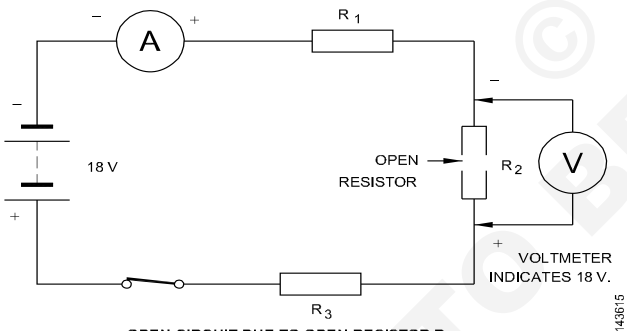
Voltmeter reading

$= 18\ V - V_{R1} - V_{R2} - V_{R3}$

$= 18\ V - O\ V - O\ V - O\ V = 18\ V.$

If the circuit was open due to a defective resistor, as shown in Fig 5 (resistors usually open when they burn out), the voltmeter would indicate 18 V when connected across this resistor, R_2.

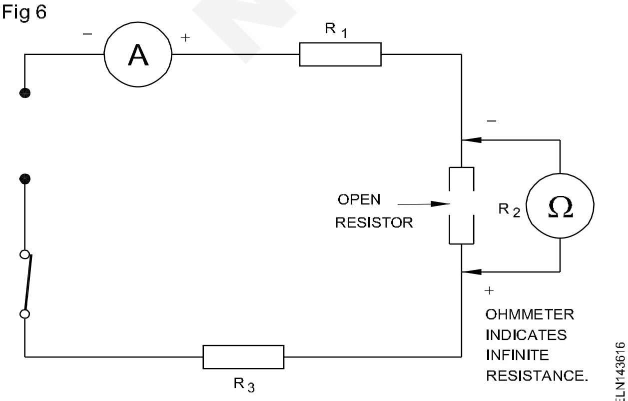
Fig 5



OPEN CIRCUIT DUE TO OPEN RESISTOR R 2

Alternatively, the open circuit may be found using an ohmmeter. With the voltage removed, the ohmmeter will show no continuity (infinite resistance), when connected across the broken wire or open resistor. (Fig 6)

Fig 6



Shorts and opens in parallel circuits

The two possible defects that can occur in an electrical circuit they are:

- short circuit
- open circuit

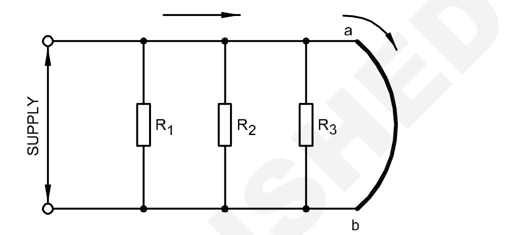
Shorts in parallel circuit:

Fig 7 shows a parallel circuit with short between points 'a' and 'b'.

This causes reduction of circuit resistance almost to zero.

Therefore, the voltage drop across 'ab' will be almost zero (by Ohms law).

Fig 7



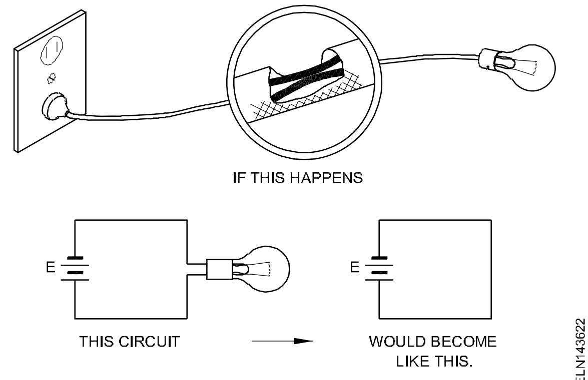
SHORT IN PARALLEL

Thus current through the resistors R_1, R_2, R_3 will be negligible and not their normal current.

The result is that a very high current in the order of hundred times of the normal current will flow through the short circuit.

A short circuit exists when current can flow from the positive terminal of the power source through connecting wires and back to the negative terminal of the power source without going through any load. (Fig 8)

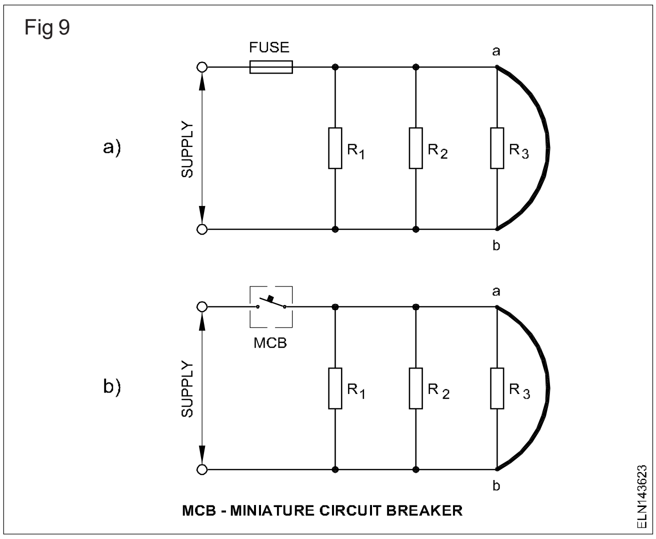
Fig 8

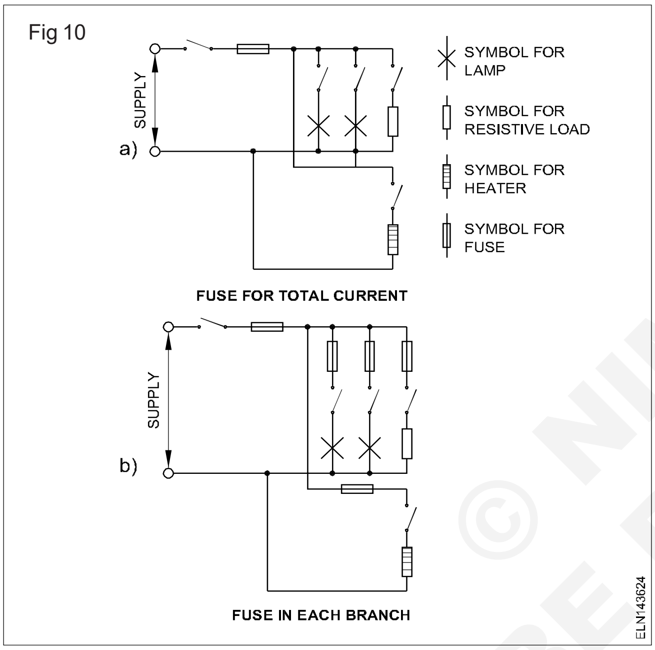


Short circuit may cause burning of the circuit elements like cables, switches etc.

To avoid burning of circuit components safety devices like 'fuse', circuit breakers etc. are used to open the circuit. (Figs 9a & 9b).

For a fuse to protect a parallel circuit, it should be placed in the circuit where the total current flows or else each branch must have a fuse. (Fig 10(a&b))



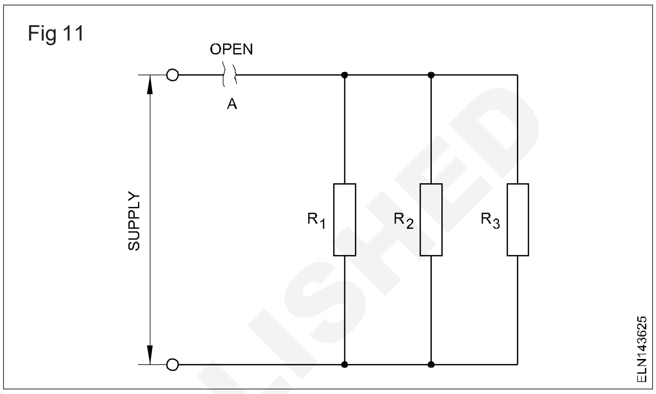


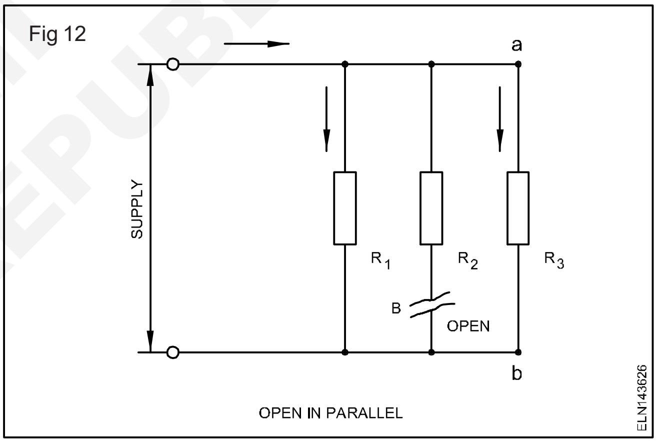
Opens in parallel circuit

An open in the common line at point A as shown in Fig 11 causes no current flow in that circuit whereas an open in the branch at point B causes no current flow only in that branch. (Fig 12)

However, the current in branches R_1 and R_3 will continue to flow so long as they are connected to the voltage source.

Full voltage of the source will be available at open circuit terminals. It is dangerous to meddle with the terminals which are open.





Laws of resistance and various types of resistors

Objectives: At the end of this lesson you shall be able to
- **state the laws of resistance, compare resistances of different materials**
- **state the relationship between the resistance and diameter of a conductor**
- **calculate the resistance and diameter of a conductor from the given data (i.e. dimensions etc.)**
- **explain various types of resistors.**

Laws of resistance: The resistance R offered by a conductor depends on the following factors.

- The resistance of the conductor varies directly with its length.
- The resistance of the conductor is inversely proportional to its cross-sectional area.
- The resistance of the conductor depends on the material with which it is made of.
- It also depends on the temperature of the conductor.

Ignoring the last factor for the time being,we can say that

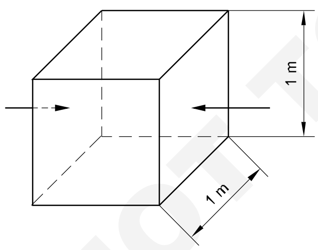
$$R = \frac{\rho L}{a}$$

where 'ρ' (rho - Greek alphabet) - is a constant depending on the nature of the material of the conductor, and is known as its **specific resistance** or **resistivity.**

If the length is one metre and the area, 'a' = 1 m^2, then R = r.

Hence, specific resistance of a material may be defined as `the resistance between the opposite faces of a metre cube of that material'. (or, sometimes, the unit cube is taken in centimetre cube of that material) (Fig 1).

Fig 1



We have $\rho = \frac{aR}{L}$

In the SI system of units

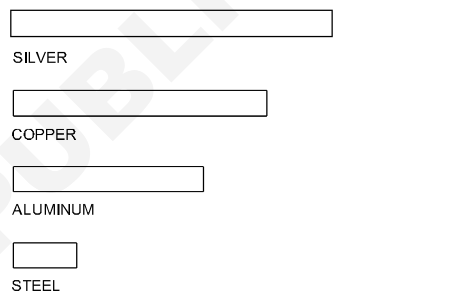
$$\rho = \frac{a\,\text{metre}^2 \times R\,\text{ohm}}{L\,\text{metre}}$$

$$= \frac{aR}{L}\,\text{ohm} - \text{metre}$$

Hence the unit of specific resistance is ohm metre (Ωm).

Comparison of the resistance of different materials: Fig 2 gives some relative idea of the more important materials as conductors of electricity. All the conductors shown have the same cross-sectional area and the same amount of resistance. The silver wire is the longest while that of copper is slightly short and that of aluminium is shorter still. The silver wire is more than 5 times longer than the steel wire.

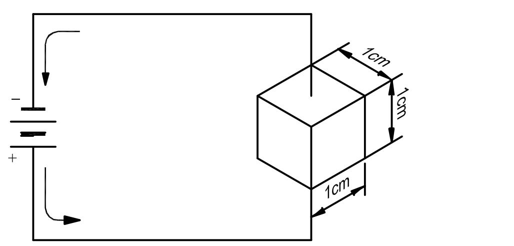
Fig 2



THE CONDUCTANCE OF DIFFERENT MATERIALS

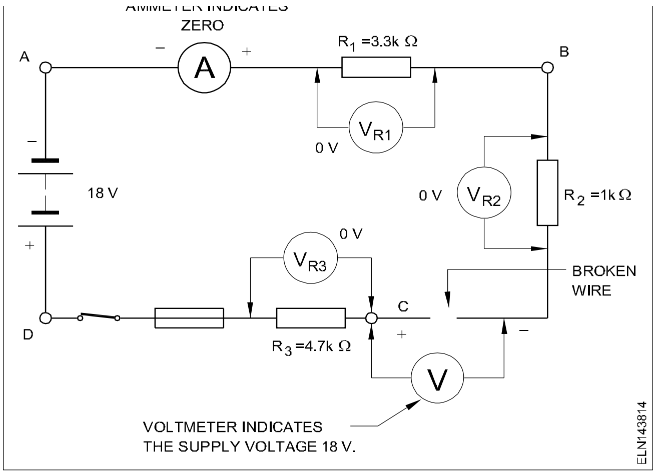
Since different metals have different conductance ratings, they must also have different resistance ratings. The resistance ratings of the different metals can be found by experimenting with a standard piece of each metal in an electric circuit. If you cut a piece of each of the more common metals to a standard size, and then connect the pieces to a battery, one at a time, you would find that different amounts of current would flow. (Fig 3)

Fig 3



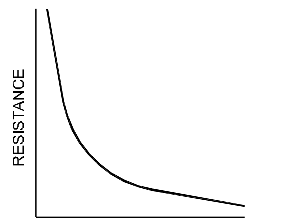
SPECIFIC RESISTANCE CIRCUIT

The bar graph (Fig 4) shows the resistance of some common metals as compared to copper. Silver is a better conductor than copper because it has less resistance. Nichrome has 60 times more resistance than copper, and copper will conduct 60 times as much current as Nichrome, if they were connected to the same battery, one at a time.



In general, we may, say that the resistance of a given length of a conductor is inversely proportional to its cross-sectional area (Fig 5)

Fig 5



INCREASING THE CROSS-SECTIONAL AREA OF A WIRE DECREASES ITS RESISTANCE

The other factor that influences the resistance is the nature of the material. Hence, we may now say that resistance of a wire

$$= \frac{\text{length}}{\text{area}} \times \text{(a constant) } \rho \text{ given material}$$

$$R(\text{ohms}) = \frac{L\ (\text{metres})}{a\ \text{metre}^2} \times \rho$$

So that $\rho = Ra \div L$ ohm/ meter

where ρ (greek letter, pronounced 'rho') represents the constant.

L is the length of the wire in metres

a is the area in square metres.

We can reduce all this into a simple statement: the larger the wire, the lower its resistacne; the smaller cross sectional area of the wire, the higher its resistance.

We can summarize with the universal rule: the electrical resistance of any metallic conductor is inversely proportional to its cross-sectional area.

Resistors

Objective: At the end of this lesson you shall be able to
- **explain the construction and characteristics of various types of resistors**

Resistors : These are the most common passive component used in electrical and electronic circuits. A resistor is manufactured with a specific value of ohms (resistance). The purpose of using a resistor in circuit is either to limit the current to a specific value or to provide a desired voltage drop (IR). The power rating of resistors may be from fractional walts to hundreds of Watts.

There are five types of resistors

1 Wire-wound resistors

2 Carbon composition resistors

3 Metal film resistors

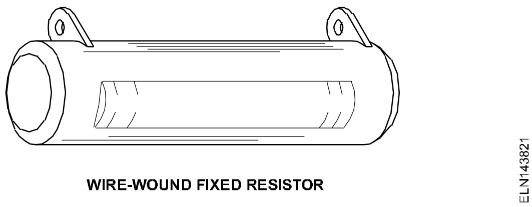
4 Carbon film resistors

5 Special resistors

1 Wire-wound resistors

Wire-wound resistors are manufactured by using resistance wire (nickel-chrome alloy called Nichrome) wrapped around an insulating core, such as ceramic porcelain, bakelite pressed paper etc. Fig 1, shows this type of resistor. Wire wound resistors are used for high current application. They are available in wattage ratings from one watt to 100 watts or more.

Fig 1

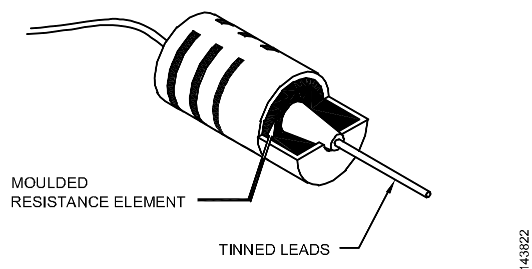


WIRE-WOUND FIXED RESISTOR

2 Carbon composition resistors

These are made of fine carbon or graphite mixed with powdered insulating material as a binder in the proportion needed for the desired resistance value. Fig 2 shows the construction of carbon composition resistor.

Fig 2



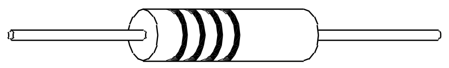
CARBON COMPOSITION RESISTOR

Carbon resistor are available in values of 1 ohm to 22 megohms.

3 Metal film resistors (Fig 3)

Metal film resistors are manufactured by two processes. Thick film resistors are pasted with metal compound and powdered glass which are spread on the ceramic base and then backed (Fig 3).

Fig 3



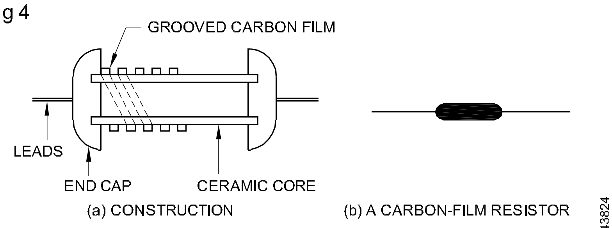
METAL FILM RESISTOR

Metal film resistors are available from 1 ohm to 10 MΩ, upto 1W.

4 Carbon film resistors (Fig 4)

In this type, a thin layer of carbon film is deposited on the ceramic base/tube. A spiral groove is cut over the surface to increase the length of the foil by a specialised process.

Fig 4



CARBON – FILM RESISTOR

Carbon film resistors are available from 1 ohm to 10 meg ohm and up to 1 W and can work from 85°C to 155°C.

The resistors can also be classified with respect to their function as

1 Fixed resistors

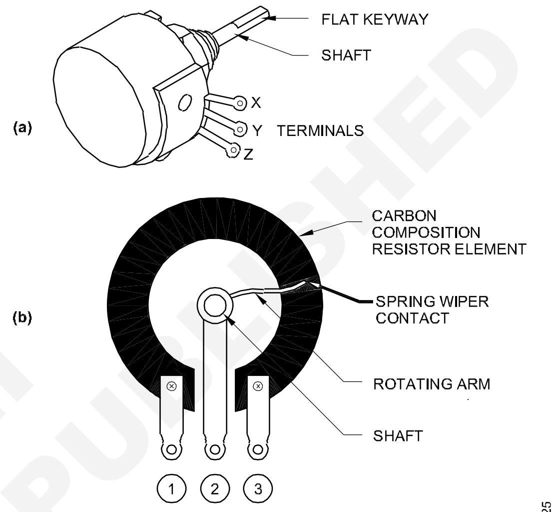
2 Variable resistors

Fixed resistors : The fixed resistors is one in which the is nominal value of resistance is fixed. These resistors are provided with pair of leads. (Fig 1 to 4)

Variable resistors (Fig 5) : Variable resistors are those whose values can be changed. Variable resistors includes those components in which the resistance value can be set at the different levels with the help of sliding contacts. These are known as potentio meter resistors or simply as a potentio meters.

Resistance depends upon temperature, voltage, light : Special resistors are also produced whose resistance varies with temperature, voltage, and light.

Fig 5



VARIABLE CARBON-RESISTANCE (a) EXTERNAL VIEW
(b) INTERNAL VIEW OF CIRCULAR RESISTANCE ELEMENT

Marking codes for resistors

Objectives: At the end of this lesson you shall be able to
- **interpret the coded marking of colours on the resistors**
- **interpret the letter and digit codes for resistance values**
- **state the tolerance value for resistors.**

Resistance and tolerance value of colour coded resistors : Commercially, the value of resistance and tolerance value are marked over the resistors by colour codes (or) letter and digital codes.

The colour codes for indicating the values to two significant figure and tolerances are given in Table 1 as per IS 8186.

Table 1

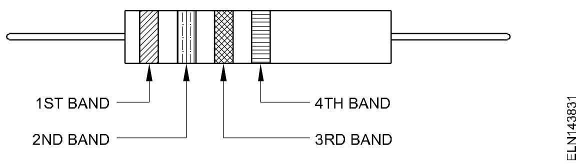
Values to two significant figures and tolerances corresponding to colours

Colour	First Band/ Dot	Second Band/ Dot	Third Band/ Dot	Fourth Band/ Dot
	First Figure	Second Figure	Multiplier	Tolerance
Silver	—	—	10^{-2}	± 10 %
Gold	—	—	10^{-1}	± 5 %
Black	—	0	1	—
Brown	1	1	10	± 1 %
Red	2	2	10^2	± 2 %
Orange	3	3	10^3	—
Yellow	4	4	10^4	—
Green	5	5	10^5	—
Blue	6	6	10^6	—
Violet	7	7	10^7	—
Grey	8	8	10^8	—
White	9	9	10^9	—
None	—	—	—	± 20 %

The two significant figures and tolerances colour coded resistors have 4 bands of colours coated on the body as in Fig.1.

The first band shall be the one nearest to one end of the component resistor. The second, third and four colour bands are shown in Fig 1.

Fig 1



The first two colour bands indicate the first two digits in the numeric value of resistance. The third colour band indicates the multiplier. The first two digits are multiplied by the multiplier to obtain the actual resistance value. The forth colour band indicates the tolerance in percentage.

Example

Resistance value : If the colour band on a resistor are in the order- Red, Green, Orange and Gold, then

First colour	Second colour	Third colour	Fourth colour
Red	Violet	Orange	Gold
2	7	1000(10^3)	±5%

the value of the resistor is 27,000 ohms with +5% tolerance.

Tolerance value : The fourth band (tolerance) indicates the resistance range within which is the actual value falls. In the above example, the tolerance is ±5%. ±5% of 27000 is 1350 ohms. Therefore, the value of the resistor is any value between 25650 ohms and 28350 ohms. The resistors with lower value of tolerance (precision) are costlier than normal value of resistors.

Methods of measuring low and medium resistance

Objectives: At the end of this lesson you shall be able to
- **state the different methods of measuring resistance**
- **describe the ammeter & voltmeter method.**

Methods of measuring low resistance: The following three methods are used to measure low resistance.

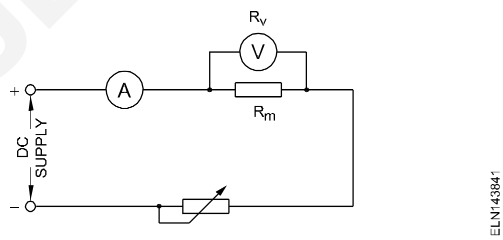
- Voltmeter and ammeter method.
- Comparison of unknown with standard using potentiometer.
- Kelvin bridge
- Shunt type Ohmmeter

Ammeter and voltmeter method: This method, which is the simplest of all, is very commonly used for the measurement of low resistance.

In Fig 1, R_m is the resistance to be measured and V is a high resistance voltmeter of resistance R_v. A current from a steady direct current supply is passed through R in series with a suitable ammeter. Then assuming the current through the unknown resistance to be the same as that measured by the ammeter A, the formula is given as

$$R_m = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}}$$

Fig 1



R_m = Measured value

Medium resistance: The following three methods are used to measure medium resistance.

- Series type Ohmmeter
- Voltmeter and ammeter method
- Wheatstone bridge method

Ohmmeter

Objectives: At the end of this lesson you shall be able to
- **explain the principle, construction and use of a series type ohmmeter**
- **explain the principle, construction and use of a shunt type ohmmeter.**

Measurement of resistances

Medium resistances could be measured by instruments like Kelvin's bridge, Wheatstone bridge, Slide wire bridge, Post Office box and Ohmmeter.

However, for measuring high resistances, instruments like megohmmeter or megger are used.

Ohmmeter

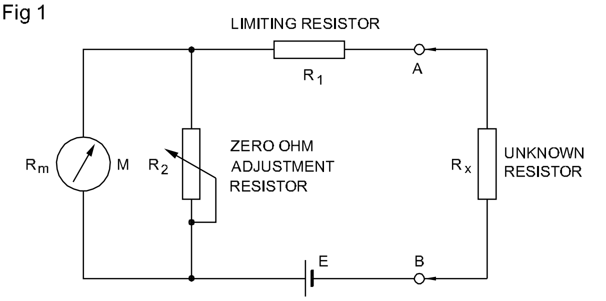
The ohmmeter is an instrument that is used for measuring resistance. There are two types of ohmmeters: the series ohmmeter is used for measuring medium resistances and the shunt type ohmmeter is used for measuring low and medium resistances. The ohmmeter in it basic form consists of an internal dry cell, a PMMC meter movement and a current limiting resistance.

Before using an ohmmeter in a circuit, for resistance measurement, the current in the circuit must be switched off and also any electrolytic capacitor in the circuit should be discharged. Remember that the ohmmeter has its own source of supply.

Series type ohmmeter: construction

A series type ohmmeter shown in Fig 1 essentially consists of a PMMC (Permanent magnet moving coil) ('d' Arsonval) movement 'M', a limiting resistance R_1 and a battery 'E' and a pair of terminals A and B to which the unknown resistance 'R_x' is to be connected. The shunt resistance R_2 connected in parallel to meter 'M' is used for adjusting the zero position of the pointer.

Fig 1



SERIES TYPE OHMMETER

Working

When the terminals A and B are shorted (unknown resistor R_x = zero), maximum current flows in the circuit. The meter is made to read full scale current (I_{fsd})by adjusting the shunt resistance R_2. The full scale current position of the pointer is marked zero(0) ohm on the scale.

When the ohmmeter leads (A & B terminals) are open, no current flows through the meter movement. Therefore, the meter does not deflect and the pointer remains in the left hand side of the dial. The left side of the dial is marked as infinity ($\propto$) resistance which means that there is infinite resistance (open circuit) between the test leads.

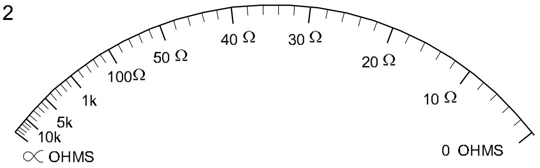
Intermediate marking may be placed in the dial (scale) by connecting different known values of R_x, to the instrument terminals A and B.

The accuracy of the ohmmeter depends greatly upon the condition of the battery. The voltage of the internal battery may decrease gradually due to usage or storage time. As such the full scale current drops and the meter does not read zero when the terminals A and B are shorted.

The variable shunt resistor R_2 in Fig 1 provides an adjustment to counteract the effect of reduced battery voltage within certain limits. If the battery voltage falls below a certain value, adjusting R_2 may not bring the pointer to zero position, and hence, the battery should be replaced with a good one.

As shown in Fig 2, the meter scale will be marked zero ohms at the right end and infinity ohms at the left end.

Fig 2



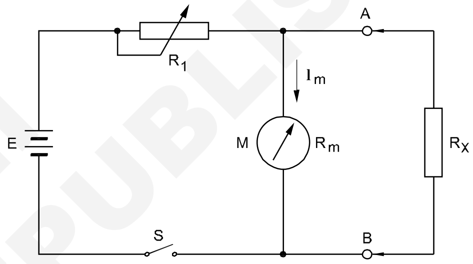
SERIES TYPE OHMMETER SCALE

This ohmmeter has a non-linear scale because of the inverse relationship between resistance and current. This results in an expanded scale near the zero end and a crowded scale at the infinity end.

Shunt type ohmmeter

Fig 3 shows the circuit diagram of a shunt type ohmmeter. In this meter the battery 'E' is in series with the zero ohm, adjustment resistor R_1 and the PMMC meter movement. The unknown resistance R_x which is connected across the terminals A and B forms a parallel circuit with the meter. To avoid draining of the battery during storage, the switch S is of a spring-loaded, push-button type.

Fig 3



SHUNT TYPE OHMMETER

Working

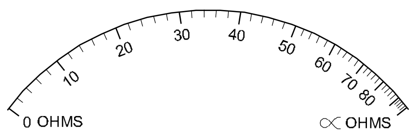
When the terminals A and B are shorted (the unknown resistance R_x = zero ohm), the meter current is zero. On the other hand if the unknown resistance $R_x = \propto$ =(keeping A and B open) the current flows only through the meter, and by proper selection of the value R_1, the pointer can be made to read its full scale.

The shunt type ohmmeter, therefore, has the zero mark at the left hand side of the scale (no current) and the infinite mark at right hand side of the scale (full scale deflection current) as shown in Fig 4. When measuring the resistance of the intermediate values the current flow divides in a ratio inversely proportional to the meter resistance and the unknown resistance. Accordingly the pointer takes an intermediate position.

Use

This type of ohmmeter is particularly suitable for measuring low value resistors.

Fig 4



SHUNT TYPE OHMMETER SCALE

Wheatstone bridge - principle and its application

Objectives: At the end of this lesson you shall be able to
- **state wheatstone bridge circuit, construction, function and uses.**
- **determine the unknown resistance by the wheatstone bridge.**

For determining the unknown resistance by Wheatstone Bridge

- The current flowing through the bridge connection should be zero.
- The values of the other three resistances should be precisely known.

How to find no current flows through the bridge connection?: An instrument, that can indicate the flow of even a few micro amperes (millionth of an ampere), called galvanometer, is used. There are galvanometers that give full scale deflection for 25 microamperes.

In the professional Wheatstone bridges, the galvanometer is provided with a parallel resistance and switch. The bridge connection is made only by pressing a push button. This enables the user to check a momentary deflection of the meter. In the case of excessive deflection, adjustment of the variable resistor is done. Final and precise adjustment of the variable resistance is made keeping the shunt resistor of the galvanometer open.

The three arms of the bridge are made of standard/ precision resistors. The contact resistance is kept very very low to increase the accuracy of the measurement made by the Wheatstone bridge.

In short, the use of the galvanometer is to ensure that the current through the bridge connection is zero, i.e. both parallel branches have equipotential points connected by the bridge connector.

This arrangement is named after its inventor and is called the Wheatstone Bridge.

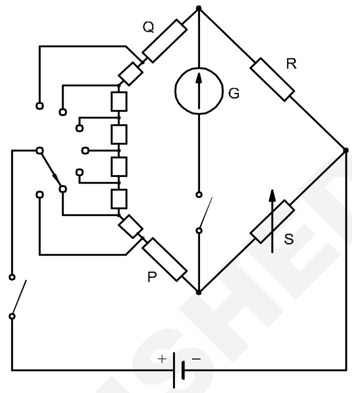
The Wheatstone Bridge is used for measurements in the range of about 1.0 ohm to 1.0 megohm. In Fig 1, resistors P,Q and S are internal to the instrument. R is the resistor of unknown value to be measured.

The instrument is adjusted until the ratio $\frac{Q}{P} = \frac{R}{S}$

This is indicated by a zero reading on the galvanometer with its switch in the closed position.

The resistors P and Q are called ratio arms. P and Q are varied in steps to give a range of values and the resistance value of 'S' is set by the decade resistance S.(Fig 2)

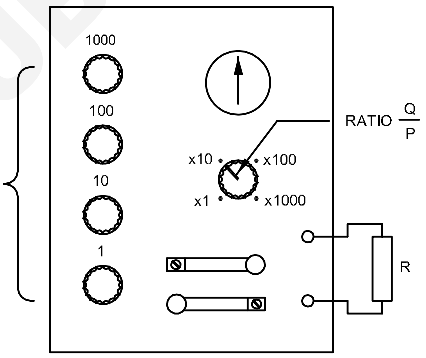
Fig 1



RESISTANCE ARRANGEMENT IN WHEATSTONE BRIDGE

ELN143916

Fig 2



FRONT VIEW OF WHEATSTONE BRIDGE

ELN143917

$R = \frac{Q}{P}$ multiplied by S.

The ratio $\frac{Q}{P}$ is arranged to be 1, 10, 100 or 1,000 for ease of calculation.

S is the variable resistance. Four decade resistances are connected in series. The value of S can be set in steps of one ohm from 1.0 ohm to 9999 ohms by suitably setting the four decade resistance units.

For example P = 10 ohm, Q = 100 ohm, S = 7ohm.

Then, $R_x = \frac{SXQ}{P} = \frac{7X100}{10} = 70\Omega$

Effect of variation of temperature on resistance

Objectives: At the end of this lesson you shall be able to
- **explain on what factors electrical resistance of a conductor depends**
- **state the temperature co-efficient of resistance.**

The resistance of material largely depends on temperature and varies according to the material.

When resistance r is a constant depending on the nature of the material of the conductor and known as its specific resistance or resistivity. Dependency of resistance on temperature is explained in detail below:-

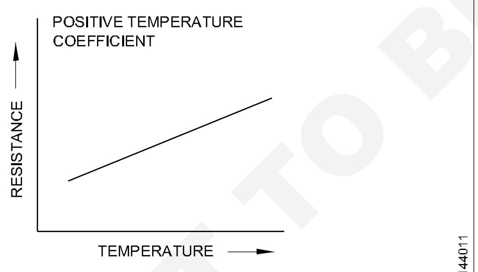
Effect of temperature on resistance: Actually, the relative values of resistance that were given earlier apply to the metals when they are at about room temperature. At higher or lower temperatures, the resistances of all materials change.

In most cases, when the temperature of a material goes up, its resistance goes up too. But with some other materials, increased temperature causes the resistance to go down.

The amount by which the resistance is affected by each degree of temperature change is called the temperature coefficient. And the words positive and negative are used to show whether the resistance goes up or down with the temperature.

When the resistance of the material goes up as temperature is increased, it has a positive temperature coefficient. It is appropriate in the case of pure metals such as silver, copper, aluminium, brass etc. (Fig 1)

Fig 1



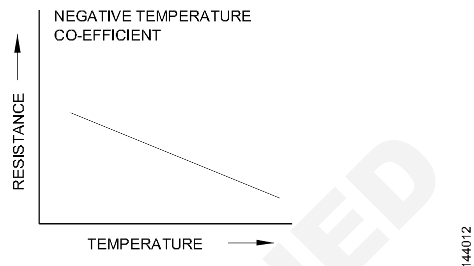
RESISTANCE INCREASES WITH TEMPERATURE

In the case of certain alloys such as eureka, manganin, etc. increase in resistance due to increase in temperature is relatively less and irregular.

When a material's resistance goes down as the temperature is increased, it has a negative temperature coefficient. (Fig 2)

This applies in the case of electrolytes, insulators such as paper, rubber, glass, mica etc. and partial conductors such as carbon.

Fig 2



RESISTANCE DECREASES WITH TEMPERATURE

Temperature coefficient of resistance (α) of a conductor: Let a metallic conductor, having a resistance of R_0 at 0°C, be heated to t°C and let its resistance at this temperature be R_t. Then, considering normal ranges of temperature, it is found that the increase in resistance depends:

- directly on its initial resistance
- directly on the rise in temperature
- on the nature of the material of the conductor

Hence $(R_t - R_o) = R_o\, t\, \alpha$ .....(i)

where α (alpha) is constant and is known as the temperature coefficient of resistance of the conductor.

Rearranging Eq.(i), we get

$$\alpha = \frac{R_t - R_0}{R_0 \times t} = \frac{\Delta R}{R_0 \times t}$$

If $R_o = 1\Omega$, t = 1°C, then $\alpha = \Delta R = R_t - R_o$.

Hence, the temperature-coefficient of a material may be defined as: the change in resistance in ohm per °C rise in temperature.

From Eq.(i), we find that $R_T = R_o(1+\alpha t)$ .....(ii)

In view of the dependence of α on the initial temperature, we may define the temperature coefficient of resistance at a given temperature as the change in resistance per ohm per degree centigrade change in temperature from the given temperature.

In case R_o is not given, the relationship between the known resistance R_1 at t_1°C and the unknown resistance R_2 at t_2°C can be found as follows:

$R_2 = R_o(1 + \alpha_o t_2)$ and

$R_1 = R_o(1 + \alpha_o t_1)$.

Therefore $\frac{R_2}{R_1} = \frac{1+\alpha_0 t_2}{1+\alpha_0 t_1}$

Resistivities and temperature coefficients

Material Metals-Alloys	**Resistivity in ohm-metre at 20°C x 10^{-8}**	**Temperature coefficient at 20°C x 10^{-4}**
Aluminimum	2.8	40.3
Brass	6 – 8	20
Carbon	3000 –7000	–(5)
Constant or Eureka	49	(+0.160 –0.4)
Copper (annealed)	1.72	39.3
German silver	20.2	2.7
Iron	9.8	65
Manganin (84% Cu; 25% Mn; 4% Ni)	44 – 48	0.15
Mercury	95.8	8.9
Nichrome (60% Cu;25% Fe; 15% Cr)	108.5	1.5
Nickel	7.8	54
Platinum	9 –15.5	36.7
Silver	1.64	38
Tungsten	5.5	47

Insulators

Insulators	**Resistivity in ohm-metre at 20°C**	**Temperature coefficient at 20°C**
Amber	5 x 10^{14}	
Bakelite	10^{10}	
Glass	10^{10}– 10^{12}	10^{12}
Mica	10^{15}	
Rubber	10^{16}	
Shellac	10^{14}	
Sulphur	10^{15}	

Example: The resistance of a field coil measures 55 ohms at 25°C and 65 ohms at 75°C. Find the temperature-coefficient of the conductor at 0°C.

$R_t = R_o(1 + \alpha_o t)$

$R_{25} = 55 = R_o(1 + 25\alpha_o)$ Eqn.1

$R_{75} = 65 = R_o(1 + 75\alpha_o)$ Eqn.2

Dividing Eqn.2 by Eqn.1 we get

$$\frac{R_{75}}{R_{25}} = \frac{65}{55} = \frac{1+75\alpha_0}{1+25\alpha_0}$$

$$\frac{13}{11} = \frac{1+75\alpha_0}{1+25\alpha_0}$$

Cross multipling we get

$13[1 + 25\alpha_o] = 11[1 + 75\alpha_o)$

$13 + 325\alpha_o = 11 + 825\alpha_o$

$13 - 11 = 825\alpha_o - 325\alpha_o$

$2 = 500\alpha_o$

$a_o = \frac{2}{500} = 0.004$ per °C.

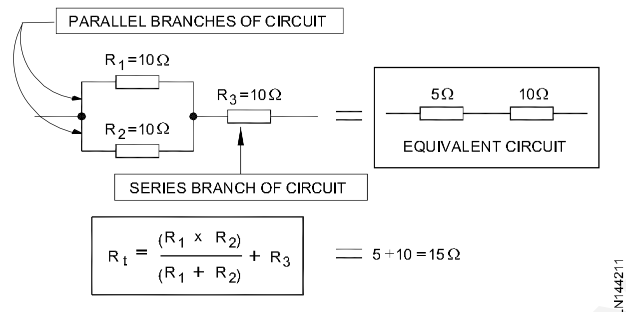
Series and parallel combination circuit

Objective: At the end of this lesson you shall be able to
- **solve series-parallel circuit problems.**

Formation of series parallel circuit

Apart from the series circuit and parallel circuits, the third type of circuit arrangement is the series-parallel circuit. In this circuit, there is at least one resistance connected in series and two connected in parallel. The two basic arrangements of the series-parallel circuit are shown here. In one, resistor R_1 and R_2 are connected in parallel and this parallel connection, in turn, is connected in series with resistance R_3. (Fig 1)

Fig 1



Thus, R_1 and R_2 form the parallel component, and R_3 the series component of a series-parallel circuit. The total resistance of any series-parallel circuit can be found by merely reducing it into a simple series circuit. For example, the parallel portion of R_1 and R_2 can be reduced to an equivalent 5-ohm resistor(two 10-ohm resistors in parallel).

Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor(R_3), giving a total resistance of 15 ohms for the series-parallel combination.

A second basic series-parallel arrangement is shown in Fig 2 where basically it has two branches of a parallel circuit. However, in one of the branches it has two resistances in series R_2 and R_3. To find the total resistance of this series -parallel circuit, first combine R_2 and R_3 into an equivalent 20-ohm resistance. The total resistance is then 20 ohms in parallel with 10 ohms, or 6.67 ohms.

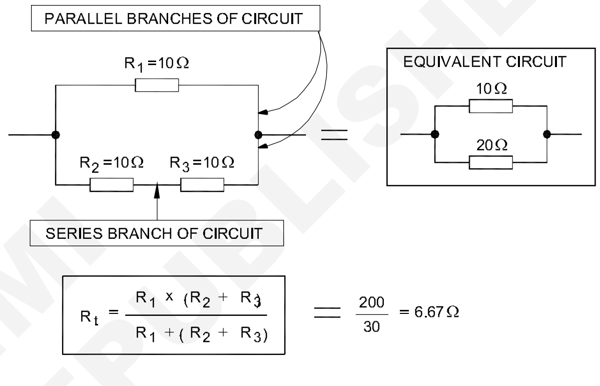
Combination circuits

A series-parallel combination appears to be very complex.

However, a simple solution is to break down the circuit into series/or parallel groups, and while solving problems, each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

Each parallel group may be replaced by one resistance value equivalent to the combined resistance of that group. Equivalent circuits are to be prepared for determining the current, voltage and resistance for each component.

Fig 2



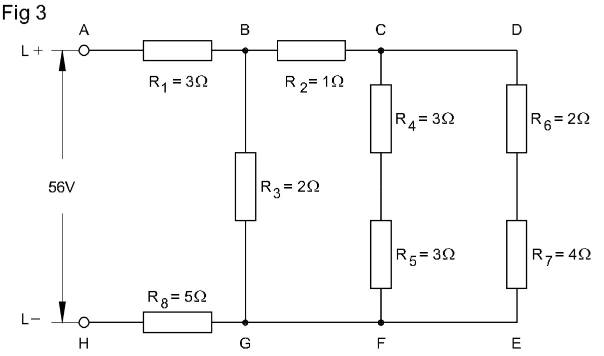
Application

Series-parallel circuits can be used to form a non-standard resistance value which is not available in the market and can be used in the voltage divider circuits.

Assignment

Determine the combined resistance of the circuit shown in Fig 3.

Fig 3



Magnetic terms, magnetic material and properties of magnet

Objectives: At the end of this lesson you shall be able to
- **state the different kinds of magnets and state the classification of magnetic material**
- **state the classifications of magnets.**

Magnetism and magnets: Magnetism is a force that acts on some materials and not on other materials. Physical devices which possess this force are called magnets. Magnets attract iron and steel, and when free to rotate, they will move to a fixed position relative to the north pole.

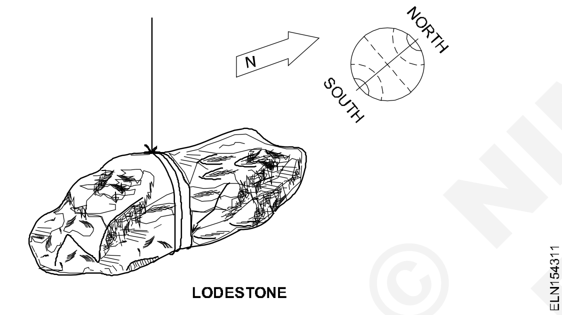
Classification of magnets

Magnets are classified into two groups.

- Natural magnets
- Artificial magnets

Lodestone (an iron compound) is a natural magnet which was discovered centuries ago. (Fig 1)

Fig 1



There are two types of artificial magnets. Temporary and permanent magnets.

Temporary magnets or electromagnets: If a piece of magnetic material, say, soft iron is placed in a strong magnetic field of a solenoid it becomes magnetised by induction. The soft iron itself becomes a temporary magnet as long as the current continues to flow in the solenoid. As soon as the source producing the magnetic field is removed, the soft iron piece will loose its magnetism.

Permanent magnets: If steel is substituted for soft iron in the same inducing field as in the previous case, due to the residual magnetism, the steel will become a permanent magnet even after the magnetising field is removed. This property of retention is termed retentiveness. Thus, permanent magnets are made from steel, nickel, alnico, tungsten all of which have higher retentiveness.

Classification of magnetic substances

Materials can be classified into three groups as follows.

Ferromagnetic substances: Those substances which are strongly attracted by a magnet are known as ferromagnetic substances. Some examples are iron, nickel, cobalt, steel and their alloys.

Paramagnetic substances: Those substances which are slightly attracted by a magnet of common strength are called paramagnetic substances. Their attraction can easily be observed with a powerful magnet. In short, paramagnetic substances are similar in behaviour to ferromagnetic materials. Some examples are aluminium, manganese, platinum, copper etc.

Diamagnetic substances: Those substances which are slightly repelled by a magnet of powerful strength only are known as diamagnetic substances. Some examples are bismuth, sulphur, graphite, glass, paper, wood, etc. Bismuth is the strongest of the diamagnetic substances.

There is no substance which can be properly called non-magnetic. It may also be noted that water is a diamagnetic material, and air is a paramagnetic substance.

Magnetic terms and properties of magnet

Objectives: At the end of this lesson you shall be able to
- **define the terms magnetic field, magnetic line, magnetic axis, magnetic neutral axis and unit pole**
- **explain the properties of a magnet**
- **state the application, care and maintenance of a permanent magnet.**

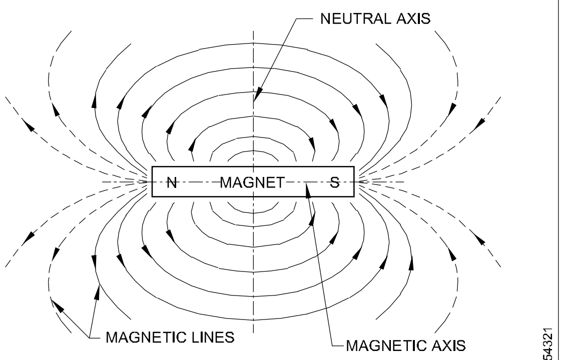
Magnetic fields: The force of magnetism is referred to as a magnetic field. This field extends out from the magnet in all directions, as illustrated in Fig 1. In this figure, the lines extending from the magnet represent the magnetic field.

The space around a magnet in which the influence of the magnet can be detected is called the magnetic field.

Magnetic lines: Magnetic lines of force (flux) are assumed to be continuous loops, the flux lines continuing on through the magnet. They do not stop at the poles.

The magnetic lines around a bar magnet are shown in Fig 1.

Fig 1

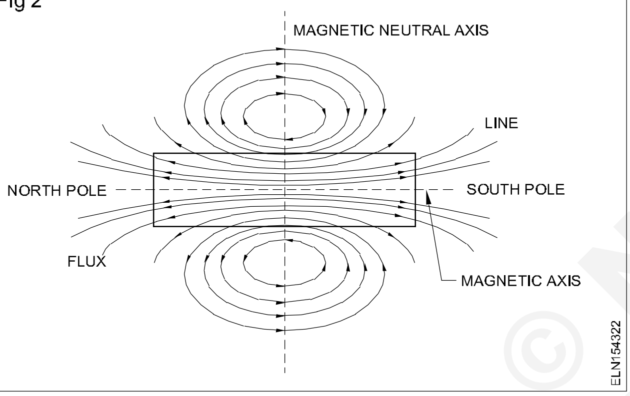


MAGNETIC FIELD OF A MAGNET. THE FLUX IS MOST DENSE AT THE POLES.

Magnetic axis: The imaginary line joining the two poles of a magnet are called the magnetic axis. It is also known as the magnetic equator.

Magnetic neutral axis (Fig 2): The imaginary lines which are perpendicular to the magnetic axis and pass through the centre of the magnet are called the magnetic neutral axis.

Fig 2



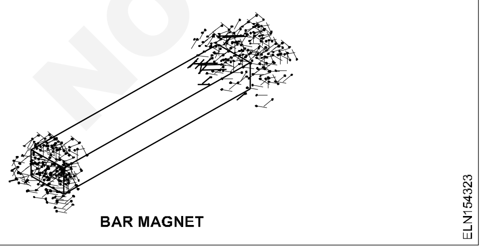
Unit pole: A unit pole may be defined as that pole which, when placed one metre apart from an equal and similar pole, repels it with a force of 10 newtons.

Properties of a magnet

The following are the properties of magnets.

Attractive property : A magnet has the property of attracting magnetic substances (such as iron, nickel and cobalt) and its power of attraction is greatest at its poles. (Fig 3)

Fig 3



BAR MAGNET

Directive property: If a magnet is freely suspended, its poles will always tend to set themselves in the direction of north and south. (Fig 4)

Induction property: A magnet has the property of producing magnetism in a nearby magnetic substance by induction. (Fig 5)

Fig 4

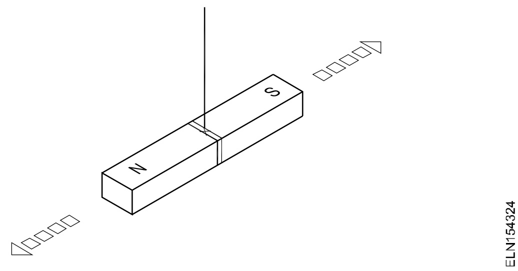
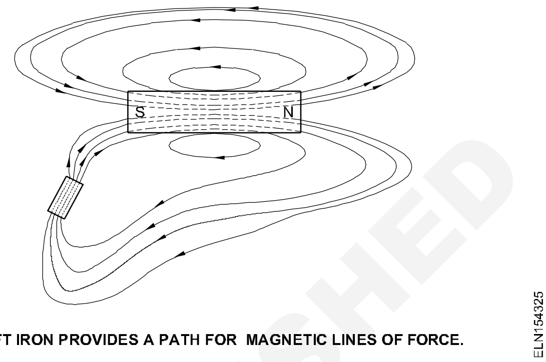


Fig 5



SOFT IRON PROVIDES A PATH FOR MAGNETIC LINES OF FORCE.

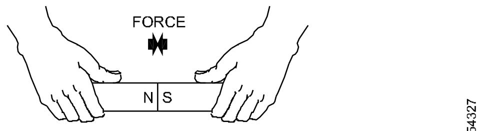
Demagnetising property: If a magnet is handled roughly by heating, hammering, etc. it will lose its magnetism.

Property of strength: Every magnet has two poles. The two poles of a magnet have equal pole strength.

Saturation property: If a magnet of higher strength is further subjected to magnetization, it will never acquire more magnetization due to its being already saturated.

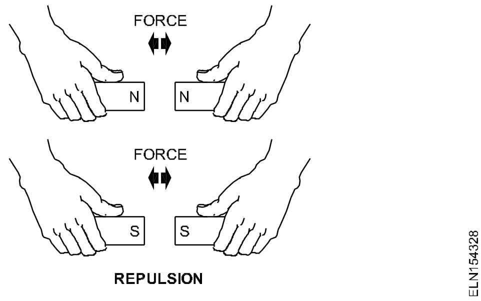
Property of attraction and repulsion: Unlike poles (i.e. north and south) attract each other, (Fig 6) while like poles (north/north and south/south) repel each other. (Fig 7)

Fig 6



ATTRACTION

Fig 7



REPULSION

Shapes of magnets: Magnets are available in various shapes, with the magnetism concentrated at their ends known as poles. The common shapes are listed here.

– Bar magnet

– Horseshoe magnet

– Ring magnet

– Cylindrical type magnet

– Specially shaped magnets

Methods of magnetizing: There are three principal methods of magnetizing a material.

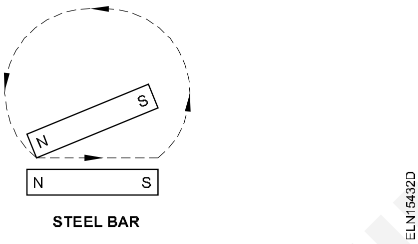
- Touch method
- By means of electric current
- Induction method.

Touch method: This method can be further divided into:

- single touch method
- double touch method, and

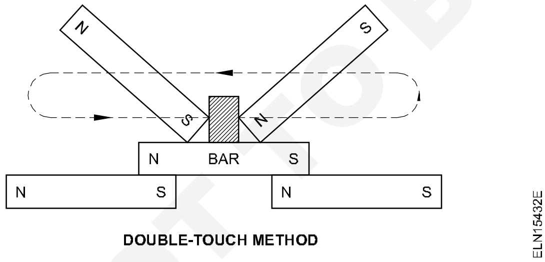
Single touch method: In the single touch method, the steel bar to be magnetized is rubbed with either of the poles of a magnet, keeping the other pole away from it. Rubbing is done only in one direction as shown in Fig 8. The process should be repeated many times for inducing magnetization of the bar.

Fig 8



Double touch method: In this method the steel bar to be magnetized is placed over the two opposite pole ends of a magnet, and the rubbing magnets are placed together over the centre of the bar with a small wooden piece in between, as shown in Fig 9. They are never lifted off the surface of the steel bar, but rubbed again and again from end to end, finally ending at the centre where the rubbing was started.

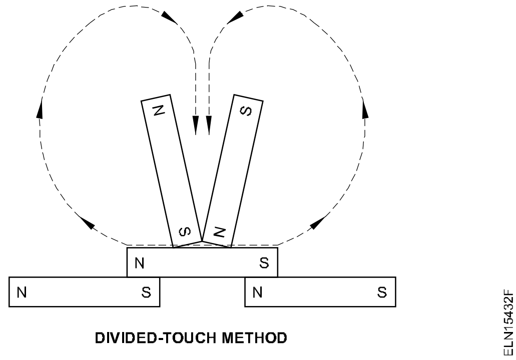
Fig 9



Divided touch method: Here the two different poles of the rubbing magnets are placed as in the previous case. They are then moved along the surface of the steel bar to the opposite ends. The rubbing magnets are then lifted off the surface of the steel bar and placed back in the centre of the bar. The whole process is repeated again and again as shown in Fig 10.

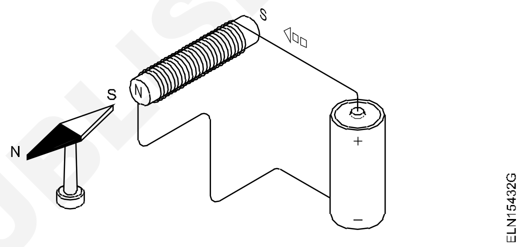
The steel bar thus magnetized becomes a permanent magnet but the degree of magnetization is very low.

Fig 10



By electric current: The bar to be magnetized is wound with an insulated copper wire, and then a strong electric current (DC) from a battery is passed through the wire for some time. The steel bar then becomes highly magnetized. The magnet made by such an arrangement is called an electromagnet and is generally used in laboratories. (Fig 11)

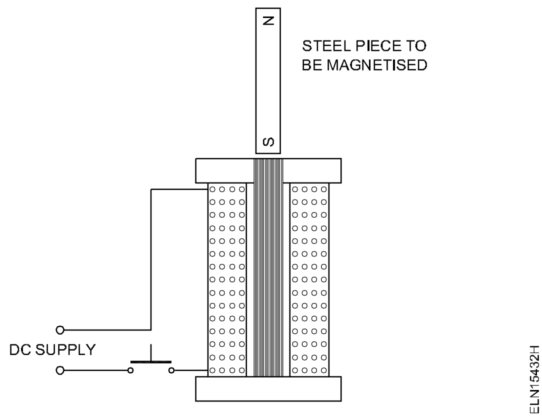
Fig 11



Induction method: This is a commercial method of making permanent magnets. In this method a pole charger is used which has a coil of many turns and an iron core inside it as shown in Fig 12. The direct current supply is fed to the coil through a push-button switch.

The steel piece to be magnetized is placed on the iron core kept inside the coil, and direct current is passed through the coil. The iron core now becomes a powerful magnet.

Fig 12



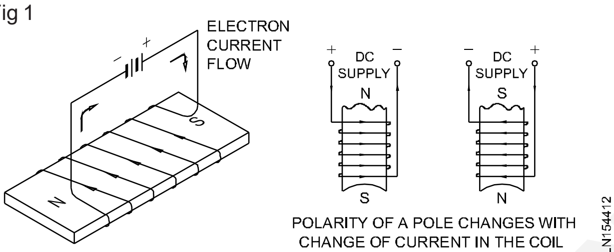
Principles and laws of electro magnetism

Objectives: At the end of this lesson you shall be able to
- **explain what is meant by electromagnetism**
- **state right Hand Grip rule, Corkscrew rule and Right Hand palm rule.**

Electromagnetism: On passing a current through a coil of wire, a magnetic field is set up around the coil. If a soft iron bar is placed in the coil of wire carrying the current, the iron bar becomes magnetized. This process is known as `electromagnetism'. The soft iron bar remains as a magnet as long as the current is flowing in the circuit. It loses its magnetism when the current is switched off from the coil.

The polarity of this electromagnet depends upon the direction of the current flowing through it. If the direction of the current is altered, the polarity of the magnetic field will also be changed as shown in Fig 1.

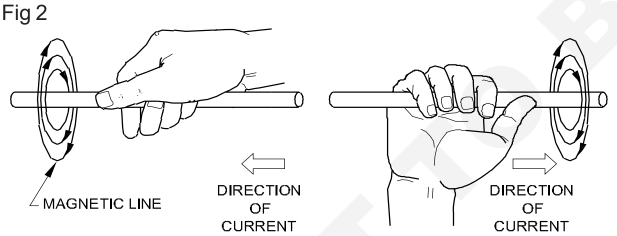
Fig 1



POLARITY OF A POLE CHANGES WITH CHANGE OF CURRENT IN THE COIL

The right hand grip rule can be used to determine the direction of the magnetic field. If you wrap your fingers around the wire with your thumb pointing in the direction of current flow, your fingers will point in the direction of the magnetic field as shown in Fig 2.

Fig 2



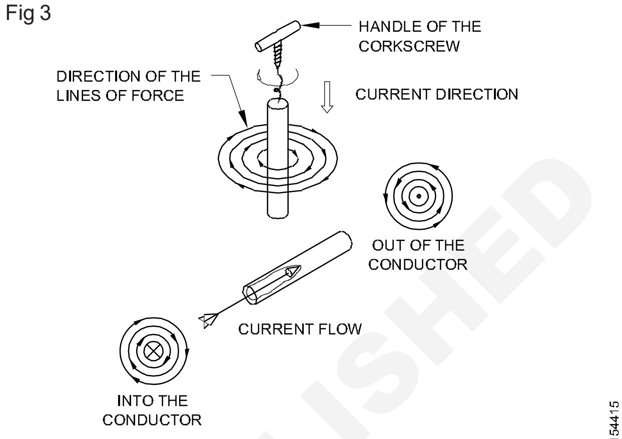
RIGHT HAND GRIP RULE SHOWING THE DIRECTION OF CURRENT AND DIRECTION OF MAGNETIC LINES

Assume a **right handed corkscrew** to be along the wire so as to advance in the direction of the current. The motion of the handle gives the direction of magnetic lines of force around the conductor (Fig 3)

The direction of the magnetic field can be found from right hand palm rule (Fig 4)

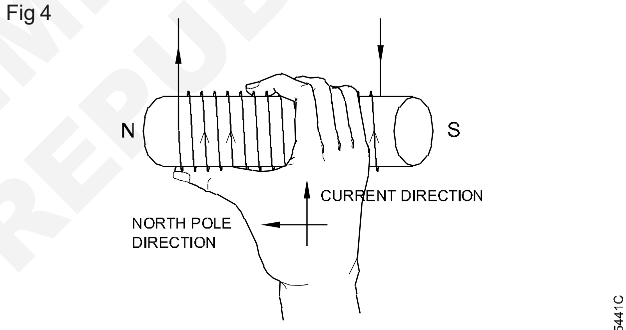
The Right Hand Palm Rule : Hold the right hand palm over the solenoid in such a way the fingers point in the direction of current in the solenoid conductors then the thumb indicates the direction of magnetic field (North Pole) of the solenoid.

Fig 3



CORKSCREW RULE

Fig 4



RIGHT HAND PALM RULE

Magnetic materials for temporary magnets: Electromagnets are generally known as temporary magnets. The magnetic strength of such magnets can be varied by varying the current passing through them. Soft iron is used in electromagnets as a magnetic core. Silicon steel is very much used in bigger magnets (steel with 2.4% silicon). Nowadays other metals like permalloy, mumetal are also used for some applications.

Permalloy is an alloy of iron and nickel which can be magnetized by a very weak magnetic field and is useful for telephones.

Mumetal is an alloy of nickel, copper, chromium and iron. It has very high permeability and resistivity. Eddy current loss is very low. It is used in instrument transformers and for screening magnetic fields.

The magnetic circuits - self and mutually induced emfs

Objectives: At the end of this lesson you shall be able to
- **define the magnetic terms in a magnetic circuit (like M.M.F., reluctance, flux, field strength, flux density, permeability, relative permeability)**
- **state hysterisis.**

MagnetoMotive Force (MMF): The amount of flux density set up in the core is dependent upon five factors - the current, number of turns, material of the magnetic core, length of core and the cross-sectional area of the core. More current and the more turns of wire we use, the greater will be the magnetising effect. We call this product of the turns and current the magnetomotive force (mmf), similar to the electromotive force (emf).

MMF = NI ampere-turns

where mmf - is the magnetomotive force in ampere turns

N - is the number of turns wrapped on the core

I - is the current in the coil, in amperes, A.

If one ampere current is flowing through a coil having 200 turns then the mmf is 200 ampere turns.

Reluctance: In the magnetic circuit there is something analogous to electrical resistance, and is called reluctance, (symbol S). The total flux is inversely proportional to the reluctance and so if we denote mmf by ampere turns. we can write

$$\phi = \frac{NI}{S}$$ Where ϕ is flux and reluctances $$S = \frac{\ell}{\mu_o \mu_r a}$$

where S - reluctance

l - length of the magnetic path in metres

μ_o - permeability of free space

μ_r - relative permeability

a - cross-sectional area of the magnetic path in sq.mm.

The unit of reluctance is ampere turns/Wb.

Magnetic flux:The magnetic flux in a magnetic circuit is equal to the total number of lines existing on the cross-section of the magnetic core at right angle to the direction of the flux. Its symbol is Ø and the SI unit is weber.

$$\phi = \frac{NI}{S}$$

$$= \frac{NIa\mu_o\mu_r}{\ell}$$

where

ϕ - total flux

N - number of turns

I - current in amperes

S - reluctance

μ_o - permeability of free space

μ_r - relative permeability

a - magnetic path cross-sectional area in m^2

ℓ - length of magnetic path in metres.

Flux density (B): The total number of lines of force per square metre of the cross- sectional area of the magnetic core is called flux density, and is represented by the symbol B. Its SI unit (in the MKS system) is tesla (weber per metre square).

$$B - \frac{\phi}{A} \text{ Weber/ } m^2$$

where ϕ - total flux in webers

A - area of the core in square metres

B - flux density in weber/metre square.

Permeability: The permeability of a magnetic material is defined as the ratio of flux created in that material to the flux created in air, provided that mmf and dimensions of the magnetic circuit remain the same. It's symbol is μ and

$$\mu = B/H$$

where B is the flux density

H is the magnetising force.

Being a ratio it has no unit and it is expressed as a mere number. The permeability of air μ air = unity. The relative permeability μr of iron and steel ranges from 50 to 2000. The permeability of a given material varies with its flux density.

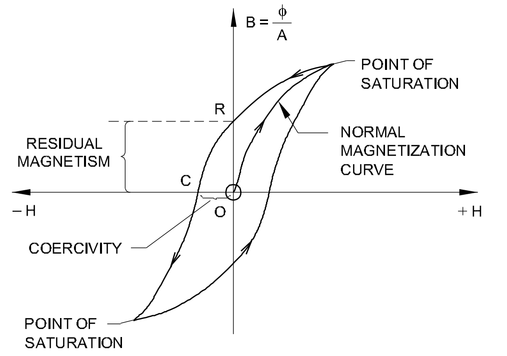
Hysteresis: Consider the graphical relation between B and H for a magnetic material. Since μ = B/H, the graphical relationship shows how the permeability of a material varies with the magnetizing intensity H.

Assume that the magnetic core is initially completely demagnetised. As we increase the current, $H = \frac{NI}{\ell}$ increases and there will be an increase in the flux density, B. Since the number of turns and the length of core of a coil are fixed, H is directly proportional to the current or ammeter reading. The flux density can be measured by inserting the probe of a flux meter into a small hole drilled in the core.

A plot of the values of B and H gives the normal magnetization curve, as shown in Fig 1.There is evidently a linear portion where B is relatively proportional to H. But then a condition of saturation occurs when a very large increase in H is required to significantly increase B. This point in the curve is called as **saturation point.**

If the current is now gradually reduced towards zero, H returns to zero, but B does not. The core exhibits retentiveness and retains some residual magnetism. The **retentiveness** is represented by the distance OR.

Fig 1



HYSTERESIS LOOP FOR MATERIAL USED IN AN AC CIRCUIT

If the connections to the coil are reversed, and the current is again increased, it is found that a certain amount of H is required to bring the magnetism in the core down to zero. This is called the **coercivity** and is represented by the distance OC.

Further, any increase in the current in the opposite direction increases the magnetism in the core as before in the opposite direction, until once again saturation occurs.

Electromagnet applications - Electromagnetic induction

Objectives: At the end of this lesson you shall be able to
- **compare the magnetic circuit and electric circuit**
- **state the applications of an electromagnet (Bell & Buzzer tubelight choke)**
- **state the principle and laws of electromagnetic induction**
- **explain about the counter EMF-induced reactance-time constant.**

Comparison between magnetic and electric circuits

Similarities (Fig 1a & 1b)

	Magnetic Current	**Electrical Current**
1	Flux = $\frac{mmf}{reluctance}$	Current = $\frac{emf}{resistance}$
2	M.M.F. (Ampere-turns)	E.M.F. (Volts)
3	Flux ϕ (Webers)	Current I (amperes)
4	Flux density B (Wb/m^2)	Current density (A/m^2)
5	Reluctance $S = \frac{\ell}{\mu_A}$ or $S = \frac{\ell}{\mu_0 \mu_r a}$	Resistance $R = \frac{\rho L}{A}$
6	Permeance = (1/reluctance)	Conductance (= 1/resistance)
7	Reluctivity $\mu_o \mu_r A$	Resistivity
8	Permeability (=1/reluctivity)	Conductivity(=1/resistivity)

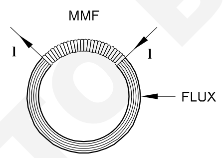


Fig 1a

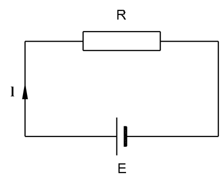


Fig 1b

Practical applications of electromagnets: Electromagnets are used in the manufacture of all types of electrical machines, such as motors, generators, transformers, convertors, some electrical measuring instruments, protective relays, for medical purposes (like removing iron pieces from eyes) and in many other electrical devices like bells, buzzers, circuit-breakers, relays, telegraphic circuits, lifts and other industrial uses.

a Bells
b Buzzers
c Circuit-breakers
d Relays
e Telegraphic circuits
f Lifts
g Industrial uses

Principles and laws of electromagnetic induction

Faraday's Laws of Electromagnetic Induction are also applicable for conductors carrying alternating current.

Faradays' Laws of Electromagnetic Induction

Faraday's First Law states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in it.

The Second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

Dyanamically Induced EMF

Accordingly induced emf can be produced either by moving the conductor in a stationery magnetic field or by changing magnetic flux over a stationery conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Ex. generators.

Statically Induced EMF

When changing flux produces emf the emf is called as statically induced emf as explained below. Ex: Transformer.

Statically induced emf: When the induced emf is produced in a stationery conductor due to changing magnetic field, obeying Faraday's laws of electro magnetism, the induced emf is called as statically induced emf.

There are two types of statically induced emf as stated below:-

1 **Self induced emf** produced with in the same coil

2 **mutually induced emf** produced in the neighbouring coil

Self-induction: The production of an electromotive force in a circuit, when the magnetic flux linked with the circuit changes as a result of the change in a current inducing in the same circuit.

According to Faraday's Laws, an emf is induced in the conductor. Similarly, when the magnetic field collapses, the flux lines cut through the conductor again, and an emf is induced once again. This is called self-induction.

Mutual Inductance: When two or more coils one magnetically linked together by a common magnetic flux, they are said to have the property of mutual inductance. It is the basic operating principal of the transformer, motor generaters and any other electrical component that interacts with another magnetic field. It can define mutual induction on the current flowing in one coil that induces a voltage in an adjacement coil.

Inductance: Inductance (L) is the electrical property of an electrical circuit or device to oppose any change in the magnitude of current flow in a circuit.

Devices which are used to provide inductance in a circuit are called inductors. Inductors are also known as chokes, coils, and reactors. Inductors are usually coils of wire.

Factors determining inductance: The inductance of an inductor is primarily determined by four factors.

- Type of core permeability of the core $m_{r.}$
- Number of turns of wire in the coil 'N'.
- Spacing between turns of wire (Spacing factor).
- Cross-sectional area (diameter of the coil core) 'a' or 'd'.

Henry: A conductor or coil has an inductance of one henry if a current that changes at the rate of one ampere per second produces a induced voltage (cemf) of 1 volt.

Counter emf - inductive reactance

Objectives: At the end of this lesson you shall be able to
- **explain the term Counter EMF (CEMF)**
- **explain about the inductive reactance**
- **state the reasons for the difference between ohmic resistance and impedance of a coil.**

Counter EMF and LENZ's law: The voltage induced in a conductor or coil by its own magnetic field is called a counter electromotive force (cemf). Since the induced emf (voltage) is always opposing, or countering, the action of the source voltage, it is known as cemf. Counter electromotive force is sometimes referred to as back electromotive force (bemf).

In any type of inductive circuit there is an important relationship between the direction of the current change and the induced voltage. **Lenz's law** states that a cemf always has a polarity which opposes the force that created it.

The inductance rating of an inductor refers to its ability to generate a counter voltage to a change in current flow. One henry (1H - the SI unit) represents the inductance of a coil in which a current change of one ampere per second (1 A/s) will produce a cemf of one volt (1V).

Inductive reactance:The opposition offered to an AC current flow by the inductive effect is called inductive reactance. Inductive reactance is the result of the cemf of the inductor.

Eddy currents are caused by voltages induced into the conductors and other surrounding metal parts. They are directly proportional to the frequency of the supply. The heat produced by these currents tends to increase the effective resistance of the circuit.

Effect of inductance present in a AC circuit: Coils have various uses in electrical engineering such as
- excitation coils in electric machines or magnets
- relay coils in switching devices
- choke coils for limiting current etc.

Capacitors - types - functions, grouping and uses

Objectives: At the end of this lesson you shall be able to
- **describe capacitor its construction and charging**
- **explain capacitance and the factors determining**
- **state the different types and application of capacitors.**

Scan the QR Code to view the video for this exercise

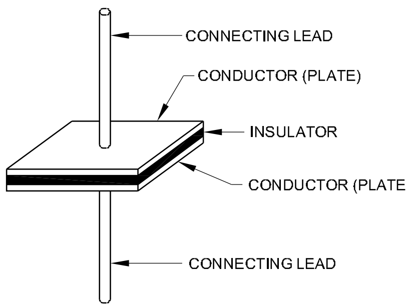
Capacitor

Capacitor is a passive two terminal electrical/electronic component that stores potential energy in the form of electrostatic field

The effect of capacitor is called as capacitance. It consists of two conducting plates separated by an insulating material called as dielectric. In simple, capacitor is a device designed to store electric charge.

Construction: A capacitor is an electrical device consisting of two parallel conductive plates, separated by an insulating material called the dielectric. Connecting leads are attached to the parallel plates. (Fig 1)

Fig 1



SIMPLE CAPACITOR. THE PLATES OF A CAPACITOR ARE ALWAYS INSULATED FROM EACH OTHER

ELN154911

Function: In a capacitor the electric charge is stored in the form of an electrostatic field between the two conductors or plates, due to the ability of dielectric material to distort and store energy while it is charged and keep that charge for a long period or till it is discharged through a resistor or wire. The unit of charge is coulomb and it is denoted by the letter `C'.

Capacitance : The ability or capacity to store energy in the form of electric charge is called capacitance. The symbol used to represent capacitance is C.

Unit of capacitance: The base unit of capacitance is the **Farad.** The abbreviation for **Farad** is **F**. One farad is that amount of capacitance which stores 1 coulomb of charge when the capacitor is charged to 1 V. In other words, a Farad is a coulomb per volt (C/V).

Farad

A farad is the unit of capacitance (C), and a coulomb is the unit of charge(Q), and a volt is the unit of voltage(V). Therefore, capacitance can be mathematically expressed as $C = \frac{Q}{V}$

Capacitive reactance

Similar to resistors and inductors, a capacitor also offers opposition to the flow of AC current. This opposition offered to the flow of current by a capacitor is called **capacitive reactance** abbreviated as X_C.

Capacitive reactance, X_C can be mathematically represented as;

$$X_c = \frac{1}{2\pi fc}$$

Factors determining capacitance: The capacitance of a capacitor is determined by four factors.

- Area of the plates ($C \alpha A$)
- Distance between the plates ($C \alpha d$)
- Type of dielectric material
- Temperature
- Resistance of the plates

Types of capacitors: Capacitors are manufactured in a wide variety of types, sizes and values. Some are fixed in value, in others the value is variable.

Fixed capacitors

Ceramic capacitors: Ceramic dielectrics provide very high dielectric constants (1200 is typical). As a result, comparatively high capacitance values can be achieved in a small physical size.

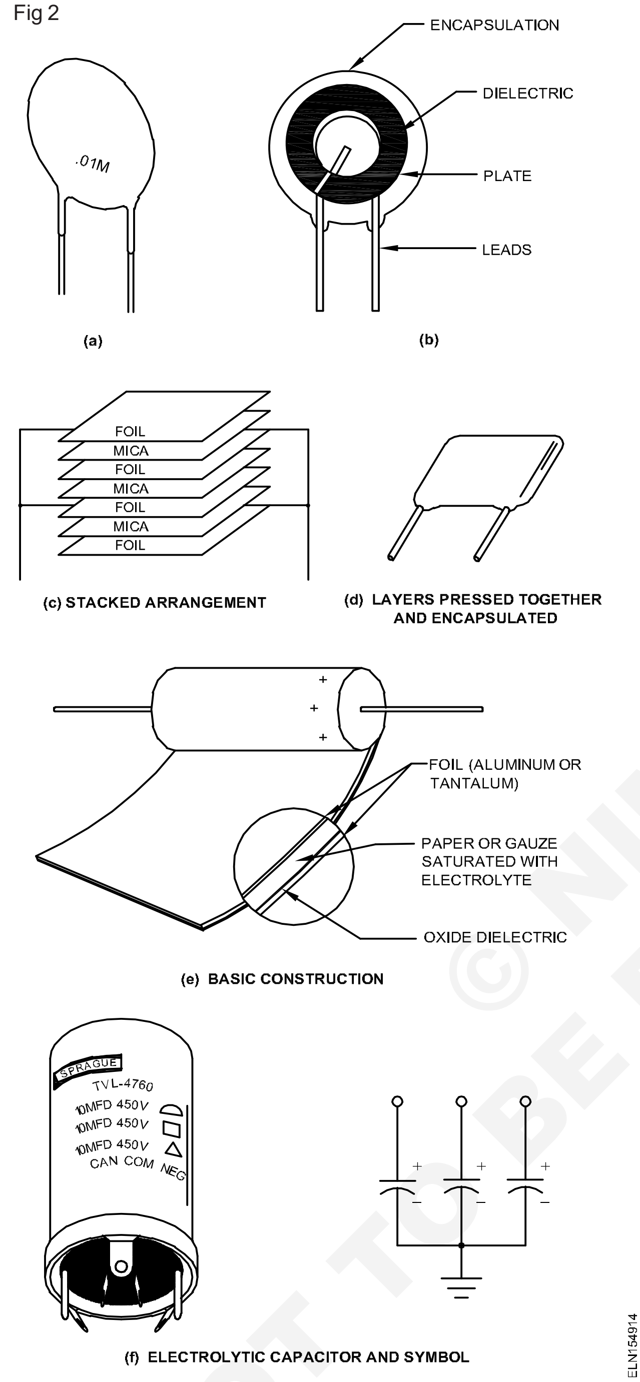
Ceramic capacitors are illustrated in Figs 2a) and (b). These discs are made by using ceramic as an insulator with a silver deposit on each side of the plates. These are used for small values of capacitance and an ordinary TV set might contain several dozens in its circuitry.

Ceramic capacitors are typically available in capacitance values ranging from 1μF to 2.2μ F with voltage ratings up to 6 KV.

Mica capacitors: There are two types of mica capacitors, stacked foil as shown in Fig 2(c). It consists of alternate layers of metal foil and thin sheets of mica. The metal foil forms the plate, with alternate foil sheets connected together to increase the plate area, thus increasing the capacitance.

The mica foil-stack is encapsulated in an insulating material such as bakelite, as shown in Fig 2d of the figure.

Fig 2



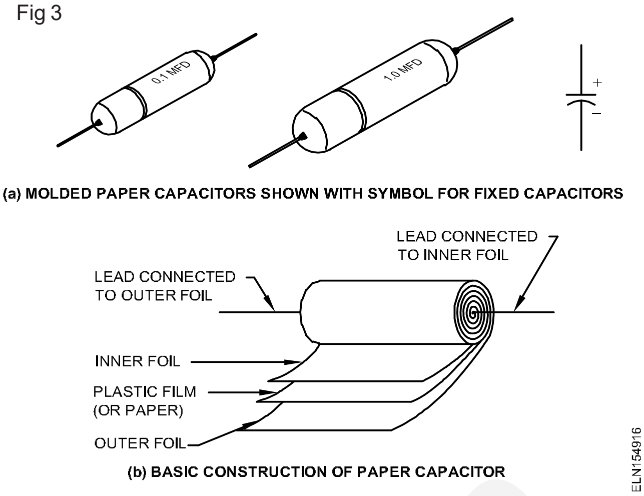
Mica capacitors are available with capacitance values ranging from 1 pF to 0.1 pF and voltgage ratings from 100 to 2500 V DC.

Electrolytic capacitors: Electrolytic capacitors are polarised so that one plate is positive and the other negative.

These capacitors are used for high capacitance values up to over 200,000μ F, but they have relatively low breakdown voltages (350 V is a typical maximum) and high amounts of leakage.

Electrolytic capacitors are available in two types: aluminium and tantalum. The basic construction of an electrolytic capacitor is shown in Figs 2(e) and (f).

Fig 3



Paper/plastic capacitors: There are several types of plastic-film capacitors and the older paper dielectric capacitors. Polycarbonate, parylene, polyester, polystyrene, polypropylene, mylar, and paper are some of the more common dielectric materials used. Some of these types have capacitance values up to 100μF.

Fig 3a show a common basic construction used in many plastic-film and paper capacitors. Fig 3b shows a construction view for one type of plastic-film capacitor.

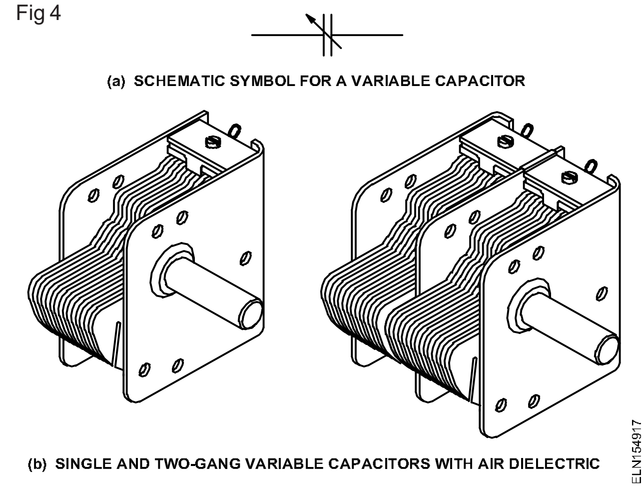
Variable capacitors

Variable capacitors are used in a circuit when there is a need to adjust the capacitance value either manually or automatically. For example, in radio or TV tuners. The major types of variable or adjustable capacitors are now discussed.

Air capacitor: Variable capacitors with air dielectrics, such as the one shown in Fig 4(b), are sometimes used as tuning capacitors in applications requiring frequency selection. This type of capapcitor is constructed with several plates that mesh together. One set of plates can be moved relative to the other, thus changing the effective plate area and the capacitance. The movable plates are linked together mechanically so that they move when a shaft is rotated.

The schematic symbol for a variable capacitor is shown in Fig 4(a).

Fig 4



Application of capacitors with type and ratings - Chart I

Type	Capacitance	Voltage WVDC (Working voltage DC)	Applications
Disc and tube ceramics	1pF - 1µF	50-500	General, VHF.
Paper	0.001-1µF	200-1600	Motors, power supplies.
Polyester	0.001-1µF	100-600	Enetertainment- electronics.
Electrolytic-aluminum	1-500,000µF	5-500	Power supplies, filters.
Electrolytic-tantalum	0.1-1000µF	3-125	Small space requirement, high reliability, low leakage.
Mica	330pF-0.05µF	50-100	High frequency.
Silver-mica	5-820pF	50-500	High frequency.
Variable-ceramic	1-5 to 16-100pF	200	Radio, TV, communications.
Air	10-365pF	50	Broadcast receivers.

Grouping of capacitors

Objectives: At the end of this lesson you shall be able to
- **state the necessity of grouping capacitors and method of connection**
- **state the conditions for connecting capacitors in parallel and in series**
- **explain the values of capacitance and voltage in parallel and series combination**

Necessity of grouping of capacitors: In certain instances, we may not be able to get a required value of capacitance and a required voltage rating. In such instances, to get the required capacitances from the available capacitors and to give only the safe voltage across capacitor, the capacitors have to be grouped in different fashions. Such grouping of capacitors is very essential.

Methods of grouping: There are two methods of grouping.

- Parallel grouping
- Series grouping

Parallel grouping

Conditions for parallel grouping

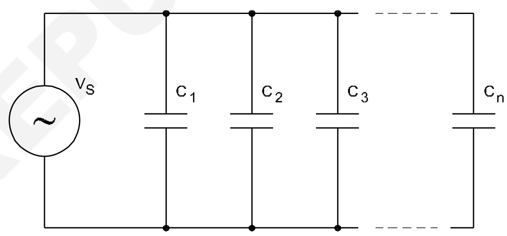
- Voltage rating of capacitors should be higher than the supply voltage Vs.
- Polarity should be maintained in the case of polarised capacitors (electrolytic capacitors).

Necessity of parallel grouping: Capacitors are connected in parallel to achieve a higher capacitance than what is available in one unit.

Connection of parallel grouping: Parallel grouping of capacitors is shown in Fig 1 and is analogous to the connection of resistance in parallel or cells in parallel.

Total capacitance: When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances, because the effective plate area increases. The calculation of total parallel capacitance is analogous to the calculation of total resistance of a series circuit.

Fig 1



CAPACITORS IN PARALLEL

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General formula for parallel capacitance: The total capacitance of parallel capacitors is found by adding the individual capacitances.

$C_T = C_1 + C_2 + C_3 + ... + C_n$

where C_T is the total capacitance,

C_1, C_2, C_3 etc. are the parallel capacitors.

The voltage applied to a parallel group must not exceed the lowest breakdown voltage for all the capacitors in the parallel group.

Example: Suppose three capacitors are connected in parallel, where two have a breakdown voltage of 250 V and one has a breakdown voltage of 200 V, then the maximum voltage that can be applied to the parallel group without damaging any capacitor is 200 volts.

The voltage across each capacitor will be equal to the applied voltage.

Charge stored in parallel grouping: Since the voltage across parallel-grouped capacitors is the same, the larger capacitor stores more charge. If the capacitors are equal in value, they store an equal amount of charge. The charge stored by the capacitors together equals the total charge that was delivered from the source.

$Q_T = Q_1 + Q_2 + Q_3 + ... + Q_n$

where Q_T is the total charge

Q_1, Q_2, Q_3.....etc. are the individual charges of the capacitors in parallel.

Using the equation Q = CV,

the total charge $Q_T = C_T V_S$

where V_S is the supply voltage.

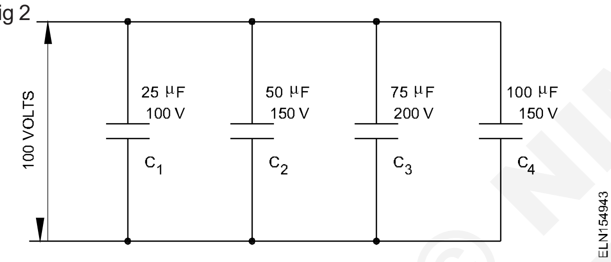
Again $C_T V_S = C_1 V_S + C_2 V_S + C_3 V_S$

Because all the V_S terms are equal, they can be cancelled.

Therefore, $C_T = C_1 + C_2 + C_3$

Question 1: Calculate the total capacitance, individual charges and the total charge of the circuit given in Fig 2.

Fig 2



Solution

Total capacitance = C_T

$C_T = C_1 + C_2 + C_3 + C_4$

C_T = 250 micro farads.

Individual charge = Q = CV

$Q_1 = C_1 V$

$= 25 \times 100 \times 10^{-6}$

$= 2500 \times 10^{-6}$

$= 2.5 \times 10^{-3}$ coulombs.

$Q_2 = C_2 V$

$= 50 \times 100 \times 10^{-6}$

$= 5000 \times 10^{-6}$

$= 5 \times 10^{-3}$ coulombs.

$Q3 = C_3 V$

$= 75 \times 100 \times 10^{-6}$

$= 7500 \times 10^{-6}$

$= 7.5 \times 10^{-3}$ coulombs.

$Q_4 = C_4 V$

$= 100 \times 100 \times 10^{-6}$

$= 10000 \times 10^{-6}$

$= 10 \times 10^{-3}$ coulombs.

Total charge $= Q_t = Q_1 + Q_2 + Q_3 + Q_4$

$= (2.5 \times 10^{-3}) + (5 \times 10^{-3})$

$+ (7.5 \times 10^{-3}) + (10 \times 10^{-3})$

$= (2.5+5+7.5+10) \times 10^{-3}$

$= 25 \times 10^{-3}$ coulombs.

or $Q_T = C_T V$

$= 250 \times 10^{-6} \times 100$

$= 25 \times 10^{-3}$ coulombs.

Series grouping

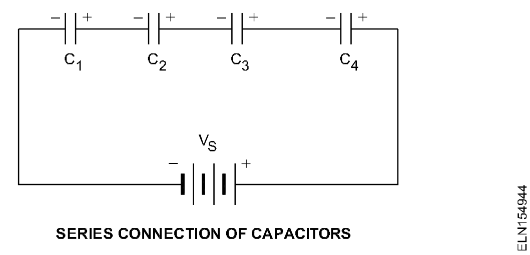
Necessity of grouping of capacitors in series: The necessity of grouping capacitors in series is to reduce the total capacitance in the circuit. Another reason is that two or more capacitors in series can withstand a higher potential difference than an individual capacitor.

Conditions for series grouping

- If different voltage rating capacitors have to be connected in series, take care to see that the voltage drop across each capacitor is less than its voltage rating.
- Polarity should be maintained in the case of polarised capacitors.

Connection in series grouping: Series grouping of capacitors, as shown in Fig 3 is analogous to the connection of resistances in series or cells in series.

Fig 3



Total capacitance: When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

- the effective plate separation thickness increases
- and the effective plate area is limited by the smaller plate.

The calcualtion of total series capacitance is analogous to the calculation of total resistance of parallel resistors.

General formula for series capacitance: The total capacitance of the series capacitors can be calculated by using the formula

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}}$$

or

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

If there are two capacitors in series

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

If there are three capacitors in series

$$C_T = \frac{C_1 C_2 C_3}{(C_1C_2) + (C_2C_3) + (C_3C_1)}$$

If there are `n' equal capacitors in series

$$C_T = \frac{C}{n}$$

Maximum voltage across each capacitor: In series grouping, the division of the applied voltage among the capacitors depends on the individual capacitance value according to the formula

$$V = \frac{Q}{C}$$

The largest value capacitor will have the smallest voltage because of the reciprocal relationship.

Likewise, the smallest capacitance value will have the largest voltage.

The voltage across any individual capacitor in a series connection can be determined using the following formula.

$$V_X = \frac{C_T}{C_X} \times V_S$$

where V_x - individual voltage of each capacitor

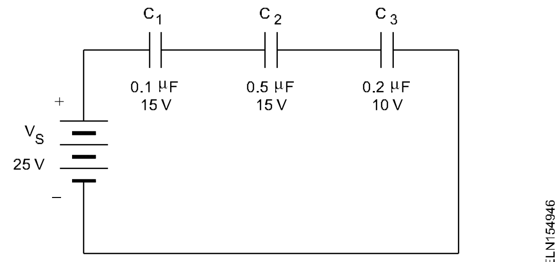
C_x - individual capacitance of each capacitor

V_s - supply voltage.

The potential difference does not divide equally if the capacitances are unequal. If the capacitances are unequal you must be careful not to exceed the breakdown voltage of any capacitor.

Question 2: Find the voltage across each capacitor in Fig 4.

Fig 4



Total capacitance: C_T

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{0.1} + \frac{1}{0.5} + \frac{1}{0.2} \text{ macro farad}$$

$$\frac{1}{C_T} = \frac{10}{1} + \frac{2}{1} + \frac{5}{1}$$

$$\frac{1}{C_T} = \frac{17}{1} \text{ and CT = 0.0588 micro farad}$$

$$V_1 = \frac{C_T}{C_1} \times V_S$$

V_1 = 14.71 V_S

$$V_2 = \frac{C_T}{C_2} \times V_S$$

$$V_2 = \frac{0.0588}{0.5} \times 25$$

V_2 = 2.94 volts

$$V_3 = \frac{C_T}{C_3} \times V_S$$

$$V_3 = \frac{0.0588}{0.2} \times 25$$

V_3 = 7.35 volts

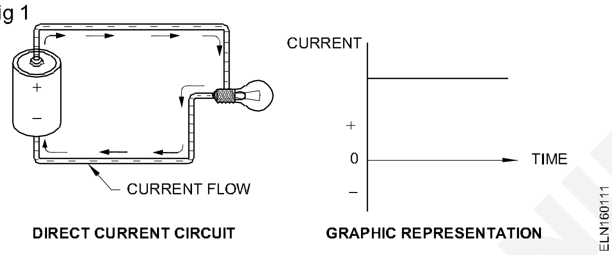
Alternating current - terms & definitions - vector diagrams

Objectives: At the end of this lesson you shall be able to
- **state the features of direct current**
- **list out the advantages of DC over AC**
- **compare the features of DC and AC**
- **explain the generation of alternating current and terms used**
- **state the advantages of AC over DC.**

Direct current (DC): Electric current can be defined as the flow of electrons in a circuit. Based on the electron theory, electrons flow from the negative (–) polarity to the positive (+) polarity of a voltage source.

Direct current (DC) is the current that flows only in one direction in a circuit. (Fig 1) The current in this type of circuit is supplied from a DC voltage source. Since the polarity of a DC source remains fixed, the current produced by it flows in one direction only.

Fig 1



Advantages of DC over AC

1 DC needs only two wires of transmission, while a 3 phase AC may need upto 4 wires.

2 The corona loss associated with DC is negligible while for AC it increases with its frequency.

3 The skin effect is also observed in AC leading to problems in transmission conductor designs.

4 No inductive and capacitive losses.

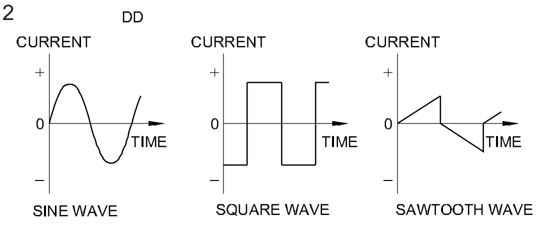
Comparison of AC and DC

	Alternating current	Direct current
Amount of energy that can be carried	Safe to transfer over longer city distances and can provide more power.	Voltage of DC cannot travel very far until it begins to lose energy.
Cause of the direction of flow of electrons	Rotating magnet along the wire.	Steady magnetism along the wire.
Frequency	The frequency of alternating current is 50Hz or 60Hz depending upon the country.	The frequency of direct current is zero.
Direction	It reverse its direction while flowing in a circuit.	It flows in one direction in the circuit.
Current	It is the current of magnitude varying with time.	It is the current of constant magnitude.
Flow of electrons	Electrons keep switching directions - forward and backward.	Electrons move steadily in one direction or 'forward'.
Obtained from	AC generator and mains.	Cell or battery.
Passive parameters	Impedence.	Resistance only.
Power factor	Lies between 0 to 1.	Nil
Types	Sinusoidal, trapezoidal, triangular, square	Pure

Alternating current (AC): An alternating current (AC) circuit is one in which the direction and amplitude of the current flow change at regular intervals. The current in this type of circuit is supplied from an AC voltage source. The polarity of an AC source changes at regular intervals resulting in a reversal of the circuit current flow.

Alternating current usually changes in both value and direction. The current increases from zero to some maximum value, and then drops back to zero as it flows in one direction. This same pattern is then repeated as it flows in the opposite direction. The wave-form or the exact manner in which the current increases and decreases is determined by the type of AC voltage source used. (Fig 2)

Fig 2



AC WAVE FORMS

Alternating current generation: Alternating current is used wherever a large amount of electrical power is required. Almost all of the electrical energy supplied for domestic and commercial purposes is alternating current.

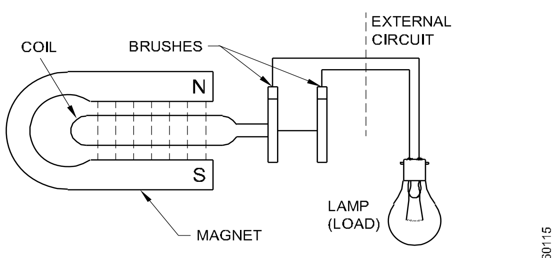
AC voltage is used because it is much easier and cheaper to generate, and when transmitted over long distances, the power loss is low.

Alternating current can be generated at higher voltages than DC. Some standard values of voltages are 1.1KV, 2.2.KV, 3.3KV for low capacity . The values are increased to 66 000, 110 000, 220 000, 400 000 volts for transmission over long distances. At the load area, the voltage is decreased to working values of 240V and 415V.

A generator is a machine that uses magnetism to convert mechanical energy into electrical energy. The generator principle, simply stated, is that a voltage is induced in a conductor whenever the conductor is moved through a magnetic field so as to cut the lines of magnetic force.

An AC generator produces an AC voltage by causing a loop of wire to turn within a magnetic field. This relative motion between the wire and the magnetic field causes a voltage to be induced between the ends of the wire. This voltage changes in magnitude and polarity as the loop is rotated within the magnetic field. (Fig 3)

Fig 3



SIMPLIFIED AC GENERATOR

The force required to turn the loop can be obtained from various sources. For example, very large AC generators are turned by steam turbines or by the movement of water.

The AC voltage induced in the armature coils is connected to a set of slip rings from which the external circuit receives the voltage through a set of brushes. An electromagnet is used to produce a stronger magnetic field.

The sine wave: The shape of the voltage wave-form generated by a coil rotating in a magnetic field is called a sine wave. The generated sine wave voltage varies in both voltage value and polarity.

If the coil is rotated at a constant speed, the number of magnetic lines of force cut per second varies with the position of the coil. When the coil is moving parallel to the magnetic field, it cuts no lines of force.

Therefore, no voltage is generated at this instant. When the coil is moving at right angles to the magnetic field, it cuts the maximum number of lines of force.

Therefore, maximum or peak voltage is generated at this instant. Between these two points the voltage varies in accordance with the sine of the angle at which the coil cuts the lines of force.

The coil is shown in five specific positions in Fig 4. These are intermediate positions which occur during one complete revolution of the coil position. The graph shows how the voltage increases and decreases in amount during one rotation of the loop.

Note that the direction of the voltage reverses each half-cycle. This is because, for each revolution of the coil, each side must first move down and then up through the field.

The sine wave is the most basic and widely used AC wave-form. The standard AC generator (alternator) produces a voltage of sine wave-form. Some of the important electrical characteristics and terms used when referring to AC sine wave voltage or current are as follows.

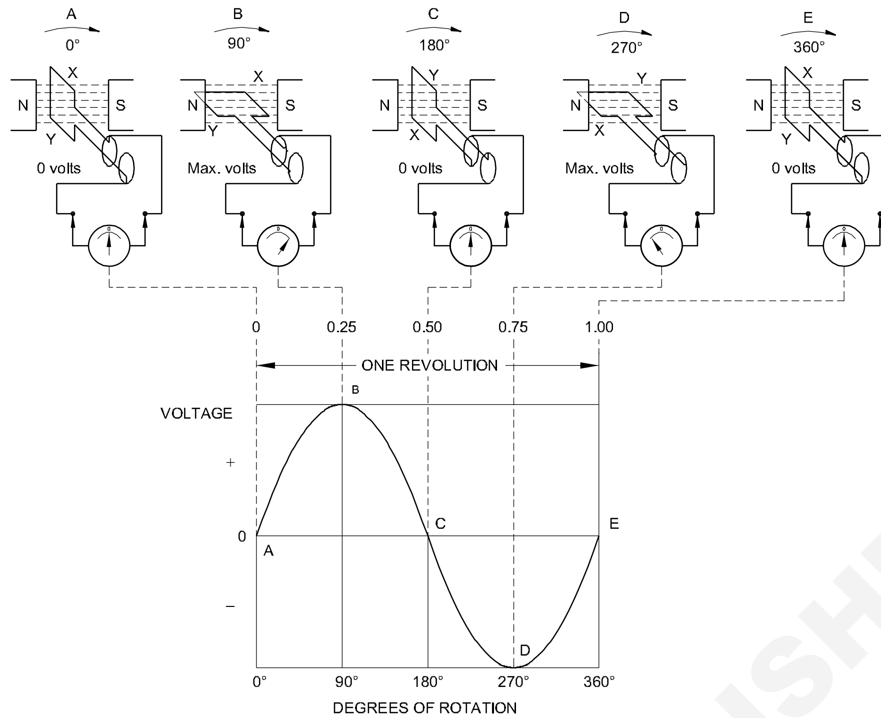
Cycle: One cycle is one complete wave of alternating voltage or current. During the generation of one cycle of output voltage, there are two changes in the polarity of the voltage.

These equal but opposite halves of a complete cycle are referred to as alternations. The terms positive and negative are used to distinguish one alternation from the other. (Fig 5)

Period: The time required to produce one complete cycle is called the period of the wave-form. In Fig 6, it takes 0.25 seconds to complete one cycle. Therefore, the period (T) of that wave-form is 0.25 seconds.

Frequency: The frequency of an AC sine wave is the number of cycles produced per second.(Fig 6) The unit of frequency is the hertz (Hz). For example, the 240V AC at your home has a frequency of 50 Hz.

Fig 4



GENERATION OF AN ALTERNATING VOLTAGE: AS THE LOOP ROTATES THROUGH THE MAGNETIC FIELD. THE AMOUNT AND POLARITY OFTHE VOLTAGE CHANGES WITH ANGLE AND DIRECTION OF MOTION.

ELN160116

Fig 5

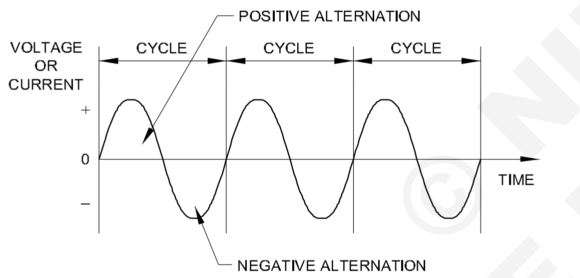


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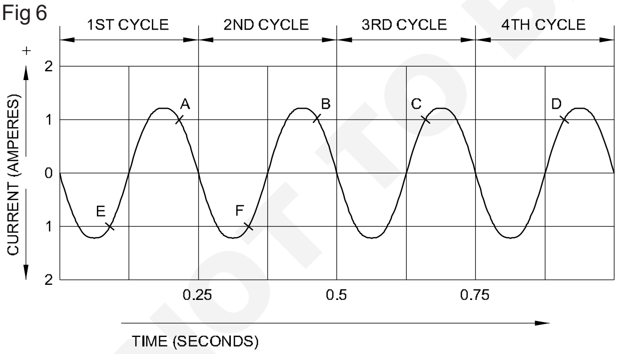
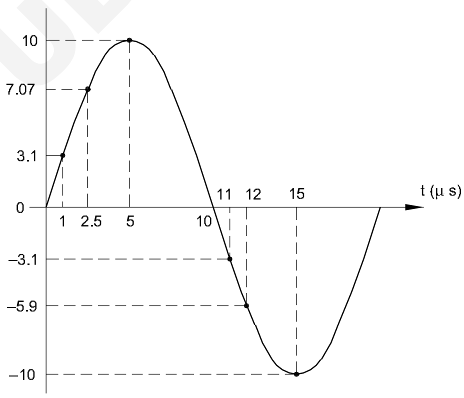
Fig 6



CYCLE, PERIOD, AND FREQUENCY. THE WAVEFORM HAS A PERIOD OF 0.25 SECONDS AND FOUR CYCLES PER SECOND.

ELN160118

Fig 7



EXAMPLE OF INSANTANEOUS VALUES OF A SINE WAVE VOLTAGE

ELN160119

Instantaneous value: The value of an alternating quantity at any particular instant is called instantaneous value. The instantaneous values of a sine wave voltage is shown in Fig 7. It is 3.1 volts at 1μs, 7.07 V at 2.5μs, 10V at 5μs, 0V at 10μs, - 3.1 volt at 11 μs and so on.

Peak value or maximum value: Each alternation of the sine wave is made up of a number of instantaneous values. These values are plotted at various heights above and below the horizontal line to form a continuous wave-form. (Fig 8)

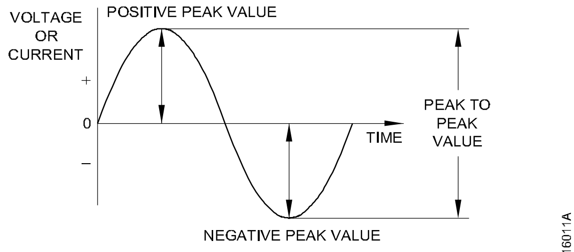
The peak value of a sine wave refers to the maximum voltage or current value. Note that two equal peak values occur during one cycle.

Peak-to-peak value: The peak-to-peak value of a sine wave refers to its total overall value from one peak to the other. (Fig 8) It is equal to two times the peak value.

Effective value: The effective value of an alternating current is that value which will produce the same heating effect as a specific value of a steady direct current. In other words, an alternating current has an effective value of 1 ampere, if it produces heat at the same rate as the heat produced by 1 ampere of direct current, both flowing in the same value of resistance.

Another name for the effective value of an alternating current or voltage is the **root mean square (rms) value.** This term was derived from a method used to compute the value. The rms is calculated as follows.

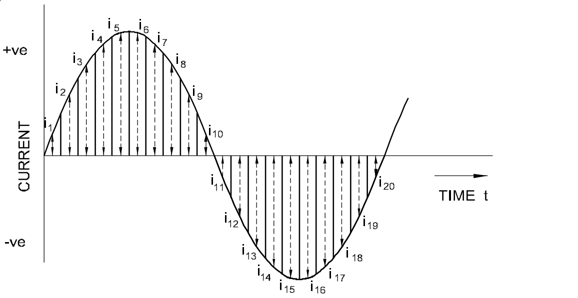
Fig 8



PEAK TO PEAK VALUE OF A SINE WAVE

The instantaneous values for one cycle are selected for equal periods of time. Each value is squared, and the average of the squares is calculated (values are squared because the heating effect varies as square of the current or voltage). The square root of this is the rms value. (Fig 9)

Fig 9



$$\text{Average of square of instantanious values} = \frac{i_1^2 + i_2^2 + i_3^2 + \cdots + i_{18}^2 + i_{19}^2 + i_{20}^2}{20}$$

By using this method it can be proved that the effective value of a sine wave of current is always equal to 0.707 times its peak value. A simple equation for calculating the effective value of sine wave is:

for voltage, $V = 0.707\ V_m$

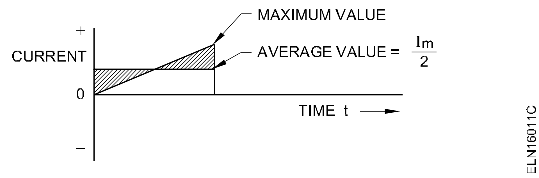
for current, $I = 0.707\ I_m$

where subscript m refers to the maximum value.

When an alternating current or voltage is specified, it is always the effective value OR RMS valve that is meant, unless otherwise stated. Standard AC meters indicate effective values only.

Average value: It is sometimes useful to know the average value for one half cycle. If the current is changed at the same rate over the entire half cycle as in Fig 10, the average value would be one half of the maximum value.

Fig 10



It has been determined that the average value is equal to 0.637 times the maximum value for sine wave-form i.e.

for voltage, $V_{av} = 0.637\ V_m$

for current, $I_{av} = 0.637 I_m$

where subscript av refers to the average value and subscript m refers to the maximum value.

Form factor (k_f): Form factor is defined as the ratio of effective value to average value of half cycle.

For sinusoidal AC

$$k_f = \frac{0.707\ I_m}{0.6637\ I_m} = 1.11$$

where the subscript m refers to the maximum value.

Advantages of AC over DC:

1 AC voltages can be raised or lowered with ease. This makes it ideal for transmission purposes.

2 Large amounts of power can be transmitted at high voltage and low currents with minimum loss.

3 Because the current is low, smaller transmission wires can be used to reduce installation and maintenance costs.

4 AC is easy to generate than DC.

5 AC generators take higher efficiency than DC.

6 The loss of energy during transmission in negligible for AC in long distance.

7 The AC can be easily converted to DC.

8 It can easily stepup or stepdown using transformer.

Neutral and earth conductors

Objectives: At the end of this lesson you shall be able to

- **describe the purpose of earthing**
- **describe the two types of earthing**
- **differentiate between `neutral' and `earth wire'.**

Earthing: The importance of earthing lies in the fact that it deals with safety. One of the most important, but least understood, considerations in the design of electrical systems is that of earthing (grounding). The word `earthing' comes from the fact that the technique itself involves making a low-resistance connection to the earth or to the ground. The earth can be considered to be a large conductor which is at zero potential.

Purpose of earthing: The purpose of earthing is to provide protection to personnel, equipment and circuits by eliminating the possibility of dangerous or excessive voltage.

There are two distinct considerations in the earthing of an electrical system: earthing of one of the conductors of the wiring system, and earthing of all metal enclosures which contain electrical wires or equipment. The two types of earthing are:

- System earthing
- Equipment earthing.

System earthing: This consists of earthing one of the wires of the electrical system, such as the neutral, to limit the maximum voltage to earth under normal operating conditions.

Equipment earthing: This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

What is an earthing electrode?: A metal plate, pipe or other conductors electrically connected to the general mass of the earth is known as an earthing electrode. Earth electrodes shall be provided at generating stations, substations and consumer premises (in accordance with the requirements of IS : 3043-1966).

The neutral used in single phase system is to provide return path for load current to the source. Various method of neutral earthing is provided to serve neutral in single phase distribution at substation according to the requirements.

What is an `earth wire'?: A conductor connected to earth and usually situated in proximity to the associated line conductors which is used for equipment earthing is called an earth wire.

The purpose of equipment earthing: By connecting the metal work not intended to carry current to earth, a path is provided for leakage current which can be detected, and, if necessary, interrupted by the following devices.

- Fuses
- Circuit breakers.

Use of vector diagram

Objective: At the end of this lesson you shall be able to
- **distinguish between scalar and vector quantity.**

Definition of scalar and vector quantity and phasor

Scalar quantity:A scalar quantity is a quantity which is determined by the magnitude alone, for example energy, volume, temperature etc.

Vector quantity: A vector quantity is a quantity which is represented by straight line with an arrow head to represent the magnitude and direction of it. For example, - force, velocity, weight.

Phasor: Phasor is a vector that is rotating at a constant angular velocity. A straight line with an arrow head is used to represent graphically the magnitude and phase of a sinusoidal alternating quantity (i.e. current, voltage and power) is called phasor.

Use of vector diagrams: The change which occurs in the value of an alternating voltage and/or current during a cycle can also be shown by using vector diagrams.

A vector is a line segment that has a define length and direction. A vector diagram is two or more vectors joined together to convey information. Vector diagrams drawn to scale can be used to determine instantaneous values of current and/or voltage.

Scalar quantity	Vector quantity
1. Scalar quantity can be presented by magnitude only, for example - energy, volume etc.	Vector quantity must represent magnitude and direction also, for example - force velocity etc.
2. Addition and substraction of scalar quantities can be done algebraically	Addition and subtraction of vector quantities cannot be done algebracially but by vector summation.

AC simple circuit

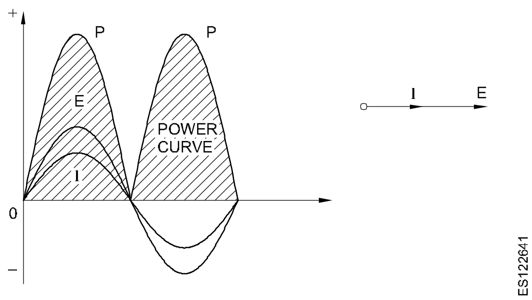
Objectives: At the end of this lesson you shall be able to
- **state phase relationship between voltage, current & power in pure resistance circuit**
- **state phase relationship between voltage, current & power in pure inductance circuit**
- **state phase relationship between voltage, current & power in pure capacitance circuit.**

Pure resistance circuit : A pure resistance circuit is one possessing neither inductance nor capacitance. Hence, if a current passes through the circuit. No back emf will be setup by any change in current. The applied voltage is required to overcome the ohmic drop only as in a dc circuit. So, we have, using effective values.

$$I = \frac{E}{R}$$

Since the current is proportional to the voltage, the wave form of current is exactly the same as that of voltage. When the voltage is zero the current is also zero. The two quantities are in phase with each other. Fig 1 shows a current wave, I, in phase with a voltage wave, E to obtain the power at each instant the current and voltage are multiplied together. With these products a new curve p, may be plotted. The power curve is positive during the first-half cycle because both the current and voltage are positive. During the second half-cycle both current and voltage are negative, hence their product will again be positive.

Fig 1

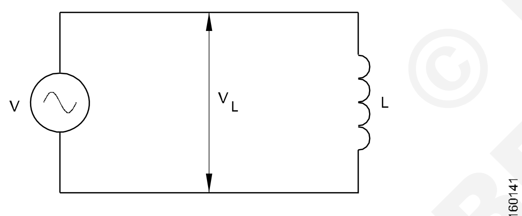


The power in a pure resistance circuit is given by the product of the effective voltage and current. Ie P = E.I.

Circuit with pure inductance only

A circuit with pure inductance alone can never be formed, because the source, the connecting wires, and the inductor all have some resistance. However, if these resistances are very small and have a much smaller effect on the circuit current than does the inductance, the circuit can be considered as containing only inductance. (Fig 2)

Fig 2



CIRCUIT DIAGRAM

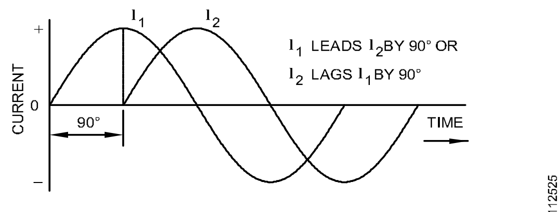
Phase difference: If two alternating quantities attain maximum value in the same direction after passing through zero value at different times, they are said to have a phase difference.

Phase difference can be expressed in fractions of a cycle. For more accuracy, phase difference is given in degrees. The terms `lead' and `lag' are used to describe the relative positions in time of two voltages or currents that are not in phase. The one that is ahead in time is said to lead, while the one behind lags. (Fig 3)

When maximum and minimum points of one voltage or current occur before the corresponding points of another voltage or current, the two are out of phase. When such a phase difference exists, one of the voltages or currents leads, and the other lags.

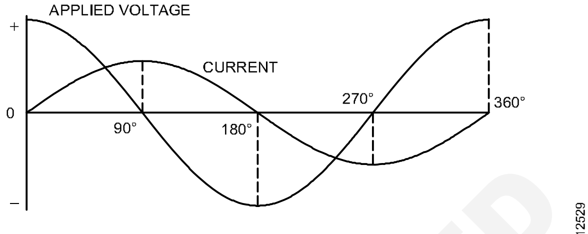
Phase relationship between current and voltage in a circuit with inductance only : When AC voltage is applied to an inductive circuit, the current lags behind the applied voltage by a quarter cycle or by 90°. (Fig 4)

Fig 3



PHASE DIFFERENCE

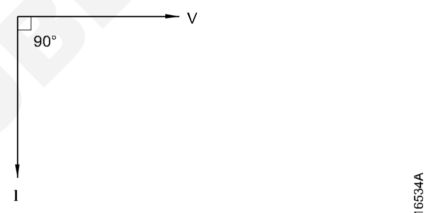
Fig 4



CURRENT LAGS VOLTAGE BY 90°

In a purely inductive circuit, the current lags behind the applied voltage by 90°. This is illustrated in the Fig 9 as wave-form. This also can be stated as voltage leads current. The vector diagram for both expressions is given in Figs 5 and 6.

Fig 5



I LAGS BEHIND V BY 90°

Fig 6

V LEADS I BY 90°

Inductive reactance: The cemf acts just like a resistance to limit the current flow. But cemf is discussed in terms of volts, so it cannot be used in Ohm's Law to compute the current. However, the effect of cemf can be given in terms of ohms. This effect is called inductive reactance, and is abbreviated as X_L. Since the cemf generated by an inductor is determined by the inductance (L) of the inductor, and the frequency (f) of the current, the inductive reactance must also depend on these things. The inductive reactance can be calculated by the equation

$$X_L = 2\pi fL$$

where X_L is the inductive reactance in ohms; f is the frequency of the current in cycles per second; and L is the inductance in henrys. The quantity 2π together actually represents the rate of change of the current, usually denoted by the Greek letter `ω' (Omega).

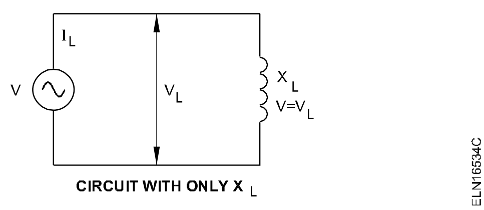
Since $2\pi = 2(3.14) = 6.28$, the Eqn. becomes similarly

$$L = \frac{X_L}{6.28\,f}$$

$$f = \frac{X_L}{6.28\,L}$$

In a circuit containing only inductance, Ohm's Law can be used to find the current and voltage by substituting X_L for R. (Fig 7)

Fig 7



CIRCUIT WITH ONLY X_L

$$I_L = \frac{V_L}{X_L}$$

$$X_L = \frac{V_L}{I_L}$$

$$V_L = I_L X_L$$

where I_L = current through the inductance,in amperes

V_L = voltage across the inductance, in volts

.
X_L = inductive reactance in ohms

Pure capacitance circuit

Fig 8 shows an alternating emf E applied to the plates of a capacitor. When the voltage starts from zero value at 0.

Fig 8

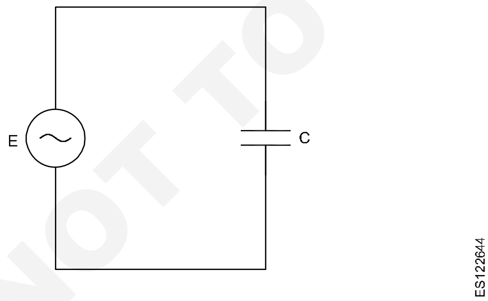


Fig 9 and increases positively, current flows into the capacitor and this current is also positive. As long as the emf across the capacitor plates increases, current flows into the capacitor.

When the instant L is reached, the increase of emf stops and current decreases to zero. Between L and M the emf decreases and current flows out of the capacitor so the capacitor discharges and as the current reverses its direction, the sign of the current become negative. This reversal of current is shown by the current wave I in Fig 5 after the voltage wave E goes through zero at M the emf is negative and the charge in the capacitor is reversed, so, the current the remains in the negative direction. This continues until the emf reaches its maximum value in the negative direction. At the instant N, the current reverse and again becomes positive charging and discharging of capacitor continue as long as the alternating emf is present across its plate.

Fig 9 shows that the alternating emf applied to a capacitor causes the current in the capacitor to lead the applied emf by 90°. This is shown by phasors in Fig 10.

Fig 9

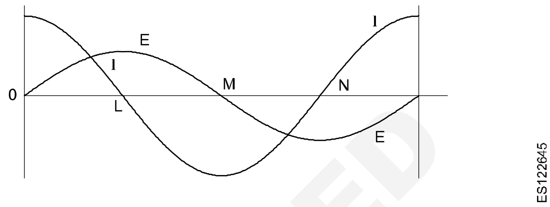


Fig 10

Capacitive reactance: The opposition offered to the flow of current by a capacitor is called capacitive reactance and is abbreviated Xc. Capacitive reactance can be calculated by:

$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C}$$

Where 2π is approximately 6.28

F is the frequency in Hz

C is the capacitance is farad and $\omega = 2\pi f$

Like its inductive counterpart - inductive reactance, capacitive reactance is expressed in ohms. Ohm's law can be also be applied to a circuit containing capacitive reactance only.

Example 1

A 10 μF capacitor is connected across a 250 V, 50 Hz supply. Calculate (a) the resistance of the capacitor and (b) the current.

Solution:

Reactance

$$X_C = \frac{1}{2\pi fC}$$

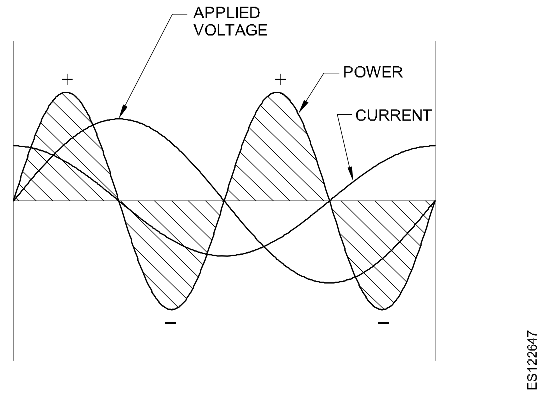
$$= \frac{1}{2 \times 3.14 \times 50 \times 10 \times 10^{-6}}$$

$$\text{Current} = \frac{250}{318.3} = 0.785\text{A}$$

The average power in a circuit containing only a capacitance is zero. This may be shown by plotting the power curve from the current and voltage curves (Fig 11) as was done for a circuit with the inductance only.

Fig 11 power curve for a purely capacitive circuit.

Fig 11



A.C. circuit with R & L in series

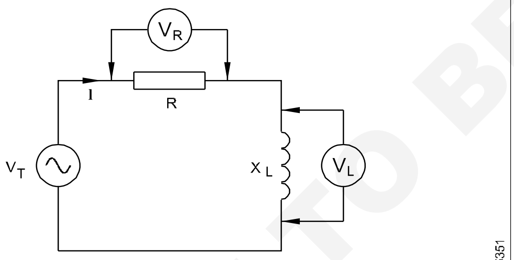
Objectives: At the end of this lesson you shall be able to

- **state the voltage and current relationship**
- **determine impedance of a series circuit with RL in series**
- **calculate power in a series circuit (with RL in series)**
- **calculate the power factor in RL series circuit.**

When resistance and inductance are connected in series, or in the case of a coil with resistance, the rms current I_L is limited by both X_L, and R however the current I is the same in X_L and R since they are in series, the voltage drop across R is V_R = IR and the voltage drop across X_L is $V_L = IX_L$. The current I through X_L must lag V_L by 90° because this is the phase angle between current through an inductance and its self-induced voltage. The current I through R,and its IR voltage drop,are in phase and so the phase angle is 0°.

Now let us apply the principle of phasor representation to a series circuit containing pure resistance and pure inductance. (Fig 1)

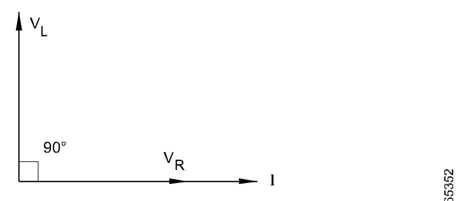
Fig 1



CIRCUIT WITH R & L IN SERIES

Since we are considering a series circuit, it is convenient if we draw the current phasor in the horizontal reference position because it is `common' to both the resistor and inductor. Superimposed upon this phasor is the voltage phasor across the resistor V_R. This is because the current and voltage are always in phase with each other in a pure resistor. (Fig 2)

Fig 2



VECTOR DIAGRAM OF R & L SERIES CIRCUIT

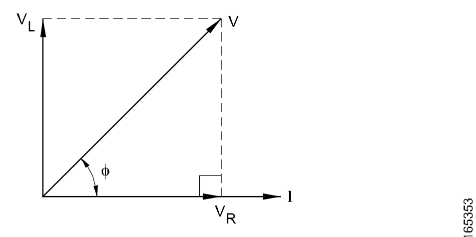
Similarly, the voltage phasor across the inductor V_L is drawn 90° ahead of the current I in other words leading the current phasor. This is because, as we know, the current always lags the inductor voltage by 90° in a pure inductance.

However, these two voltages are 90° out of phase with each other. This means that the total voltage across the series combination cannot be obtained simply by adding V_R to V_L algebraically. We must take into account the angle between them.

The applied voltage V is the (phasor) sum of V_R and V_L with the phase angle added.

This phasor addition can be carried out simply by constructing a parallelogram (a square in this case) and drawing the diagonal. This is shown in Fig 3. Clearly, the phasor sum V is less than the algebraic sum of V_L and V_R. Also, because V is the hypotenuse of a right-angled triangle, V is given by

Fig 3



PHASOR DIAGRAM OF R & L SERIES CIRCUIT

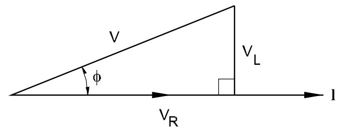
$$V^2 = V_R^2 + V_L^2$$

Impedance of a series RL circuit: The total opposition to current in a series, RL circuit, is called the **impedance** Z. It is the ratio of the total applied voltage V to the current I. Impedance is measured in ohms as are resistance and inductive reactance. But, as shown by the following, impedance is the vector sum of resistance and reactance.

Consider the `voltage triangle' for a series, RL circuit, as shown in Fig 4.

Given $V^2 = V_R^2 + V_L^2$ and V_R = IR and $V_L = IX_L$

Fig 4



(a) VOLTAGE TRIANGLE

then $V = \sqrt{(IR)^2 + (IX_L)^2}$

$= \sqrt{I^2R^2 + (I^2X_L)^2}$

$= \sqrt{I^2(R^2 + X_L{}^2)}$

$= I\sqrt{R^2 + X_L{}^2}$ and $\frac{V}{I} = \sqrt{R^2 + X_L{}^2}$

But $\frac{V}{I}$ is the impedance Z.

Therefore, $Z = \sqrt{R^2 + X_L{}^2}$ ohms

where Z is the impedance in ohms

R is the resistance in ohms

X_L is the inductive reactance in ohms

and $I = \frac{V}{Z}$ amperes (A).

Power factor: The ratio of the true power delivered to an AC circuit compared to the apparent power that the source must supply is called the power factor of the load.

If we examine any power triangle, we see that the ratio of the true power to the apparent power is cosine of the angle Ø.

Power factor $= \frac{W}{VA} = \text{Cos}\,\phi$

power factor must also be equal to $\frac{V_R}{V}$ and to $\frac{R}{Z}$

Power factor (PF) $= \frac{W}{VA} = \frac{V_R}{V} = \frac{R}{Z}$

What should be the power factor for a circuit containing pure resistance only?. As the phase angle Ø between current and voltages is $\phi = 0$.

Cos ϕ = 1 and PF = 1.

Similarly the power factor for circuit containing pure inductance or pure capacitance only is zero as

Cos ϕ = Cos 90° = zero.

Example: An inductive circuit has a resistance of 2 ohms in series with an inductance of 0.015 henry. Find (i) current and (ii) power factor when connected across 200 volt 50 cycles per second supply mains.

Solution

$X_L = 2\pi fL = 2x3.142x50x0.015 = 4.71$ ohms

$Z = \sqrt{R^2 + X_L{}^2} = \sqrt{(2)^2 + (4.71)^2}$

$= \sqrt{4 + 17.39} = \sqrt{26.19}$

i $I = \frac{200}{5.11} = 39.13$ amps

ii Power factor $= \frac{R}{Z} = \frac{2}{5.11} = 0.39$

Power and power factor in AC single phase circuit

Objective: At the end of this lesson you shall be able to
- **calculate power and power factor of a single phase AC circuit from the given relevant values.**

Power in pure resistance circuit: Power can be calculated by using the following formulae.

1) $P = V_R x I_R$ watts

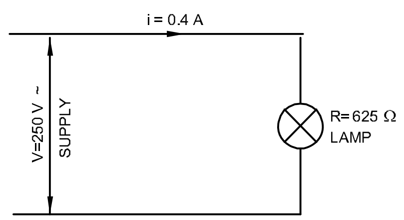
2) $P = I^2_R\ R$ watts

3) $P = \frac{E^2}{R}$ watts

Example 1: Calculate the power taken by an incandescent lamp rated 250V when it carries a current of 0.4A if the resistance is 625 ohms.(Fig 1)

$P = V_R x I_R$

Fig 1



= 250 x 0.4

= 100 watts.

Alternately

$$P = I^2R$$

$$= 0.4 \times 0.4 \times 625$$

$$= 100 \text{ watts}$$

$$\text{or } P = \frac{E^2}{R} = \frac{250^2}{625}$$

$$P = \frac{250 \times 250}{625}$$

$$= 100 \text{ watts.}$$

Since the current and voltage are in phase, the phase angle is zero and the power factor is unity. Therefore, the power can be calculated with voltage and current itself.

Power in pure inductance: If an AC circuit contains only inductance, the voltage and current are 90° out of phase, and the circuit of the instantaneous values of voltage and current gives with positive and negative power. Net result is the power consumed in a pure inductive circuit is zero.

Power in pure capacitance: If an AC circuit contains only capacitor, the voltage and current are 90°. Out of phase and the product of instantaneous values of voltage and current gives both positive and negative power. Net result is the power consumed in a pure capacitive circuit is zero.

Most industrial installations have a lagging PF because of the large number of AC induction motors that are inherently inductive.

Effect of a low power factor

For a given quantity of true power if the power factor of the load is less than unity it requires a higher current to deliver. This higher current means that more energy is wasted in the feeder wires serving the motor. In fact, if an industrial installation has a power factor less than 85% (0.85) overall, a `power factor penalty' is assessed by the electric utility company. It is for this reason that power factor correction is necessary in large installations.

Power factor correction: In order to make the most efficient use of the current delivered to a load we desire a high PF or a PF that approaches unity.

A low PF is generally due to the large induction loads such as discharge lamps, induction motors, transformers etc. which take a lagging current and produce heat which returns to the generating station without doing any useful work as such it is essential to improve or correct the low PF so as to bring the current as closely in phase with the voltage as possible. That is the phase angle θ is made as small as possible. This is usually done by placing a capacitor load which produces a leading current.

The capacitor is to be connected in parallel with the inductive load.

R - C Series circuit

Objectives: At the end of this lesson you shall be able to
- **state the effect of frequency on capacitive reactance in R-C series circuit**
- **calculate power factor**
- **determine the power factor and phase angle**
- **state the R-C time constant while charging and discharging.**

In a circuit with capacitance, when the supply frequency (f) increses the capacitive reactance (X_C) decreases

$$X_C \propto \frac{1}{f}$$

When the capacitive reactance X_C increases the circuit current decreases.

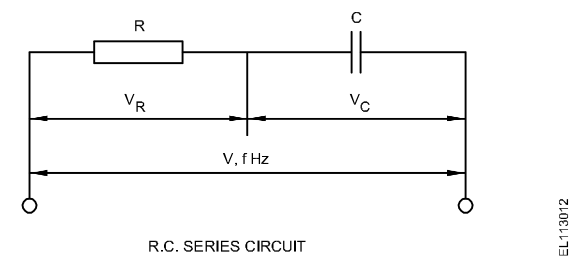
$$I \propto \frac{1}{X_C}$$

Therefore the increase in frequency (f) results in the increase of the circuit current in the capacitive circuit. When resistance (R), capacitance (C) and frequency f are known in a circuit, the power factor cos θ can be determined as follows. (Fig 1)

$$X_C = \frac{1}{2\pi fC}$$

$$Z = \sqrt{R^2 + X_C^2}$$

Fig 1



R.C. SERIES CIRCUIT

$$\text{Power factor, } \cos\theta = \frac{R}{Z}$$

Capacitive reactance X_C in a capacitive circuit can be determined with the formula

$$X_C = \frac{1}{2\pi fC}$$

where X_C = capacitive reactance in ohm

f = frequency in Hz

C = Capacitance in farad

Power consumed in a R-C series circuit can be determined using the formula

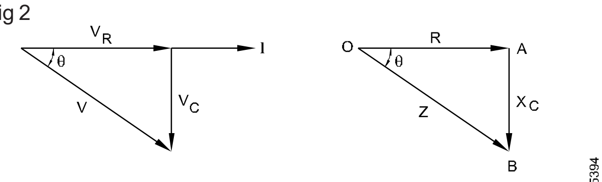
P = VI cos θ where P = power in watts

I = current in ampere

cos θ = power factor.

Vector diagram of voltages and their use to determine pf angle θ. (Fig 2)

Fig 2



a) VOLTAGE TRIANGLE b) IMPEDENCE TRIANGLE

$V_R = I_R$ drop across R (in phase with I)

$V_C = IX_C$ drop across capacitor (lagging I by 90°)

$$V = \sqrt{V_R^2 + V_C^2} = \sqrt{(IR)^2 + (IX_C)^2} = I\sqrt{R^2 + X_C^2}$$

$$\therefore I = \frac{V}{\sqrt{R^2 + X_C^2}} = \frac{V}{Z}$$

$\therefore Z = \sqrt{R^2 + X_C^2}$ where Z is the impedance of the circuit.

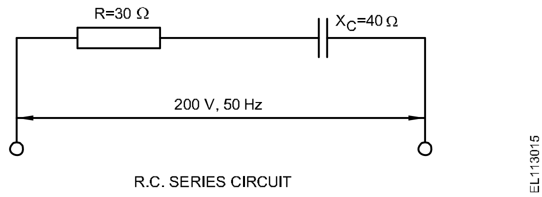
Power factor, cos θ = R/Z.

From pf cos θ the angle θ can be known referring to the Trignometric table.

Example 2: In RC series circuit shown in the diagram (Fig 3) obtain the following.

- Impedance in ohms

Fig 3



R.C. SERIES CIRCUIT

- Current in amps
- True power in watts
- Reactive power in var
- Apparent power in volt amp.
- Power factor

Solution

1 Impedence (Z)

$$= \sqrt{R^2 + X_C^2} = \sqrt{30^2 + 40^2} = \sqrt{2500} = 50\Omega$$

2 Current $I = \frac{V}{Z} = \frac{200}{50} = 4A$

3 True power W = $I^2R = 4^2 \times 30 = 480W$
(Power consumed by capacitoir = zero)
$V_C = IX_C = 4 \times 40 = 160$ V

4 Reactive power VAR = $V_C I = 160 \times 4 = 640$ VAR

5 Apparent power VI = 200 x 4 = 800 VA

6 PF □ $\cos\theta = \frac{R}{Z} = \frac{30}{50} = 0.6$

R.L.C Series circuit

Objectives: At the end of this lesson you shall be able to
- **draw the vector diagram of the voltage**
- **determine impedance**
- **solve problem.**

Resistance, Inductance and capacitance in series (Fig 1a) shows resistance R, inductive reactance XL and capacitive reactance Xc, are connected in series. The voltage across the circuit is E, the frequency is f and the current is I.

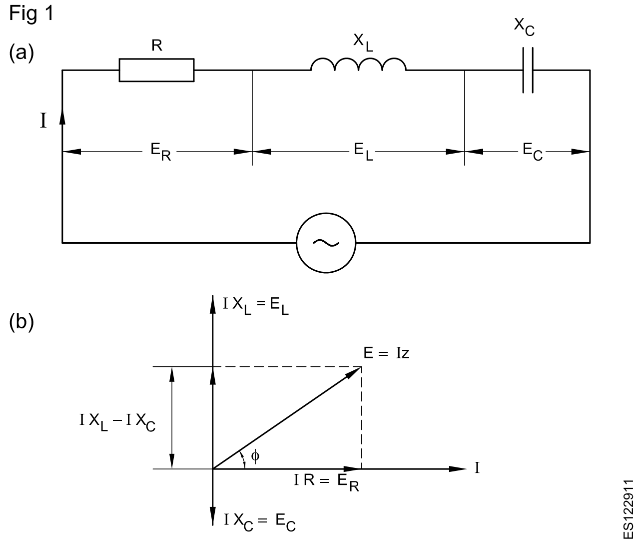
As this is a series circuit, the current is the same in all parts of the circuit, and for convenience the current phasor I is laid off horizontally in the circuit phasor diagram. The voltage E_R - IR across the resistance is in phase with the current and drawn to scale along the current phasor. The voltage E_L - IX_L across the inductance is drawn at right angles to the current and leading. The voltage $E_c = IX_c$ across the capacitor is drawn at right angles to the current and lagging.

The voltage across the inductance and that across the capacitance are in opposition Fig 1 (b) so that the resultant voltage of these two is their arithmetical difference. In Fig (1b) IX_L is shown greater than IX_C therefore, is subtracted directly form IX_L. The line voltage must be phasor sum of three voltages and is the hypotenuse of a right - angled triangle and is the hypotenuse of a right - angled triangle of which IR and $IX_L - IX_c$ are the sides. Therefore,

$$E = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

$$= I\sqrt{(R)^2 + (X_L - X_C)^2}$$

Fig 1



$= IZ$

$$\therefore Z = \sqrt{(R)^2 + (X_L - X_C)^2}$$

And $I = \dfrac{E}{Z}$

The phase angle is found by

$$\tan\phi = \frac{X_L - X_C}{R}$$

Example: A series circuit consist of a resistance of 20 ohms. An inductance of 0.2 Henry and a capacitance of 100 MFD is connected to 220 volts 50 HZ supply. Calculate

a the impedance of the circuit

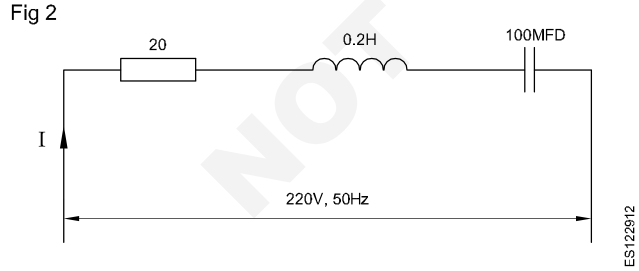
b the current flowing in the circuit

c power factor of the circuit

d power consumed in the circuit

e voltage drop in each element (Fig 2)

Fig 2



Solution:

R = 20 ohms

L = 0.2 Henry

C = 100 MFD

V = 220V

F = 50 Hz

Inductive reactance XL = 2π x 50 x 0.2 = 62.8 ohms

Capacitance reactance Xc.

$$= \frac{1}{2\pi fC} = \frac{10}{2\pi \times 50 \times 100} = 32\text{ohms}$$

a impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$$= \sqrt{20^2 + (62.8 - 32)^2} = 36.7 \text{ ohms}$$

b current in the circuit I = V/Z = 220/36.7 = 5.99 amps

c Power factor = cos = R/Z = 20/36.7 = 0.54 (lag)

d Power P = VI Cos = 220 x 5.99 x 0.54 watts

P = 711.61 watts

E Voltage drop in R = IR = 5.99 x 20 = 119.8V

Voltage drop in L = IXL = 5.99 x 62.8 = 376.17V

Voltage drop in C = IXC = 5.99 x 32 = 191.68V.

Resonance circuit: When the value of X_L and X_C are equal, the voltage drop across them will be equal and hence they cancel each other. The value of voltage drops V_L and V_C may be much higher than the applied voltage. The impedance of the circuit will be equal to the resistance value. Full value of applied voltage appears across R and the current in the circuit is limited by the value of resistance only. Such circuits are used in electronic circuits like radio/ TV turning circuits. When $X_L = X_C$ the circuit is said to be in resonance. As current will be maximum in series resonant circuits it is also called acceptor circuits. For a known value of L and C the frequency at which this occurs is called as resonant frequency. This value can be calculated as follows when $X_C = X_L$.

$$2\pi fL = \frac{1}{2\pi fC}$$

Hence resonance frequency $fr = \dfrac{1}{2\pi\sqrt{LC}}$

Note: Power factor angle is commonly denoted by Theta. In some pages of this text it is denoted by Phi. As such these terms are used alternatively in this text.

Series resonance circuit

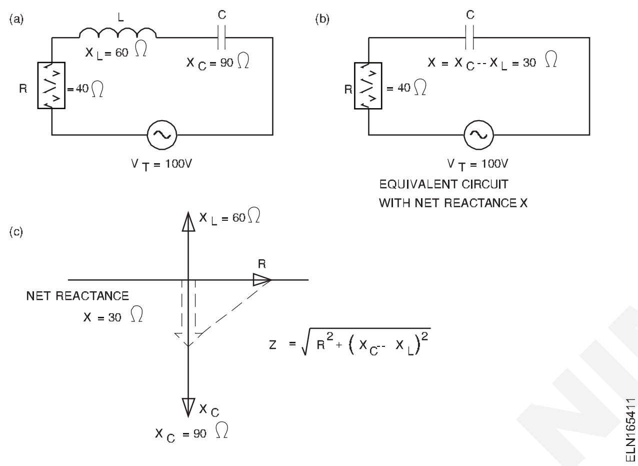
Objectives: At the end of this lesson you shall be able to
- **explain the impedance of series resonance circuit**
- **state the condition for series resonance and its expression**
- **state the resonance frequency and its formula.**

Series resonance circuit

Impedance of series resonance circuit

A simple series LC circuit shown in Fig 1. In this series LC circuit,

Fig 1



- resistance R is the total resistance of the series circuit(internal resistance) in ohms,
- X_L is the inductive reactance in ohms, and
- X_C is the total capacitive reactance in ohms.

In the circuit at Fig 1a, since the capacitive reactance(90Ω) is larger than inductive reactance(60Ω), the net reactance of the circuit will be capacitive. This is shown in Fig 1b.

> **Note: If the capacitive reactance was smaller than inductive reactance the net reactance of the circuit would have been inductive.**

All though the unit of measure of reactance and resistance is the same(ohms), the impedance, Z of the circuit is not given by the simple addition of R, X_L and X_C. This is because, X_L is +90° out of phase with R and X_C is -90° out of phase with R.

Hence the impedance Z of the circuit is the phasor addition of the resistive and reactive components as shown by dotted lines in Fig 1c. Therefore, Impedance Z of the circuit is given by,

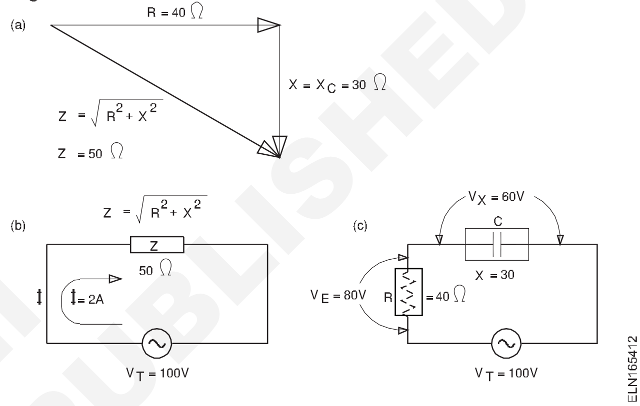
$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

If X_L were greater than X_C, then the absolute value of impedance Z is will be,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

For the circuit in Fig 2(a), total impedance Z is,

Fig 2



$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

$$Z = \sqrt{40^2 + 30^2}$$

Z = 50Ω, Capacitive (because $X_C > X_L$)

Current I through the circuit is given by,

$$I = \frac{V}{Z} = \frac{100}{50\Omega} = 2 \text{ Amps}$$

Therefore, the voltage drop across the components will be,

V_R = voltage drop across R = I.R = 2x40 = 80 volts

V_L = voltage drop across L = $I.X_L$ = 2x60 = 120 volts

V_C = voltage drop across C = $I.X_C$ = 2x90 = 180 volts.

Since V_L and V_C are of opposite polarity, the net reactive voltage V_X is = 180 - 120 = 60V as shown in Fig 2.

Note that the applied voltage is not equal to the sum of voltage drops across reactive component X and resistive component. This is again because the voltage drops are not in phase. But the phasor sum of V_R and V_X will be equal to the applied voltage as given below,

$$V_T = \sqrt{{V_R}^2 + {V_X}^2}$$

$$= \sqrt{V_R{}^2 + (V_L - V_C)^2}$$

$$= \sqrt{80^2 + 60^2} \text{ = 100 volts(applied voltage).}$$

Phase angle θ of the circuit is given by,

$$\theta = \tan^{-1}\frac{X_C - X_L}{R}$$

Condition at which current through the RLC Series circuit is maximum

From the formula,

$Z = \sqrt{R^2 + (X_C - X_L)^2}$ it is clear that the total impedance Z of the circuit will become purely resistive when,

reactance $X_L = X_C$

In this condition, the impedance Z of the circuit will not only be purely resistive but also minimum.

Since the reactance of L and C are frequency dependent, at some particular frequency say f_r, the inductive reactance X_L becomes equal to the capacitive reactance X_C. In such a case, since the impedance of the circuit will be purely resistive and minimum, current through the circuit will be maximum and will be equal to the applied voltage divided by the resistance R.

Series resonance

From the above discussions it is found that in a series RLC circuit,

<u>*Impedance*</u> $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Current $I = \frac{V}{Z}$

and,

Phase angle $\theta = \tan^{-1}\frac{X_L - X_C}{R}$

If the frequency of the signal fed to such a series LC circuit is increased from 0 Hz, as the frequency is increased, the inductive reactance(X_L = 2πfL) increases linearly and the capacitive reactance (X_C = 1/2πfL) decreases exponentially.

At a particular frequency called the resonance frequency, f_r, the sum of X_L and X_C becomes zero($X_L - X_C = 0$).

From above, at resonant frequency ,

- Net reactance, X = 0 (i.e, $X_L = X_C$)
- Impedance of the circuit is minimum, purely resistive and is equal to R
- Current I through the circuit is maximum and equal to V/R
- Circuit current, I is in-phase with the applied voltage V (i.e. Phase angle = 0).

At this particular frequency f_r called resonance frequency, the series RLC is said to in a condition of series resonance.

Resonance occurs at that frequency when,

$X_L = X_C$ or 2πfL = 1/2πfC

Therefore, **Resonance frequency, f_r** is given by,

$$f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hz} \quad ....[1]$$

R-L, R-C and R-L-C parallel circuits

Objectives: At the end of this lesson you shall be able to
- **explain the admittance triangle and the relationship between conductance, susceptance and admittance**
- **explain susceptance, conductance and admittance by symbols.**

R-L Parallel circuit : When a number of impedances are connected in parallel across an AC voltage, the total current taken by the circuit is the phasor sum of the branch currents (Fig 1).

There are two methods for finding the total current.

- Admittance method
- Phasor method

Admittance method

The current in any branch $I = \frac{E}{Z}$

$$= E \times \left|\frac{1}{Z}\right| \text{ where } \left|\frac{1}{Z}\right|$$

is called the **admittance** of the circuit i.e. admittance is the reciprocal of impedance. Admittance is denoted by 'Y' (Fig 2).

$$I = E \times \left|\frac{1}{Z}\right| = EY \quad \text{or} \quad Y = \frac{I}{E}$$

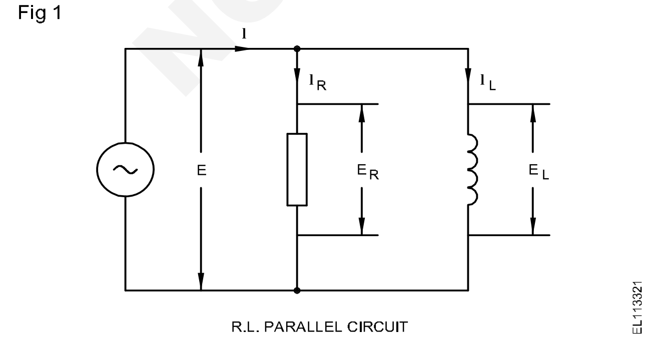
$$\therefore \text{Total admittance } (Y_T) = \frac{\text{total current}}{\text{common applied voltage}}$$

$$= \frac{\text{phasor sum of branch currents}}{\text{common applied voltage}}$$

= phase sum of separate admittance

> **Note: Supply voltage is referred as V or E interchangeably.**

Fig 1

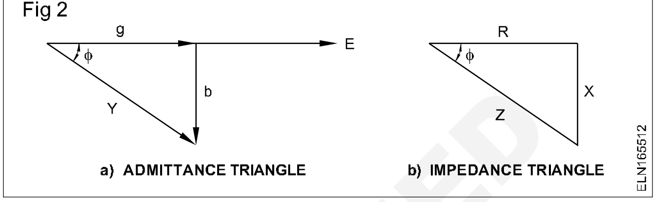


R.L. PARALLEL CIRCUIT

An admittance may be resolved into two components.

- A component in phase with the applied voltage called the conductance denoted by g.
- A component in quadrature (at right angle) with the applied voltage called **susceptance,** denoted by b.

Fig 2



a) ADMITTANCE TRIANGLE b) IMPEDANCE TRIANGLE

$$g = Y \cos\phi = \frac{1}{Z} \times \frac{R}{Z}$$

$$= \frac{R}{Z^2} = \frac{R}{R^2 + Z^2}$$

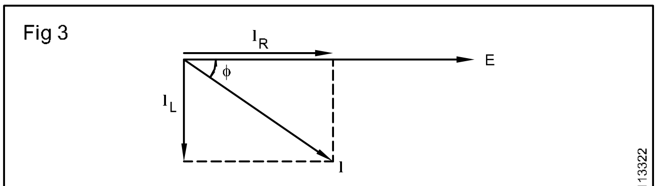
$$b = Y \sin\phi = \frac{1}{Z} \times \frac{X}{Z} = \frac{X}{Z^2}$$

$$= \frac{X}{R^2 + X^2}$$

The unit of admittance, conductance and susceptance is called the mho symbol ℧.

Relationship between branch current and supply voltage : In a R-L parallel circuit, the voltage across resistor (E_R) and inductor (E_L) are the same and equal to the supply voltage E. Hence E is the reference vector. The current through resistor (I_R) in phase with E_R is E. (Fig 3) The current through inductor (I_L) is lagging the E_L is E by 90^o. In short the current through resistor I_R is in phase and the current through inductor I_L, lags with applied voltage (E) by 90° . The power factor of R-L parallel circuit is cos φ where φ is the angle in between the total current and applied voltage.

Fig 3



R.L. PARALLEL CIRCUIT VECTOR

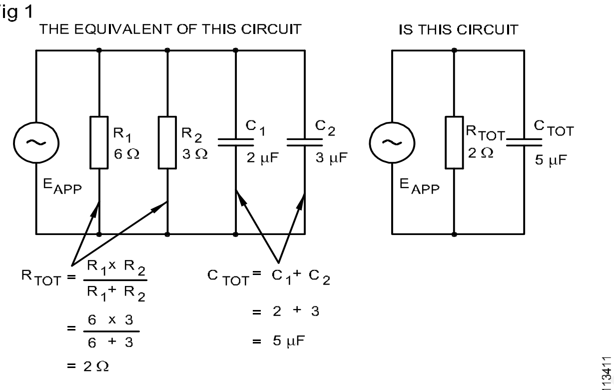
Assignment : A coil of resistance 15 ohms and inductance 0.05 H is connected in parallel with a non-inductive resistor of 40 ohms. Find the total current when a voltage of 200 V at 50 Hz. is applied. Give the phasor diagram.

AC Parallel circuit (R and C)

Objectives: At the end of this lesson you shall be able to
- **state the relationship between branch current, voltage in a parallel circuit**
- **solve problems in RC parallel circuit by admittance method**
- **compare the charecteristics of A.C series and parallel circuits**
- **state the R-L-C parallel circuit vector diagram**

Parallel RC circuits: In a parallel RC circuit, one or more resistive loads and one or more capacitive loads are connected in parallel across a voltage source. Therefore, resistive branches, containing only resistance and capacitive branches, containing only capacitance. (Fig 1) The current that leaves the voltage source divides among the branches; so there are different currents in different branches. The current is, therefore, not a common quantity, as it is in the series RC circuits.

Fig 1



R.C. PARALLEL CIRCUITS

Voltage: In a parallel RC circuit, as in any other parallel circuit, the applied voltage is directly across each branch. The branch voltages are, therefore, equal to each other. So, if you know any one of the circuit voltages, you know any one of the circuit voltages, you know all of them.

Branch current: The current in each branch of a parallel RC circuit is independent of the current in the other branches. The current within a branch depends only on the voltage across the branch, and the resistance or capacitive reactance contained in it. (Fig 2)

The current in the resistive branch is calculated from the equation: $I_R = E_{APP}/R$.

The current in the capacitive branch is found with the equation: $I_C = E_{APP}/X_C$.

The current in the resistive branch is in phase with the branch voltage, while the current in the capacitive branch leads the branch voltage by 90 degrees. Since the two branch voltages are the same, the current in the capacitive branch (I_C) must lead the current in the resistive branch (I_R) by 90 degrees. (Fig 3)

Impedance: The impedance of a parallel RC circuit represents the total opposition to the current flow offered by the resistance of the resistive branch and the capacitive reactance of the capacitive branch. Like the impedance of a parallel RL circuit, it can be calculated with an equation that is similar to the one used for finding the total resistance of two parallel resistances.

Fig 2

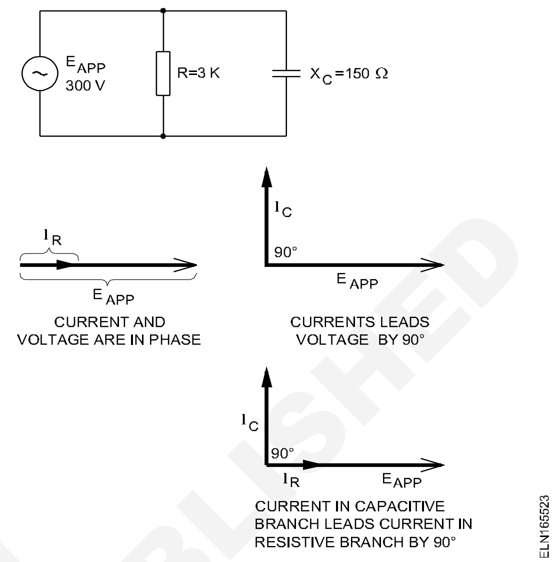
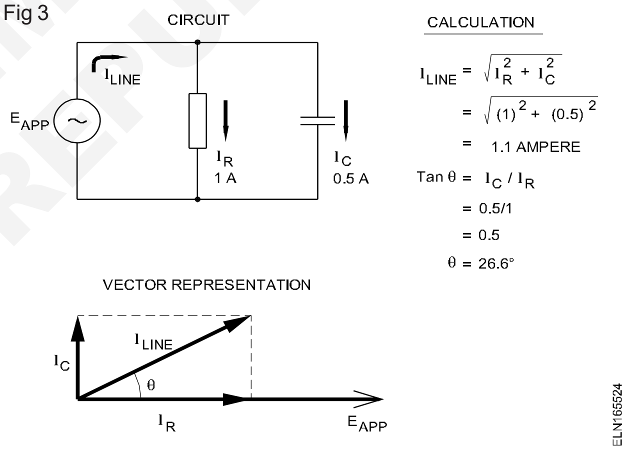


Fig 3



However, just as you learned for parallel RL circuits, two vector quantities cannot be added directly, vector addition must be used. Therfore, the equation for calculating the impedance of a parallel RC circuit is

$$Z = \frac{RX_C}{\sqrt{R^2 + X_C{}^2}}$$

where $\sqrt{R^2 + X_C{}^2}$ is the vector addition of the resistance and capacitive reactance.

In cases where you know the applied voltage and the circuit line current, the impedance can be found simply by using Ohm's law in the form:

$$Z = \frac{E_{APP}}{I_{LINE}}$$

The impedance of a parallel RC circuit is always less than the resistance or capacitive reactance of the individual branches.

The relative values of X_C and R determine how capacitive or resistive the circuit line current is. The one that is the smallest, and therefore, allows more branch current to flow, is the determining factor.

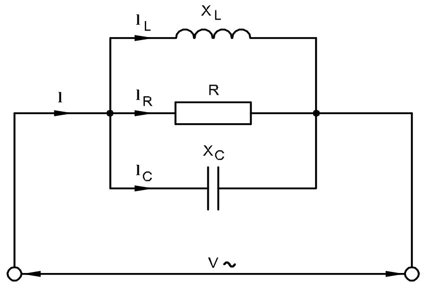
Thus, if X_C is smaller than R, the current in the capacitive branch is larger than the current in the resistive branch, and the line current tends to be more capacitive.

The opposite is true if R is smaller than X_C. When X_C or R is 10 or more times greater than the other, the circuit will operate for all practical purposes as if the branch with the larger of the two did not exist.

R, L and C Parallel circuit - Vector diagram

Parallel connection of R, X_L and X_C: X_L and X_C oppose each other, that is to say, I_L and I_C are in opposition, and partly oppose one another (Fig 4).

Fig 4



R, L & C PARALLEL CIRCUIT

$I_X = I_C - I_L$ or $I_L - I_C$, depending on whether the capacitive or inductive current dominates.

Graphic solution: when $I_L > I_C$

1 V as common value

2 I_R in phase with V

3 I_C leads by 90°

4 I_L lags by 90°

5 $I_X = I_L - I_C$

6 I as resultant

ϕ in this case inductive, I lags (Fig 5)

Particular case*:* X_L and X_C are equally large - I_L and I_C cancel each other. Z = R; parallel resonance occurs.

Currents in the reactances may be greater than the total current.

The calculation of the resonant frequency is the same as for the series connection.

Example: Calculate the value of I_T , Z and power factor for the circuit in Fig 6.

Given

V_T = 10V

R = 1000 Ω

X_L = 1570 Ω

X_C = 637 Ω

Fig 5

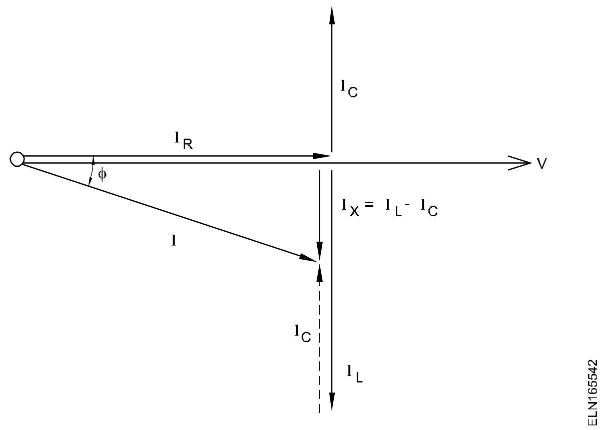
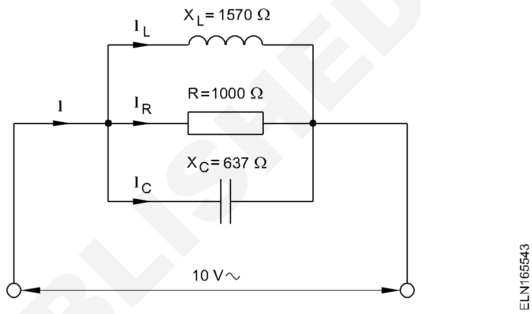


Fig 6



Known: Ohm's Law

$$I_T = \sqrt{(I_C - I_L)^2 + I_R^2}$$

Solution

$$I_C = \frac{10\ V}{637\ \Omega} = 0.0157\ A = 15.7\ mA$$

$$I_L = \frac{10\ V}{1570\ \Omega} = 0.0064\ A = 6.4\ mA$$

$$I_R = \frac{10\ V}{1000\ \Omega} = 0.01 = 10\ mA$$

$$I_T = \sqrt{(0.0157 - 0.0064)^2 + (0.01)^2}$$

$$= 0.0137A = 13.7\ mA$$

$$Z = \frac{10V}{0.0137\ A} = 730\ \Omega$$

$$P.F = \frac{Z}{R} \quad Y = \frac{1}{Z} \quad \text{and} \quad g = \frac{1}{R}$$

$$= \frac{730}{1000} = 0.73$$

Parallel resonance circuits

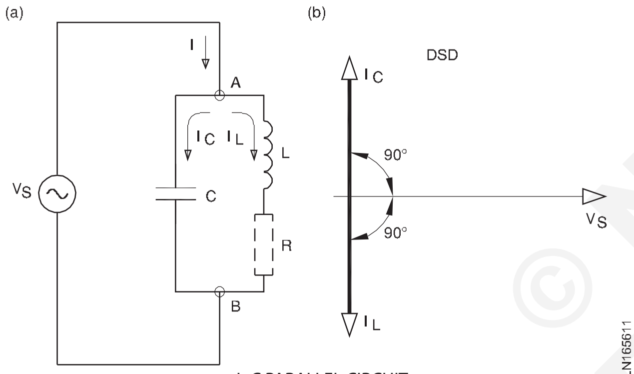
Objectives: At the end of this lesson you shall be able to
- **state the characteristics of R-L-C parallel circuits at resonance**
- **explain the term band-width in parallel LC circuits**
- **explain the storage action in parallel LC circuits**
- **list a few applications of parallel LC circuits**
- **compare the properties of series and parallel resonance circuits.**

Parallel resonance

The circuit at Fig 1, having an inductor and a capacitor connected in parallel is called parallel LC circuit or parallel resonance circuit. The resistor R, shown in dotted lines indicate the internal DC resistance of the coil L. The value of R will be so small compared to the inductive reactance, that it can be neglected.

From Fig 1a, it can be seen that the voltage across L and C is same and is equal to the input voltage V_S.

Fig 1



L-C PARALLEL CIRCUIT

By Kirchhoff's law, at junction A,

$$I = I_L + I_C.$$

The current through the inductance I_L (neglecting resistance R), lags V_S by 90°. The current through the capacitor I_C, leads the voltage V_S by 90°. Thus, as can be seen from the phasor diagram at Fig 1b, the two currents are out of phase with each other. Depending on their magnitudes, they cancel each other either completely or partially.

If $X_C < X_L$, then $I_C > I_L$, and the circuit acts capacitively.

If $X_L < X_C$, then $I_L > I_C$, and the circuit acts inductively.

If $X_L = X_C$, then $I_L = I_C$, and hence, the circuit acts as a purely resistive.

Zero current in the circuit means that the impedance of the parallel LC is infinite. This condition at which, for a particular frequency, f_r, the value of $X_C = X_L$, the parallel LC circuit is said to be in parallel resonance.

Summarizing, for a parallel resonant circuit, at resonance,

$X_L = X_C$,

$Z_p = \infty$

$I_L = I_C$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$I = \frac{V}{Z_P} \approx 0$$

In a parallel resonance circuit, with a pure L(no resistance) and a pure C(loss-less), at resonance the impedance will be infinite. In practical circuits, however small, the inductor will have some resistance. Because of this, at resonance, the phasor sum of the branch currents will not be zero but will have a small value I.

This small current I will be in phase with the applied voltage and the impedance of the circuit will be very high although not infinite.

Summarizing, the three main characteristics of parallel resonance circuit at resonance are,

– phase difference between the circuit current and the applied voltage is zero

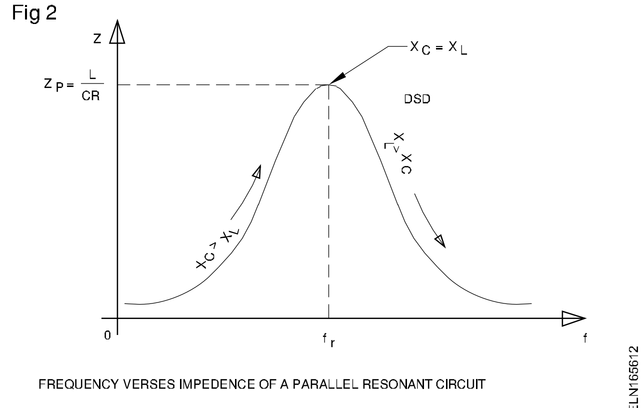
– maximum impedance

– minimum line current.

The variation of impedance of a parallel resonance circuit with frequency is shown in Fig 2.

In Fig 2, when the input signal frequency to the parallel resonance circuit is moved away from resonant frequency f_r, the impedance of the circuit decreases. At resonance the impedance Z_p is given by,

Fig 2



FREQUENCY VERSES IMPEDENCE OF A PARALLEL RESONANT CIRCUIT

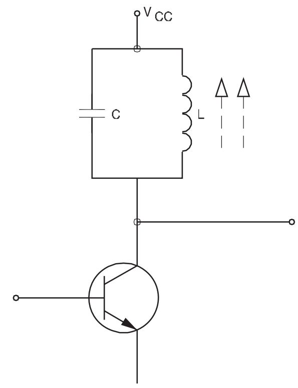
$$Z_P = \frac{L}{CR}$$

At resonance, although the circuit current is minimum, the magnitudes of I_L & I_C will be much greater than the line current. Hence, a parallel resonance circuit is also called current magnification circuit.

Application of parallel resonant circuits

Parallel resonance circuits or tank circuits are commonly used in almost all high frequency circuits. Tank circuits are used as collector load in class-C amplifiers instead of a resistor load as shown in Fig 3.

Fig 3



TANK CIRCUIT

ELN165614

Table below gives a comparison between series resonant and parallel resonant circuit at frequencies above and below their resonant frequency f_r.

Property	Series circuit	Parallel circuit
	At resonant frequency	
Resonant frequency, f_r	$= \frac{1}{2\pi\sqrt{LC}}$	$= \frac{1}{2\pi\sqrt{LC}}$
Reactance	$X_L = X_C$	$X_L = X_C$
Impedance	Minimum (Z_r = R)	Maximum (Z_r = L/CR)
Current	Maximum	Minimum
Quality factor	$\frac{X_L}{R}$	$\frac{X_L}{R}$
Bandwidth	$\frac{X_L}{R}$	$\frac{X_L}{R}$
	Above resonant frequency	
Reactance	$X_L > X_C$	$X_C > X_L$
Impedance	Increases	Decreases
Phase difference	The current lags behind the applied voltage.	The current leads the applied voltage.
Type of reactance	Inductive	Capacitive
	Below resonant frequency	
Reactance	$X_C > X_L$	$X_L > X_C$
Impedance	Increases	Decreases
Phase difference	The current leads the applied voltage.	The current lags behind the applied voltage.
Type of reactance	Capacitive	Inductive

Power, energy and power factor in AC single phase system - Problems

Objectives: At the end of this lesson you shall be able to
- **state the relationship between power and power factor in single phase circuits**
- **state the connection diagram for measuring power factor using a direct reading meter**
- **calculate the problem related to P.F and power in A.C circuits.**

Scan the QR Code to view the video for this exercise

The power in a DC circuit can be calculated by using the formulae.

- $P = E \times I$ watts
- $P = E^2/R$ watts.

The use of the above formulae in AC circuits will give true power only if the circuit contains pure resistance. Note that the effect of reactance is present in AC circuits.

Power in AC circuit: There are three types of power in AC circuits.

- Active power (True power)
- Reactive power
- Apparent power

Active power (True power)**:** The calculation of active power in an AC circuit differs from that in a direct current circuit. The active power to be measured is the product of $V \times I \times \cos\theta$ where $\cos\theta$ is the power factor (cosine of the phase angle between current and voltage). This indicates that with a load which is not purely resistive and where the current and voltage are not in phase, only that part of the current which is in phase with the voltage will produce power. This can be measured with a wattmeter.

Reactive power (P_r): With the reactive power (wattless power)

$$P_r = V \times I \times \sin\theta$$

only that part of the current which is 90° out of phase (90° phase shift) with the voltage is used in this case. Capacitors and inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt/ampere reactive or vars. Unlike true power, reacitve power can do no useful work.

Apparent power: The apparent power, $P_a = V \times I$.

The measurement can be made in the same way as for direct current with a voltmeter and ammeter.

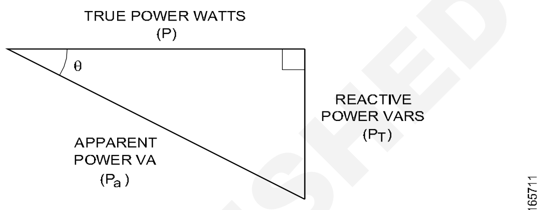
It is simply the product of the total applied voltage and the total circuit current and its unit is volt-ampere (VA).

The power triangle: A power triangle identifies three different types of power in AC circuits.

- True power in watts (P)
- Reactive power in vars (P_r)
- Apparent power VA (P_a)

The relationship among the three types of power can be obtained by referring to the power triangle. (Fig 1)

Fig 1



POWER TRIANGLE

Therefore

$P_a^2 = P^2 + P_r^2$ volt-amperes (VA)

where `P_a' is the apparent power in volt-ampere (VA)

`P' is the true power in watts (W)

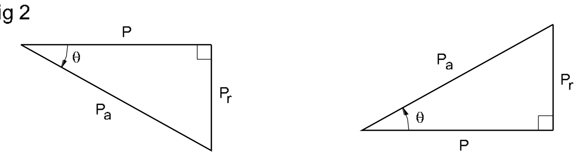
P_q is the reactive power in volt-amperes reactive. (VAR)

Power factor: The ratio of the true power delivered to an AC circuit compared to the apparent power that the source must supply is called the power factor of the load. If we examine any power triangle (Fig 2), you may see the ratio of the true power to the apparent power is the cosine of the angle θ.

$$\text{Power factor} = \frac{P}{P_a} = \cos\theta$$

From the equation, you can observe that the three powers are related and can be represented in a right-angled power triangle, from which the power factor can be obtained as the ratio of true power to apparent power. For inductive loads, the power factor is called lagging to distinguish it from the leading power factor in a capacitive load. (Fig 2)

Fig 2



(a) POWER TRIANGLE FOR A SERIES OR PARALLEL RL CIRCUIT.

(b) POWER TRIBNGLE FOR A SERIES OR PARALLEL RC CIRCUIT.

POWER TRIANGLES SHOWING THAT $\frac{P}{P_a}$=COS θ

A circuit's power factor determines how much current is necessary from the source to deliver a given true power. A circuit with a low power factor requires a higher current than a unity power factor circuit.

Single phase energy

The product of true power and time is known as energy.

(ie) Energy = T.Power x time

= Voltage x current x power factor x time

= VI Cos θ x t (time is in hour)

The unit of energy is watt hour and commercial unit is represented in 'KWH' (or) unit. (Board of trade unit. B.O.T)

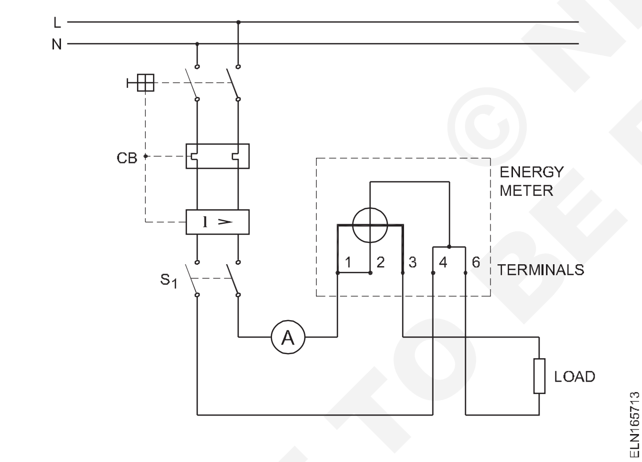
The energy depends upon the following factors:

- Voltage
- Current
- Power factor (load)
- Time

Single phase energy can be measured by energy meter. It contains 4 terminals (Incoming 2 and outgoing 2 common neutral)

The connection is shown in Fig 3.

Fig 3



AC Parallel circuit problem

In practice all industrial and domestic electrical circuits are connected in parallel as we follow the constant voltage system. In a parallel circuit, the voltage across any branch circuit is the same as the supply voltage. However, the arithmetical sum of the branch currents does not necessarily equal the total current. This is true because the branch current values may be out-of-phase due to the fact that the loads connected may be resistive, inductive, (V lead I) or capacitive (I lead V).

Therefore, the total current must be obtained by adding or subtracting vectors of the branch currents either mathematically (admittance method) or graphically (vector method).

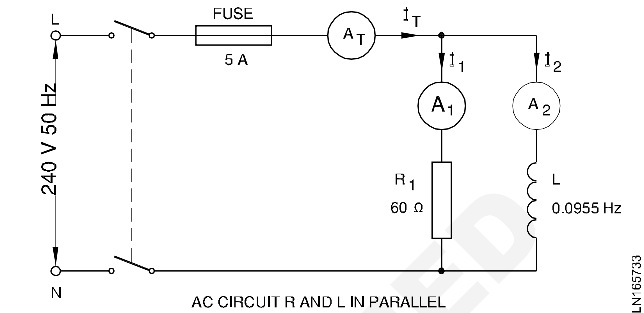
Example 1

Parallel circuit with R and X_L in branches

Now consider a parallel circuit having one branch consisting of a pure resistance and the other branch having pure inductance.

Determine the following for the circuit shown in Fig 4.

Fig 4



AC CIRCUIT R AND L IN PARALLEL

i The branch currents.

ii Draw the vector diagram.

iii The total current.

iv The power factor angle and the power factor.

v The combined impedance.

vi The power in the circuit.

SOLUTION

i The branch current $I_1 = \frac{V}{R_1}$

$$= \frac{240}{60} = 4 \text{ amps}$$

Pure resistive, hence, in phase with the voltage.

To calculate the branch current I_2 first find out the inductive reactance X_L.

$$X_L = 2\pi FL = 2 \times \frac{22}{7} \times 50 \times 0.0955$$

= 30 ohms.

So the branch current $I_L = \frac{V}{X_L} = \frac{240}{30} = 8$ amps.

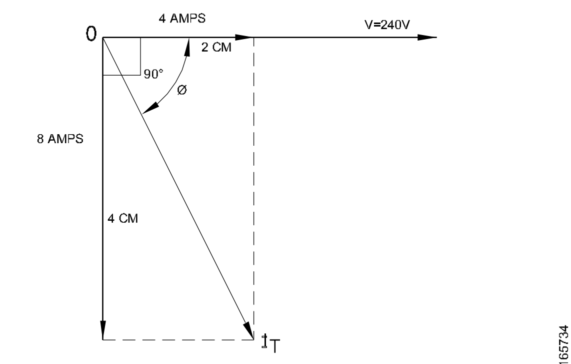
Pure inductive, hence, lags the applied voltage by 90°.

ii Draw the vector diagram by following the rules: Scale 1 cm = 2 amps. (Fig 5)

Complete the parallelogram to find the total current I_T.

Measure the angle ø and the length of $0I_T$.

Fig 5



VECTOR DIAGRAM - R AND L IN PARALLEL

iii Measured angle is 63º 26'

Power factor = Cos 63º 26'

= 0.447 lagging.

iv Length of $0I_T$ = 4.47 cm.

Hence, I_T = 4.47 x 2 = 8.94 amps.

The combined impedance of the circuit = Z.

v Power taken by the circuit

$P = VI \cos ø = I_1^2 R$

= 240 x 8.94 x 0.447 = 4^2 x 60

= 959 watts approx. 960 watts.

Example 2

In Fig 6, Parallel circuit with R, X_L and X_c

Find the following.

i Conductance and susceptance of each branch.

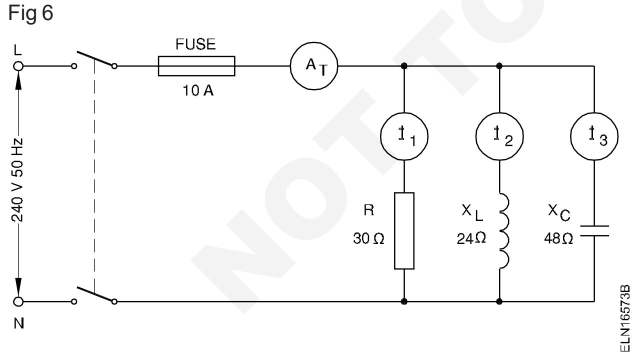
ii Total G, B and Y.

iii Branch currents.

iv PF and PF angle.

v Power taken by the circuit.

Fig 6



i Conductance in branch circuits

$$g_1 = \frac{R_1}{Z_1^2} = \frac{30}{30^2} = \frac{1}{30}$$

= 0.0333 siemens

$$g_2 = \frac{R_2}{Z_2^2} = \frac{0}{24^2} = 0$$

$$g_3 = \frac{R_3}{Z_3^2} = \frac{0}{48^2} = 0$$

Susceptance in branch circucits

$$b_1 = \frac{X_1}{Z_1^2} = \frac{0}{30^2} = 0$$

$$b_2 = \frac{X_2}{Z_2^2} = \frac{24}{24^2} = \frac{1}{24}$$

= 0.04167 siemens

$$b_3 = \frac{-X_3}{Z_1^2} = \frac{-48}{-48^2} = -\frac{1}{48}$$

= - 0.02083 siemens

ii Total conductance G = $g_1 + g_2 + g_3$

= 0.0333 + 0 + 0

= 0.0333 Siemens.

Total susceptance B = $b_1 + b_2 + b_3$

= 0 + 0.04167 + (– 0.02083)

= 0.02084 Siemens.

$$Y = \sqrt{G^2 + B^2}$$

$$= \sqrt{0.333^2 + 0.02084^2}$$

= 0.03928 Siemens.

iii The branch current $I_1 = \frac{V}{Z_1}$

$$= \frac{V}{R} = \frac{240}{30} = 8 \text{ amps in phase with V}$$

The branch current $I_2 = \frac{V}{Z_2}$

$$\frac{V}{X_L} = \frac{240}{24} = 10 \text{ amps lagging 90° with V}$$

The branch current $I_3 = \frac{V}{X_3}$

$= \frac{240}{48}$ = 5 amps lagging 90° with V

Total current

$I_T = \sqrt{I_1^2 + (I_2 - I_3)^2}$

$= \sqrt{8^2 + (10-5)^2} = \sqrt{89}$

= 9.43 amps

Alternatively

I_T = VY = 240 X 0.03928

= 9.43 amps.

iv Power factor $= \frac{G}{Y} = \frac{I_R}{I_T}$

$= \frac{0.0333}{0.03929} = \frac{8}{9.43}$

= 0.848.

v Power factor angle = 32° lagging.

Power taken by the circuit = VIcos ø

= 240 x 9.43 x 0.848

= 1919 watts.

Total impedance = Z = $\frac{1}{Y}$

$\frac{1}{0.03929}$ = 25.5.ohms

Check these answers with the answers obtained by the vector method.

Power factor - improvement of power factor

Objectives: At the end of this lesson you shall be able to
- **define power factor - explain the causes of low power factor**
- **list out disadvantage of low power factor and advantage of higher power factor in a circuit**
- **explain the methods to improve the power factor in an AC circuit**
- **illustrate the importance of power factor improvement in industries**
- **distinguish between leading, lagging and zero PF**
- **state the recommended power factor as per ISI 7752 (Part I) 1975 for electrical equipment.**

Power Factor (P.F.)

The power factor is defined as the ratio of true power to apparent power and it is denoted by Cos θ.

$$\text{i. e. Power Factor} = \frac{\text{True Power } (W_T)}{\text{Apparent Power } (W_a)} = \text{Cos } \theta$$

$$\text{or Cos } \theta = \frac{W_T}{V \times I}$$

Where W_T is the real power (true power) and is measured in watts or some times in kilowatts (kW). Similarly the product VI is known as the apparent power measured in volt amperes or sometimes in kilo-volt amperes written as kVA.

The principal cause of a low power factor is due to the reactive power flowing in the circuit. The reactive power mostly due to inductive load rather than capacitive load.

Variation in power factor and the type of circuits

The following are the different conditions of the power factor in different circuits.

Unity power factor

A circuit with a unity power factor will have equal real and apparent power, so that the current remains in phase with the voltage, and hence, some useful work can be done. (Fig 1a)

Leading power factor

A circuit will have a leading power factor if the current leads voltage by an angle of Ø electrical degrees and the true power will be less than the apparent power. Mostly capacitive circuits and synchronous motors operated at over excitation contribute for leading power factor. (Fig 1b)

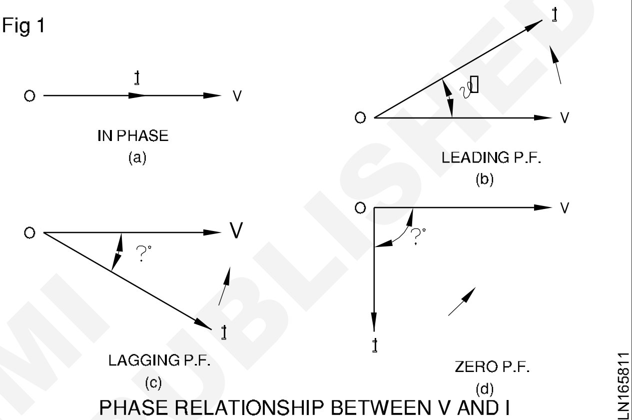
Lagging power factor

In such a circuit the true power is less than the apparent power and current lags behind the voltage by an angle, in electrical degrees. Mostly inductive loads like induction motors and induction furnaces account for lagging power factor. (Fig 1c)

Zero power factor

When there is a phase difference of 90° between the current and voltage, the circuit will have zero power factor and no useful work can be done. Pure inductive or pure capacitive circuits account for zero power factor. (Fig 1d)

Fig 1



PHASE RELATIONSHIP BETWEEN V AND I

> **The power factor can be one or less than one but can never be greater than one.**

Table 1 shows the most common electrical appliances used, the power in watts and the average power factor.

Causes of low power factor

The following are the reasons.

i In industrial and domestic fields, the induction motors are widely used. The induction motors always take lagging current which results in low power factor.

ii The industrial induction furnaces have low power factor.

iii The transformers at substations have lagging power factor because of inductive load and magnetising currents.

iv Inductive load in houses like fluorescent tubes, mixers, fans etc.

The disadvantages of low power factor are as follows.

a For a given true power, a low power factor causes increased current, thereby, overloading of the cables, generators, transmission and distribution lines and transformers.

b Decreased line voltage at the point of application (voltage drop at consumer end) due to voltage drop and power losses in the supply system.

c Penal power rates (increased electricity bills).

The advantages of high power factor are as follows.

As the higher PF for a given load, reduces the current, there will be:

a a possibility of connecting extra load on existing generators and transmit additional power through the same lines

b lesser losses and voltage drop in lines; thereby, transmission efficiency is high and the voltage at the point of application will be normal without much drop

c normal voltage improves the efficiency of operation of plants and machinery

d reduction in electricity bills for the given load during the given time.

Method of improving the power factor

To improve the power factor of a circuit, two methods are used:

i to run a lightly loaded synchronous motor with over-excitation on that line in which the PF is to be improved

ii to connect capacitors in parallel with the load.

Usually the capacitor method is used in Indian factories.

Synchronous condenser method

The synchronous motor is used in certain industries as well as in receiving end substations to drive a mechanical load and also to correct the power factor. An over-excited synchronous motor draws leading current to compensate the lagging current taken by the other loads.

The leading volt-ampere reactive power taken by a synchronous motor, when over- excited will be opposite in nature to the lagging voltage pure reactive due to inductive loads, and, thereby, reduces the volt-ampere reactive component to improve the power factor.

Condenser method

Capacitors when used for PF improvement are connected in parallel to the supply. In three-phase circuits the capacitors are connected in delta across the load lines. Now automatic devices are available which can be connected to the supply lines to detect low power factor and to switch on the required capacity of capacitors in the line to improve the power factor.

Normally these capacitors are provided with discharge resistances to discharge the stored energy. However, no capacitor terminal should be touched to avoid shock.

TABLE 1

Power factor for single phase electrical appliances and equipment (Reference IS 7752 (Part I) - 1975)

Sl.No.	Appliance/Equipment	Power output		Average natural
		Min.(W)	Max.(W)	power factor
1	Neon sign	500	5000	0.5 to 0.55
2	Window type air- conditioners	750	2000*	0.75 to 0.85
				0.68 to 0.82
				0.62 to 0.65
3	Mixer	150	450	0.8
4	Coffee grinder	200	400	0.75
5	Refrigerator	200	800	0.65
6	Freezer	600	1000	0.7

Assignment

A factory is having a load of 100 kW working at 0.6 PF lagging. A synchronous motor is connected in the factory and is made to run over-excited to improve the power factor. The synchronous motor is of 30 kW and is working at 0.8 PF leading. Calculate the following:

i the true power in watt, aspperent power in VAR for the factory load at 0.6p.f lagging.

ii The true power in watt, apparent power in volt- ampere and leading reactive power in VAR for the synchoronous motor at 0.8P.F lagging.

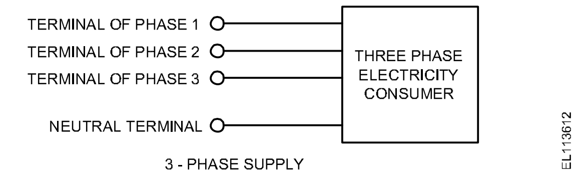
iii The true power in watt, reactive power in VAR and apparent power in Volt - ampere and PF supplied by the feeder lines.

3-Phase AC fundamentals

Objectives: At the end of this lesson you shall be able to
- **state and describe the generation of 3-phase system with single loops**
- **state the advantages of the 3-phase system over a single phase system**
- **state and explain the 3-phase, 3-wire, and 4-wire system**
- **state and explain the relation between phase and line voltage.**

A three-phase power consumer is provided with the terminals of three phases. (Fig 1)

Fig 1



3 - PHASE SUPPLY

One great advantage of a three-phase AC supply is that it can produce a rotating magnetic field when a set of stationary three-phase coils is energized from the supply. This is the basic operating principle for most modern rotating machines and, in particular, the three-phase induction motor.

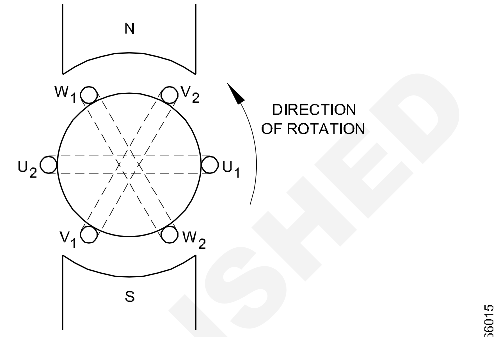
Further, lighting loads can be connected between any one of the three phases and neutral.

Review: Further to the above two advantages the following are the advantages of polyphase system over single phase system.

- 3-phase motors develop uniform torque whereas single phase motors produce pulsating torque only
- Most of the 3-phase motors are self starting whereas single phase motors are not
- Power factor of 3-phase motors are reasonably high when compared to single phase motors
- For a given size the power out put is high in 3-phase motors whereas in single phase motors the power output is low.
- Copper required for 3-phase transmission for a given power and distance is low when compared to single phase system.
- 3-phase motor like squirrel cage induction motor is robust in construction and more are less maintenance free.

Three-phase generation: To generate three-phase voltages, a similar method to that used for generating single-phase voltages is employed but with the difference that, this time, three wire loops U_1, U_2, V_1, V_2 and W_1, W_2 rotate at a constant angular speed about the same axis in the uniform magnetic field. U_1, U_2, V_1, V_2 and W_1, W_2, are displaced 120° in position with respect to each other, permanently. (Fig 2)

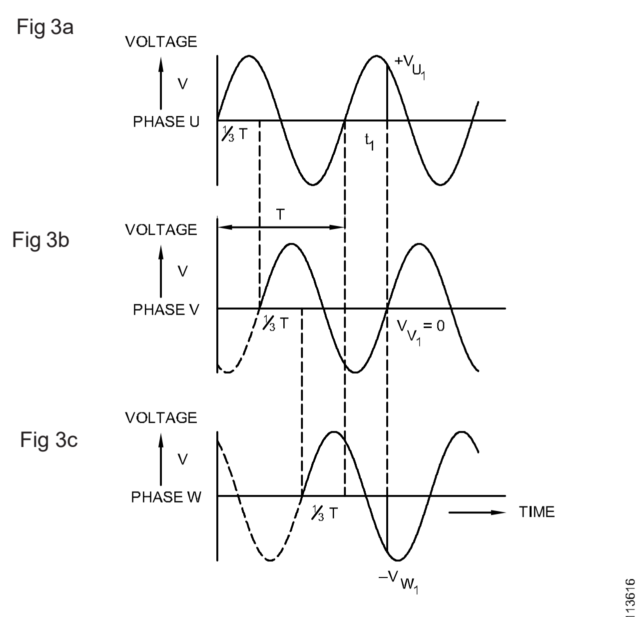
Fig 2



SIMPLIFIED THREE – PHASE ALTERNATOR

For each wire loop, the same result is obtained as for the alternating voltage generator. This means that an alternating voltage is induced in each wire loop. However, since the wire loops are displaced by 120° from each other, and a complete revolution (360°), takes one period, the three induced alternating voltages are delayed in time by a third of a period with respect to each other.

Because of the spatial displacement of the three wire loops by 120°, three alternating phase voltages result, which are displaced by one third of a period, T, with respect to each other. (Fig 3)



PHASE DISPLACEMENT OF 3 - PHASE

To distinguish between the three phases, it is a common practice in (heavy current) electrical engineering to designate them by the capital letters U,V and W or by a colour code red, yellow and blue. At a time 0, U is passing through zero volts with positively increasing voltage. (Fig 3a) V follows with its zero crossing 1/3 of the period later (Fig 3b), and the same applies to W with respect to V. (Fig 3c)

In three-phase networks, the following statements can be made about the three-phase voltages.

- The three-phase voltages have the same frequency.
- The three-phase voltages have the same peak value.
- The three-phase voltages are displaced by one third of a period in time with respect to each other.
- At every instant in time, the instantaneous sum of the three voltages

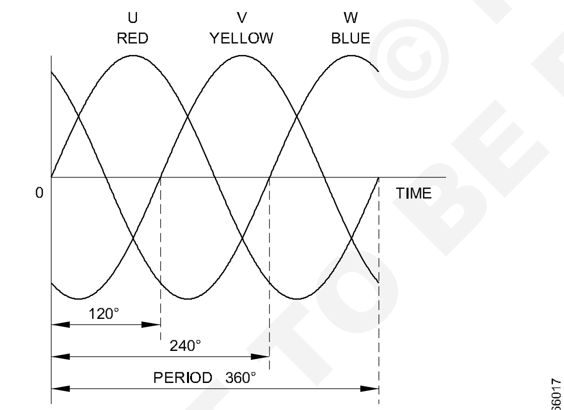
$$V_U + V_V + V_W = 0.$$

The fact that the sum of the instantaneous voltages is zero. At time t_1, U has the instantaneous value V_U. At the same time, $V_V = 0$, and the instantaneous value for W is $-V_W$. Because V_U and V_W have the same value but are opposite in sign, it follows that

$$V_{U1} + V_{V1} + V_{W1} = 0.$$

The three voltages of the same amplitude and frequency are shown together in Fig 4.

Fig 4



COMBINED WAVE - FORMS OF THREE PHASE SUPPLY

Three-phase network: A three-phase network consists of three lines or phases. In Fig 5, these are indicated by the capital letters U, V and W.

The return lead of the individual phases consists of a common neutral conductor N, which is described later in more detail. Voltmeters are connected between each of the lines U, V and W, and the neutral line N. They indicate the RMS (effective) values of the voltages between each of the three phases and neutral.

These voltages are designated as phase voltages V_{UN}, V_{VN} and V_{WN}.

The individual, phase voltages all have the same magnitude. They are simply displaced from each other by one third of a period in time. (Fig 6)

The individual instantaneous, peak and RMS values are the same as for a single-phase alternating voltage.

Fig 5

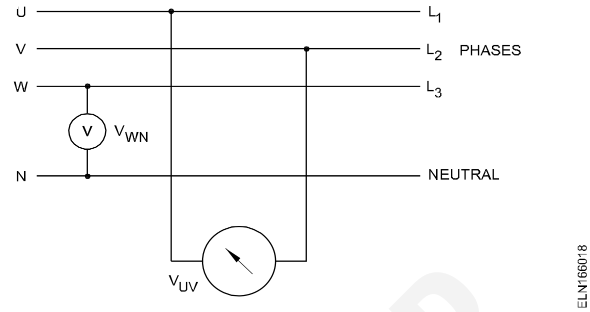
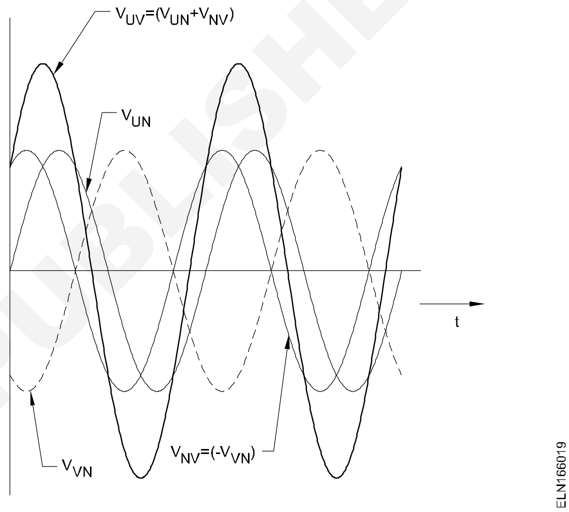


Fig 6



Line and phase voltage: If a voltmeter is connected directly between line U and line V (Fig 7), the RMS value of the voltage V_{UV} is measured, and this is different from any of the three phase voltages.

Its magnitude is directly proportional to the phase voltage. The relationship is shown in Fig 6, where the time-variation wave- forms of V_{UV} and the phase voltages V_{UN} and V_{VN} are drawn.

V_{UV} has a sinusoidal wave-form and the same frequency as the phase voltages. However, V_{uv} has a higher peak value since it is computed from the phase voltages V_{UN} and V_{VN}. The varying positive and negative instantaneous values of V_{UN} and V_{VN} at a particular time produce the instantaneous value of V_{UV}. V_{UV} is the phasor sum of the two phase voltages V_{UN} and V_{NV}.

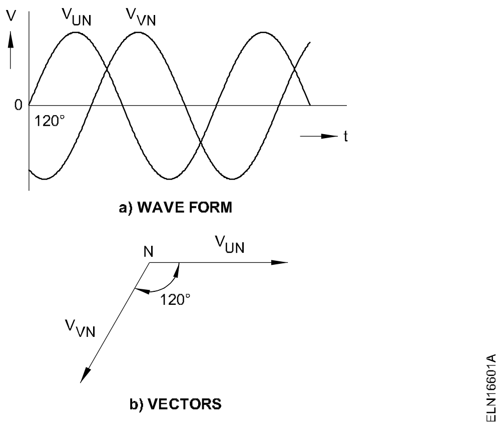
This combination of phase-displaced alternating voltages is called phasor addition.

The voltage across phase-to-phase is called the line voltage.

Relationship between line and phase voltage: The possibility of combining pairs of phases in a generator is a basic property of three-phase electricity. The understanding of this relationship will be enhanced by studying the following illustrative example which explains the concept of phase difference in a very simple way.

The phase voltages V_{UN} and V_{VN} are separated in phase by one third of a period, or 120° between the two phasors. (Fig 7)

Fig 7



The phasor sum of the two phase voltages V_{UN} and V_{NV} can be obtained geometrically, and the resultant phasor so obtained is the line voltage V_{UV} through the relation $V_{UV} = V_{UN} + V_{NV}$.

Note that to obtain the line voltage V_{UV} the measurement is made from the U terminal through the common point N to the V terminal, for a star connection.

This fact is illustrated in Fig 8. Starting with the phasors V_{UN} and V_{VN} (Fig 7), the phasor $-V_{VN} = V_{NV}$ is produced from the point N. The diagonal of the parallelogram with sides V_{UN} and V_{NV} is the phasor representing the resulting line voltage V_{UV}.

It can be concluded, therefore, that in a generator the line voltage V_L is related to the phase voltage V_P by a multiplying factor. This factor can be shown to be $\sqrt{3}$, so that $V_L = \sqrt{3} \times V_P$

In a three-phase generating system, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is $\sqrt{3}$.

It was shown that the line voltage is greater than the phase voltage. Here is a numerical example.

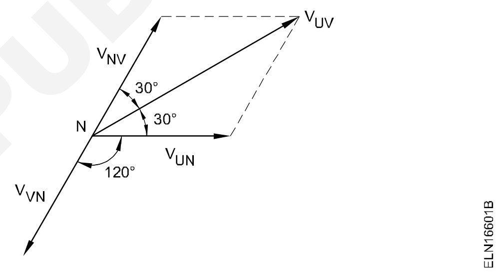
The RMS phase voltage in a three-phase system is 240V. Since the ratio of line voltage to phase voltage is $\sqrt{3}$ the RMS line voltage is

$$V_L = \sqrt{3} \times V_P = \sqrt{3} \times 240$$

$$= 415.68V$$

or rounded down, $V_L = 415V$.

Fig 8



Systems of connection in 3-phase AC

Objectives: At the end of this lesson you shall be able to
- **explain the star and delta systems of connection**
- **state phase relationship between line and phase voltages and current in a star connection delta connection**
- **state the relationship between phase and the voltage and current in star and delta connection**

Methods of 3-phase connection: If a three-phase load is connected to a three-phase network, there are two basic possible configurations. One is `star connection' (symbol Y) and the other is `delta connection' (symbol Δ).

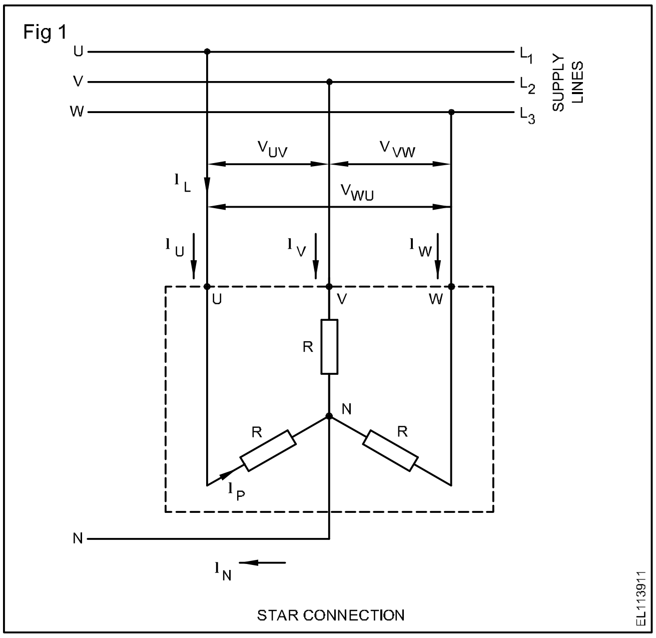
Star connection: In Fig 1 the three-phase load is shown as three equal magnitude resistances. From each phase, at any given time, there is a path to the terminal points U, V, W of the equipment, and then through the individual elements of the load resistance. All the elements are connected to one point N: the `star point'. This star point is connected to the neutral conductor N. The phase currents i_U, i_V, and i_W flow through the individual elements, and the same current flows through the supply lines, i.e. in a star connected system, the supply line current (I_L) = phase current (I_P).

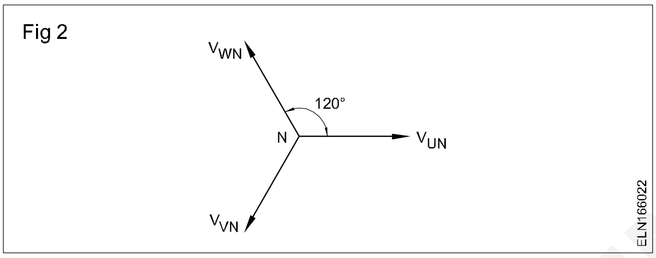
The potential difference for each phase, i.e. from a line to the star point, is called the phase voltage and designated as V_P. The potential difference across any two lines is called the line voltage V_L. Therefore, the voltage across each impedance of a star connection is the phase voltage V_P. The line voltage V_L appears across the load terminals U-V, V-W and W-U and designated as V_{UV}, V_{VW} and V_{WU} in the Fig 1. The line voltage in a star-connected system will be equal to the phasor sum of the positive value of one phase voltage and the negative value of the other phase voltage that exist across the two lines (Fig 2).

Thus

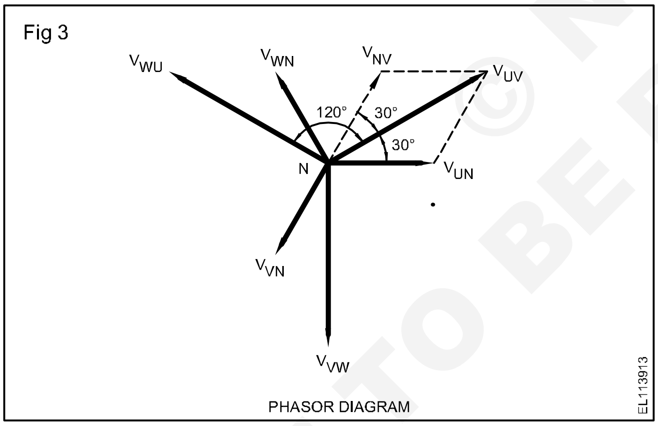
$$V_L = V_{UV} = (\text{phasor } V_{UN}) - (\text{phasor } V_{VN})$$

$$= \text{phasor } V_{UN} + V_{VN}.$$





In the phasor diagram (Fig 3)



$V_L = V_{UV} = V_{UN} \text{Cos } 30^o + V_{NV} \text{Cos } 30^o$

But Cos $30^o = \frac{\sqrt{3}}{2}$.

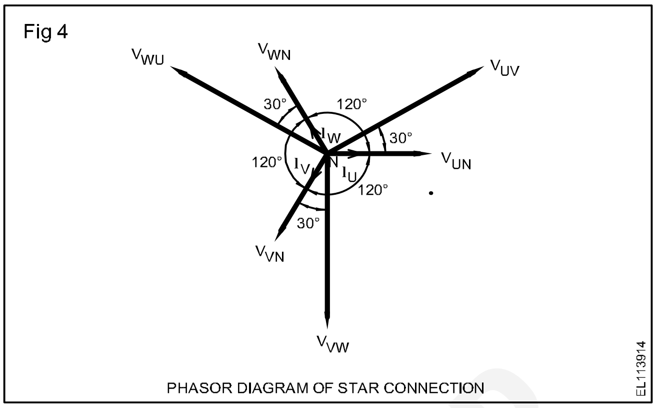
Thus as $V_{UN} = V_{VN} = V_P$

$V_L = \sqrt{3}\, V_P$.

This same relationship is applied to V_{UV}, $V_{VW}$and V_{WU}.

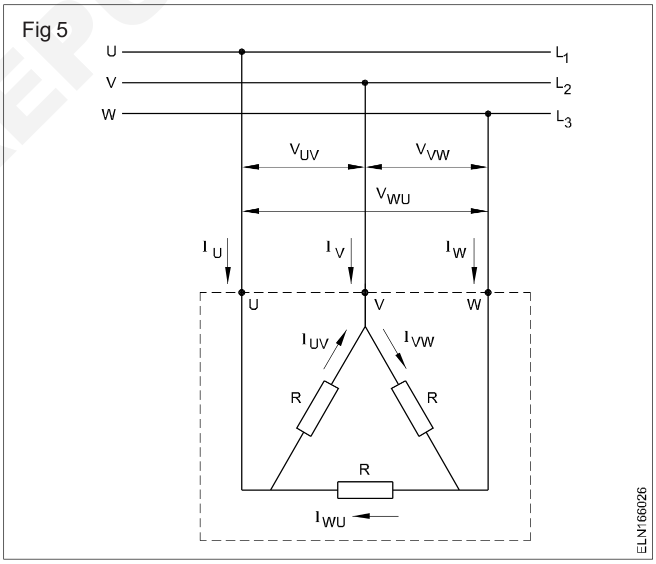
> **In a three-phase star connection, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is $\sqrt{3}$ (Fig 3).**

The voltage and current relationship in a star connection is shown in the phasor diagrams. (Fig 4) The phase voltages are displaced 120^o in phase with respect to each other.



Derived from these are the corresponding line voltages. The line voltages are displaced 120^0 in phase with respect to each other. Since the loads in our example are provided by purely resistive impedances, the phase currents I_P (I_U, I_V, I_W) are in phase with the phase voltages V_P (V_{UN}, V_{VN} and V_{WN}). In a star connection, each phase current is determined by the ratio of the phase voltage to the load resistance R.

Delta connection: There is a second possible arrangement for connecting a three-phase load in a three-phase network. This is the delta or mesh connection (Δ).(Fig 5)



The load impedances form the sides of a triangle. The terminals U, V and W are connected to the supply lines of the L_1, L_2 and L_3.

> **In contrast to a star connection, in a delta connection the line voltage appears across each of the load phases.**

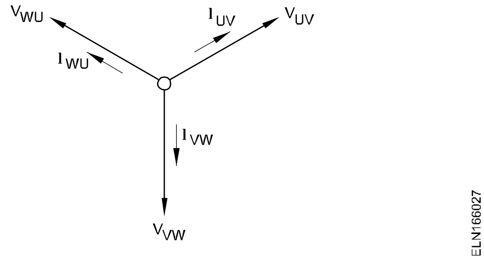
The voltages, with symbols V_{UV}, $V_{VW}$and V_{WU} are, therefore, the line voltages.

The phase currents through the elements in a delta arrangement are composed of I_{UV}, I_{VW} and I_{WU}. The currents from the supply lines are I_U, I_V and I_W, and one line current divides at the point of connection to produce two phase currents.

The voltage and current relationships of the delta connection can be explained with the aid of an illustration. The line voltages V_{UV}, V_{VW} and V_{WU} are directly across the load resistors, and in this case, the phase voltage is the same as the line voltage. The phasors V_{UV}, V_{VW} and V_{WU} are the line voltages. This arrangement has already been seen in relation to the delta connection.

Because of the purely resistive load, the corresponding phase currents are in phase with the line voltages. (Fig 6)

Fig 6



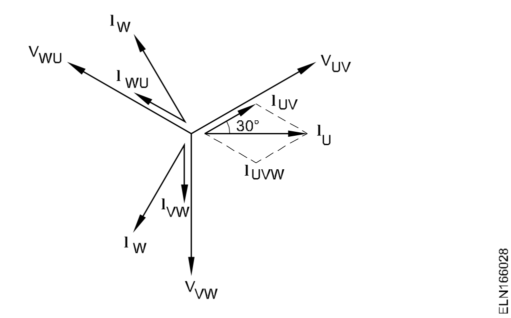
Their magnitudes are determined by the ratio of the line voltage to the resistance R.

On the other hand, the line currents I_U, I_V and I_W are now compounded from the phase currents. A line current is always given by the phasor sum of the appropriate phase currents. This is shown in Fig 7. The line current I_U is the phasor sum of the phase currents I_{UV} and I_{UW}. (See also Fig 7)

Hence, $I_U = I_{UV} \cos 30^\circ + I_{UW} \cos 30^\circ$

But $\cos 30^\circ = \dfrac{\sqrt{3}}{2}$.

Fig 7



Thus $I_L = \sqrt{3}\, I_{ph}$

Thus, for a balanced delta connection, the ratio of the line current to the phase current is $\sqrt{3}$.

Thus, line current = $\sqrt{3}$ x phase current.

Application of star and delta connection with balanced loads

An important application is the `star-delta change over switch' or star-delta starter.

Application of star connection: Alternators and secondoary of distribution transformers, have their three, single-phase coils interconnected in star.

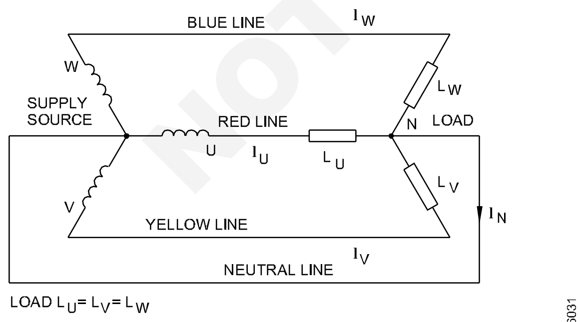
Assignment : Three identical coils, each of resistance 10 ohms and inductance 20mH is delta connected across a 400-V, 50Hz, three-phase supply. Calculate the line current.

Neutral in 3-phase system

Objectives: At the end of this lesson you shall be able to
- **explain the current in neutral of a 3-phase star connection**
- **state the earthing the neutral.**

Neutral: In a three-phase star connection, the star point is known as neutral point, and the conductor connected to the neutral point is referred as neutral conductor (Fig 1).

Fig 1



THREE-PHASE SUPPLY AND LOAD

Current in the neutral conductor: In a star-connected, four-wire system, the neutral conductor N must carry the sum of the currents I_U, I_V and I_W. One may, therefore, get the impression that the conductor must have sufficient area to carry a particularly high current. However, this is not the case, because this conductor is required to carry only the phasor sum of the three currents.

I_N = phasor sum of I_U, I_V and I_W

Fig 2 shows this phasor addition for a situation where the loads are balanced and the currents are equal. The result is that the current in the neutral line I_N is zero.

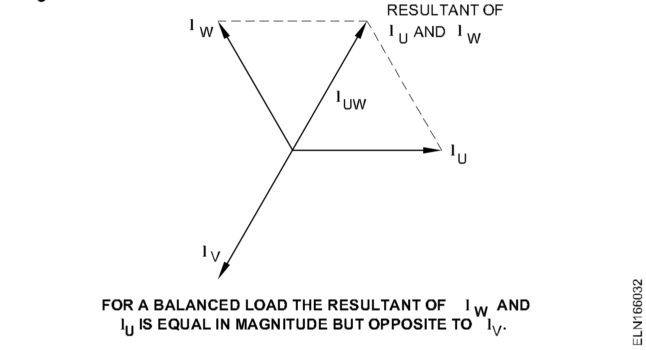
Therefore, for a balanced load the neutral conductor carries no current.

Earthing of neutral conductor: Supply of electrical energy to commercial and domestic consumers is an important application of three-phase electricity. For `low voltage distribution' - in the simplest case, i.e. supply of light and power to buildings - there are two requirements.

1 It is desirable to use conductors operating at the highest possible voltage but with low current in order to save on expensive conductor material.

2 For safety reasons, the voltage between the conductor and earth must not exceed 250V.

Fig 2



A voltage distribution system according to criterion 2, only possible with a low line voltage below 250 V. However, this is contrary to criterion 1. On the other hand, with a star connection, a line voltage of 415V is available. In this case, there is only 240V between the supply line and the neutral conductor. Criterion 1 is satisfied and, to comply with 2, the neutral conductor is earthed.

Indian Electricity Rules: I.E.Rules insist that the neutral conductor must be earthed by two separate and distinct connections to earth. Rule No.61(1)(a), Rule No.67(1)(a) and Rule No.32 insist on the identification of neutral at the point of commencement of supply at the consumer's premises, and also prevent the use of cut outs or links in the neutral conductor. BIS stipulate the method of earthing the neutral. (Code No.17.4 of IS 3043-1966)

Cross-sectional area of neutral conductor: The neutral conductor in a 3-phase, 4-wire system should have a smaller cross-section. (half of the cross-section of the supply lines).

Power in star and delta connections

Objectives: At the end of this lesson you shall be able to
- **explain active, appparent and reactive power in AC 3 phase ϕ**
- **explain behaviour of unbalanced and balance load**
- **state the earthing the neutral.**
- **determine the power in 3-phase star and delta connected balanced load.**

Fig 1 shows the load of three resistances in a star connection. So the power must be three times as great as the single phase power.

$$P = 3V_pI_p.$$

If the quantities V_P and I_P in the individual phases are replaced by the corresponding line quantities V_L and I_L respectively, we obtain:

$$P = 3\frac{V_L}{\sqrt{3}}I_L.$$

(Because $V_P = V_L \div \sqrt{3}$ and $I_p = I_L$)

Since $3 = \sqrt{3} \times \sqrt{3}$, this equation can be simplified to the form

$$P = \sqrt{3}\, V_L I_L$$

> **Note that power factor in resistance circuit is unity. Hence power factor is not taken into account.**

The power in this purely resistive load(ϕ=0°, cosϕ= 1) is entirely active power which is converted into heat. The unit of active power is the watt (W).

As the last formula shows, three-phase power in a star-connected load circuit can be calculated from the line quantities, and there is no need to measure the phase quantities.

$P = \sqrt{3} \times V \times I$ (Formula holds good for pure resistive load)

It is always possible, in practice, to measure the line quantities but the accessibility of the star point cannot always be guaranteed, and so it is not always possible to measure the phase voltages.

Three-phase power with a delta-connected load: Fig 2 shows the load of three resistances connected in delta. Three times the phase power will be dissipated.

Fig 1

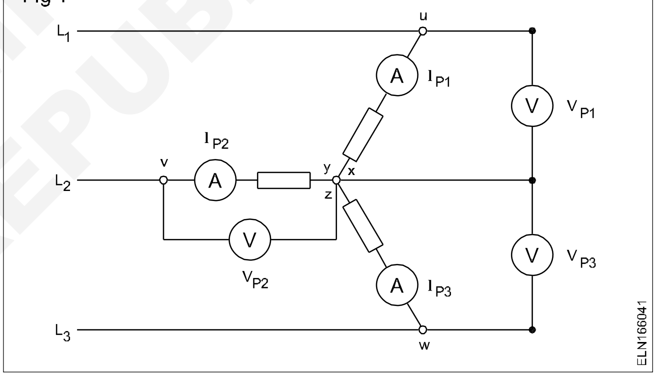
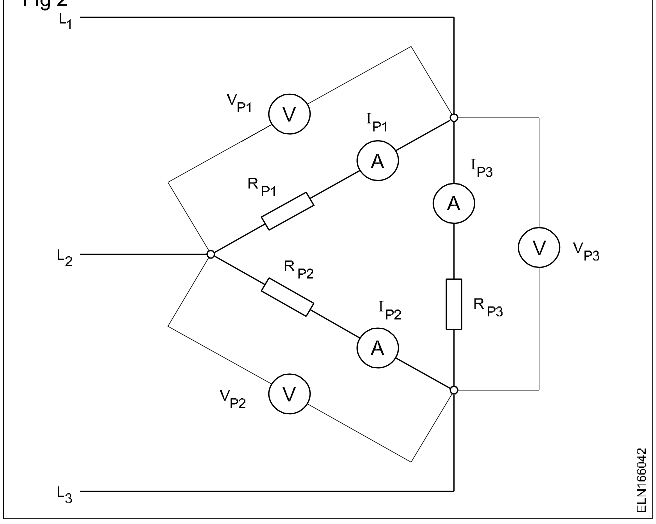


Fig 2



$$P = 3P_P = 3V_PI_P$$

If the quantities V_P and I_P are replaced by the corresponding line quantities V_L and I_L, we obtain:

Since, $V_L = V_P$

$$I_L = \sqrt{3} I_P \text{ and } I_P = \frac{I_L}{\sqrt{3}}$$

but since 3 = $\sqrt{3}$ x $\sqrt{3}$, this equation can be simplified to the form:

$P = \sqrt{3}\ V_L I_L$.(Formula holds good for pure resistive load)

If we compare the two power formulae for the star and delta connections, we see that the same formula applies to both. In other words, the way in which the load is connected has no effect on the formula to be used, assuming that the load is balanced.

Active,reactive and apparent power: As you already know from AC circuit theory, load circuits which contain both resistance and inductance, or both resistance and capacitance, take both active and reactive power because of the phase difference existing between the voltage and current in them. If these two components of power are added geometrically, we obtain the apparent power. Precisely the same happens in each phase of the three-phase systems. Here we have to consider the phase difference f between the voltage and current in each phase.

Applying the factor $\sqrt{3}$, the components of power in a three-phase system follow from the formulae derived for single-phase, AC circuits, namely:

Apparent power	$S=VI$	$S = \sqrt{3} V_L I_L$	VA
Active power	$P=VI \cos\phi$	$P = \sqrt{3}\ V_L I_L \cos Ø$	W
Reactive power	$Q=VI \sin\phi$	$Q = \sqrt{3} V_L I_L \sin Ø$	var

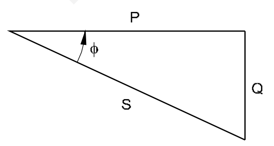
Finally, the well known relationships found in single-phase AC circuits apply also to three-phase circuits.

$$\cos\phi = \frac{\text{activepower}}{\text{apparentpower}} = \frac{P}{S}$$

$$\sin\phi = \frac{\text{reactivepower}}{\text{apparentpower}} = \frac{Q}{S}$$

This can also be seen from Fig 3.

Fig 3

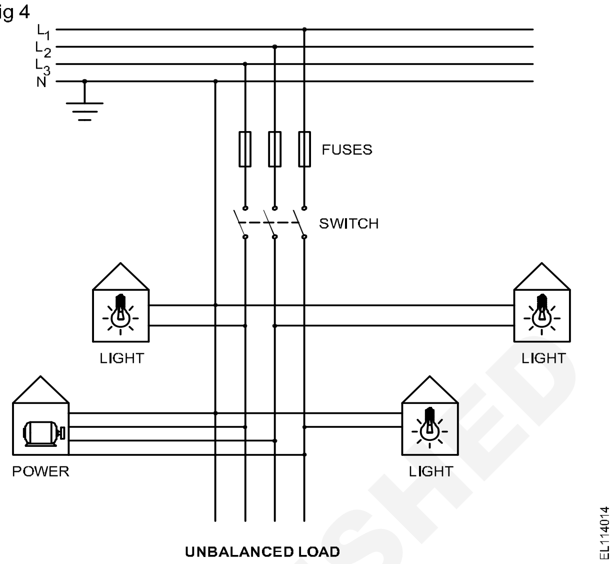


Cos ϕ is called the power factor, while sin ϕ is sometimes called the reactive power factor.

Unbalanced load: The most convenient distribution system for electrical energy supply is the 415/240 V four-wire, three-phase AC system.

This offers the possibility of supplying three-phase, as well as single-phase current, to users simultaneously. Supply to buildings can be arranged as in the given example. (Fig 4)

Fig 4



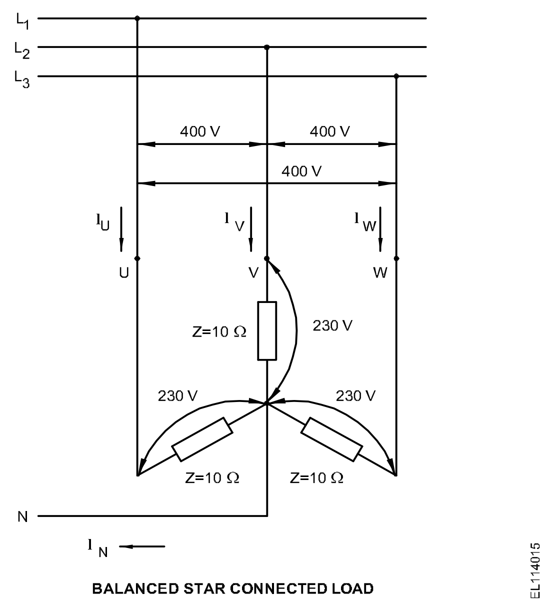
The individual houses utilize one of the phase voltages. L_1, L_2 and L_3 to N are distributed in sequence (light current). However, large loads (eg.three-phase AC motors) may be fed with the line voltage (heavy current).

However, certain equipment which needs single or two phase supply can be connected to the individual phases so that the phases will be differently loaded, and this means that there will be unbalanced loading of the phases of the four-wire, three-phase network.

Balanced load in a star connection: In a star connection, each phase current is determined by the ratio of phase voltage and load impedance `Z'.
This fact will now be confirmed by a numerical example.

A star-connected load consisting of impedances `Z' each of 10 ohms, is connected to a three-phase network with line voltage V_L = 415V. (Fig 5)

Fig 5



Because of the arrangements of a star connection, the phase voltage is 240V (415/ $\sqrt{3}$).

The three load currents taken froms supply have the same magnitude since the star-connected load is balanced, and they are given by

$I_U = I_V = I_W = V_P \div Z.$

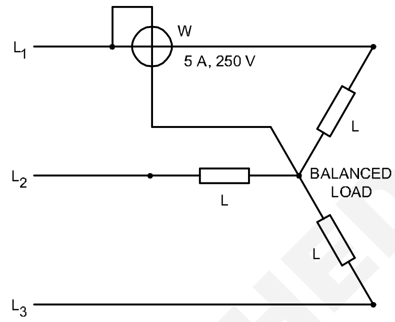
The measurement of power: The number of wattmeters used to obtain power in a three-phase system depends on whether the load is balanced or not, and whether the neutral point, if there is one, is accessible.

- Measurement of power in a a star-connected balanced load with neutral point is possible by a single wattmeter.
- Measurement of power in a star or delta-connected, balanced or unbalanced load (with or without neutral) is possible with two wattmeter method.

Single wattmeter method: Fig 6 shows the circuit diagram to measure the three-phase power of a star-connected, balanced load with the neutral point accessible the current coil of the wattmeter being connected to one line, and the voltage coil between that line and neutral point. The wattmeter reading gives the power per phase. So the total is three times the wattmeter reading.

Power/phase = $3V_P I_P \cos\theta = 3P = 3W$.

Fig 6



POWER MEASUREMENT - SINGLE WATTMETER

The two-wattmeter method of measuring power

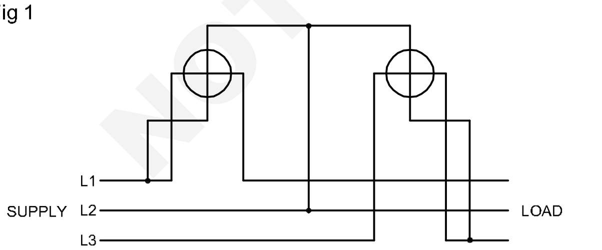
Objectives: At the end of this lesson you shall be able to:
- **measure 3-phase power using two single phase wattmeter**
- **calculate power factor from meter reading**
- **explain the `two-wattmeter' method of measuring power in a three-phase, three-wire system.**

Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, if the load is unbalanced and the assumption that $I_U + I_V + I_W = 0$ will not be valid.

The two wattmeters are connected to the supply system as shown in Fig 1. The current coils of the two wattmeters are connected in two of the lines, and the voltage coils are connected from the same two lines to the third line. The total power is then obtained by adding the two readings:

$P_T = P_1 + P_2.$

Fig 1



TWO WATTMETER - POWER MEASUREMENT

Consider the total instantaneous power in the system $P_T = P_1 + P_2 + P_3$ where P_1, P_2 and P_3 are the instantaneous values of the power in each of the three phases.

$P_T = V_{UN}\, i_U + V_{VN}\, i_V + V_{WN}\, I_W$

Since there is no fourth wire, $i_U + i_V + i_W = 0$; $i_V = -(i_U + i_W)$.

$$\begin{aligned} P_T &= V_{UN} i_U - V_{VN}(i_U + i_W) + V_{WN}\, i_W \\ &= i_U(V_{UN} - V_{VN}) + i_W(V_{WN} - V_{UN}) \\ &= i_U V_{UV} + i_W V_{WV} \end{aligned}$$

Now $i_U V_{UV}$ is the instantaneous power in the first wattmeter, and $i_W V_{WV}$ is the instantaneous power in the second wattmeter. Therefore, the total mean power is the sum of the mean powers read by the two wattmeters.

It is possible that with the wattmeters connected correctly, one of them will attempt to read a negative value because of the large phase angle between the voltage and current for that instrument. The current coil or voltage coil must then be reversed and the reading given a negative sign when combined with the other wattmeter readings to obtain the total power.

At unity power factor, the readings of two wattmeter will be equal. Total power = 2 x one wattmeter reading.

When the power factor = 0.5, one of the wattmeter's reading is zero and the other reads total power.

When the power factor is less than 0.5, one of the wattmeters will give negative indication. In order to read the wattmeter, reverse the pressure coil or current coil connection. The wattmeter will then give a positive reading but this must be taken as negative for calculating the total power.

When the power factor is zero, the readings of the two wattmeters are equal but of opposite signs.

Power factor calculation in the two-watmeter method of measuring power

As you have learnt in the previous lesson, the total power $P_T = P_1 + P_2$ in the two-wattmeter method of measuring power in a 3-phase, 3-wire system.

From the readings obtained from the two wattmeters, the tan ϕ can be calculated from the given formula

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$$

from which ϕ and power factor of the load may be found.

***Example 1**:* Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. Find the power factor of the circuit.

Solution

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

P_1 = 4.5 KW

P_2 = 3 KW

$P_1 + P_2$ = 4.5 + 3 = 7.5 KW

$P_1 - P_2$ = 4.5 – 3 = 1.5 KW

$$\tan\phi = \frac{\sqrt{3} \times 1.5}{7.5} = \frac{\sqrt{3}}{5} = 0.3464$$

$\phi = \tan^{-1} 0.3464 = 19^0 6'$

Power factor Cos $19^0 6'$ = 0.95

Phase-sequence indicator (Meter)

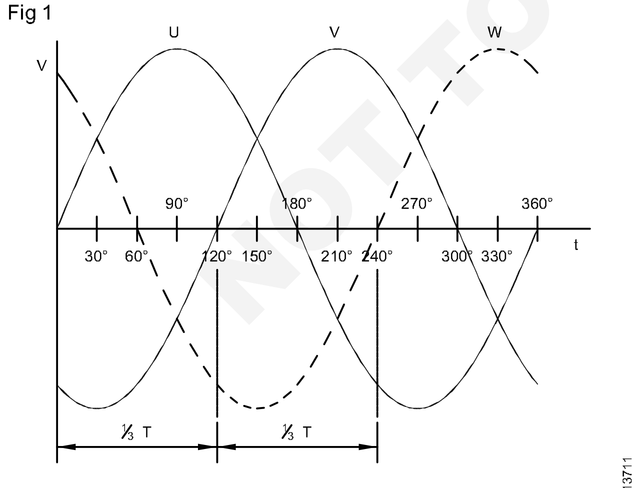
Objectives: At the end of this lesson you shall be able to
- **describe the method of finding the phase sequence of a 3-phase supply using a phase-sequence indicator**
- **explain the methods of finding phase sequence using lamps.**

Phase sequence

A three-phase alternator contains three sets of coils positioned 120° apart and its output is a three-phase voltage as shown in Fig 1. A three-phase voltage consists of three voltage waves, 120 electrical degrees apart.

At a time 0, phase U is passing through zero volts with positively increasing voltage. (Fig 1) V follows with its zero crossing 1/3 of the period later and the same applies to W with respect to V. The order in which the three-phases attain their maximum or minimum values is called the phase sequence. In the illustration given here the phase sequence is U,V,W.

Fig 1



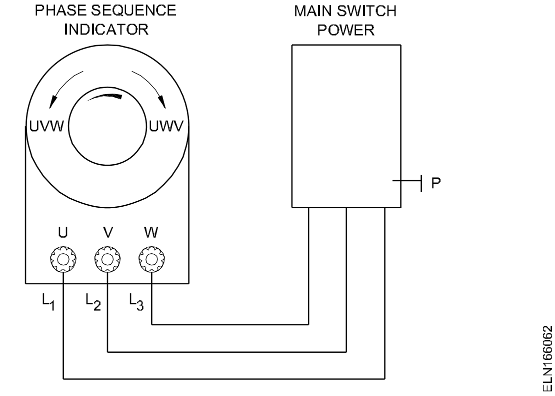
3 - PHASE OUTPUT VOLTAGE

Importance of correct phase sequence: Correct phase sequence is important in the construction and connection of various three-phase systems. For example, correct phase sequence is important when the outputs of three-phase alternators must be paralleled into a common voltage system. The phase `U' of one alternator must be connected to phase `U' of another alternator. The phase `V' to phase `V' and phase `W' to phase `W' must be similarly connected to each other.

In the case of an induction motor, reversal of the sequence results in the reversal of the direction of motor rotation which will drive the machinery the wrong way.

Phase-sequence indicator(meter)**:** A phase-sequence indicator (meter) provides a means of ensuring the correct phase-sequence of a three-phase system. The phase-sequence indicator consists of 3 terminals `UVW' to which three-phases of the supply are connected. When the supply is fed to the indicator a disc in the indicator moves either in the clockwise direction or in the anticlockwise direction. The direction of the disc movement is marked with an arrowhead on the indicator. Below the arrowhead the correct sequence is marked. (Fig 2)

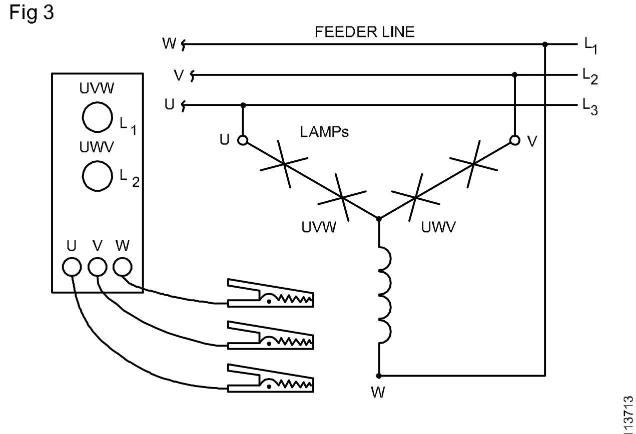
Fig 2



The phase sequence of the three-phase system may be reversed by interchanging the connections of any two of the three phases.

Phase-sequence indicator using choke and lamps: The phase-sequence indicator consists of four lamps and an inductor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One lamp is labelled U-V-W, and the other is labelled U-W-V. When the three leads are connected to a three-phase line, the brighter lamp indicates the phase sequence. (Fig 3)

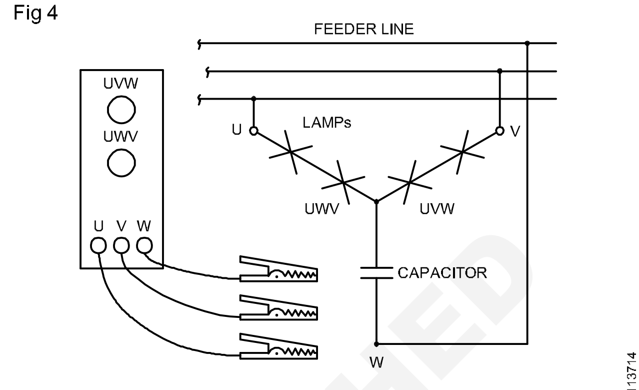
Fig 3



PHASE SEQUENCE INDICATOR USING CHOKE & LAMPS

Phase-sequence indicator using capacitor & lamps: The phase-sequence indicator consists of four lamps and a capacitor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One pair of lamps are labelled U-V-W,and the other pair are labelled U-W-V. When the three leads are connected to a 3-phase line, the brighter lamp indicates the phase sequence. (Fig 4)

Fig 4



PHASE SEQUENCE INDICATOR USING CAPACITOR & LAMPS

Primary cells and secondary cells

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **state the chemical effect of electric current**
- **state the Laws of electrolysis**
- **state the basic principles of electroplating**
- **state the principle and construction of primary cells**
- **state the principle and construction of secondary cells (lead acid, nickel iron and nickel cadmium)**
- **compare the primary cells and secondary cells.**

Chemical effects of electric current

'There are some liquids in which a passage of electric current is accompanied by chemical changes.' This effect is known as chemical effect of electric current.

The applications of chemical effect of electric current may be observed in daily life; e.g., nickel or copper plating on metallic articles, production of E.M.F by a cell, etc. If two leads taken from the positive and negative terminals of a battery are immersed in a salted water, then the production of bubbles can be seen at the lead ends; it is all due to chemical effect of electric current.

Electrolysis

The process of chemical changes due to the passage of an electric current through a liquid or a solution is called electrolysis.

Electrolyte

'The liquid or solution which undergoes a chemical change in it on account of the passage of an electric current, is called an electrolyte'; e.g., salted water, acidic or a basic solution etc.

Electrodes (Anode and cathode)

'Two conductor plates are immersed in the liquid to form a passage of current through it, they are known as electrodes'. The electrode through which the current enters the liquid, is called a positive electrode or anode, while the other through which it leaves the liquid (electrolyte) is called a negative electrode or cathode.

Ions

During electrolysis, the molecules of the electrolyte split into their constituents whcih are called ions. When a p.d. is applied across the two electrodes, the positively charged ions (cat ions) move towards the cathode and the negatively charged ions (an ions) move towards the anode. On reaching at any electrode, an ion give up its charge and ceases to be an ion . The process of converting atoms into ions is called **Ionization.**

Electrochemical equivalent: The mass of a substance liberated or deposited during electrolysis by one coulomb of electricity is termed as electrochemical equivalent (ECE) of that substance.

The ECE of silver is 1.1182 milligram/coulomb.

Coulomb: The coulomb (C) is the unit of electric charge (Q) or the quantity of electricity.

The coulomb is the product of current in ampere and time in seconds.

Faraday's Law of Electrolysis

1. First law: The mass of the substance liberated or deposited at any electrode during electrolysis is propotional to the quantity of eletricity passed through the electrolyte. The mass of the substance liberated at any electrode will be more, if more current is passed or a current for more time is passed through the electrolyte.If the mass liberated is m then

$$m \propto I$$

$$m \propto t \qquad \text{-----(i)}$$

$$m \propto I \cdot t \qquad \text{-----(ii)}$$

$$m = Z \cdot I \cdot t$$

Where, I = current, amperes

t = time, seconds

m= mass of the substance liberated, grams

Z = constant

Here, the constant Z is known as electro-chemical equivalent (ECE).

2 Second Law - 'When the same quantity of electricity is passed through different electrolytes , then the quantites of elements liberated at the different electrodes are proportional to their electro-chemical equivalents.'

$$\text{Mass} \propto \text{E.C.E}$$

$$M \propto Z$$

Where Z = electro-chemical equivalent

According to Faraday's laws of electrolysis

$$m = Z \cdot I \cdot t$$

Where, m = mass of substance liberated in grams

z = Electro chemical equivalent of the substance in gram

I= Current in amperes

t= Time in seconds

Note. Mass deposited m = Volume x Density

$$\text{Equivalent weight} = \frac{\text{Atomic weight}}{\text{Valency}}$$

$$\text{E.C.E.of nickel} = \frac{\text{Equivalent wt.of nickel}}{\text{Equivalent wt.of silver}} \text{x E.C.E.of silver}$$

Table for Elecro-Chemical Equivalents of Elements

Name of Element	Atomic Weight	Valency	Electro-Chemical Equivalent mg/c	Chemical equivalent g/c
Hydrogen	1.008	1	0.01045	1.008
Aluminium	27.1	3	0.0936	9.03
Copper	63.57	2	0.3293	31.78
Silver	107.88	1	1.118	107.88
Zinc	65.38	2	0.3387	32.69
Nickel	58.68	2	0.304	29.34
Chromium	52.0	3	0.18	17.33
Iron	55.85	2	0.2894	27.925
Lead	207.21	2	1.0738	103.6
Mercury	200.6	1	2.0791	200.6
Gold	197.0	1	2.0438	197

Note. (mg/c = milli-gram per coulomb)

Application of electrolysis

The principal applications of electrolysis are as follows:

1. Electroplating
2. Electro-refining of metals
3. Electrolytic capacitor
4. Electrotyping
5. Extraction of metals.

Electroplating

The process of depositing a metal on the surface of another metal by electrolysis is known as electroplating. Electroplating is widely used in giving an attractive appearance and finish to all types of products. In this process inferior metals are coated with costly metals (such as silver, nickel, gold, chromium, etc.) to give an attractive shiny appearance and rust-proof surface.

Conditions for electroplating

The following conditions must be fulfilled before electroplating an article.

i The article to be electroplated must have a chemically cleaned surface, i.e. it must not have any sort of dirt, rust and greasy surface.

ii The article to be plated should form a cathode.

iii The anode must be of the metal to be deposited for maintaining the concentration of the solution constantly during electrolysis.

iv The metal to be coated has to be in the solution of an electrolyte.

The electrolyte is contained in a wooden reinforced cement concrete tank which is known as a "vat". The anode as well as the article to be plated are hung through the conducting wires so as to dip in the solution. The value of the current is adjusted according to the metal deposited on the surface area of the article. The time required for electroplating can be calculated if we know the mass of the metal deposited and ECE with the formula

M = ZIt

Therefore, Time $t = \frac{M}{IZ}$

we know M = ZIt ------ (1)

$I = \frac{M}{Zt}$ and $Z = \frac{M}{It}$ mg / Coulomb

We know Volume = Area x Thickness ------(2)

$$\text{Area} = \frac{\text{Volume}}{\text{Thickness}} \text{ and}$$

$$\text{Thickness} = \frac{\text{Volume}}{\text{Area}}$$

Mass = Volume x Density ----- (3)

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} \text{ cc}$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \text{ gm /cc}$$

Example1: If 111.83 mg of silver is deposited on the cathode in 3 min 20 s, by a DC current of 0.5A, calculate the ECE of silver.

Solution:

t = 3 min 20 s = 200 s

M = 111.83 mg

From Faraday's law,

M = ZIt

$$Z = \frac{M}{It} = \frac{111.83}{0.5 \times 200}$$

= 1.1183 mg/ C

Current required for plating

Low pressure direct current (DC) supply is always used for electroplating purposes. The pressure used varies from 1 to 16 V depending upon the rate of plating and the nature of the electrolyte.

Cathodic protection in Eletroplating

Cathodic protection (CP) is a technique used to control the corrossion of a metal surface by making it as the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded sacrifical metal to act as the anode.

The sacrificial metal then corrodes instead of the protected metal. For the structures such as long pipe lines where passive galvanic cathodic protection is not adequate an external DC electrical power source is used to provide sufficicent current.

The CP system protects a wide range of metallic structures steel water, fuel pipe line, storage tanks water heaters, steel wire pipes, oil platform, oil well casing, wind farms etc. Another common application is in galvanised steel in which a sacrificial coating of zinc on steel parts protects them from rust. CP protection can in some cases prevents the stress corrossion cracking.

Type of cells

Cell: A cell is an electrochemical device consisting of two electrodes made of different materials and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage.

Cells are classified as

- dry cells
- wet cells.

A dry cell is one that has a paste or gel electrolyte. With newer designs and manufacturing techniques, it is possible to completely (hermetically) seal a cell. With complete seals and chemical control of gas build-up, it is possible to use liquid electrolytes in dry cells. Today the term `dry cell' refers to a cell that can be operated in any position without electrolyte leakage.

Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charge or discharge to escape. The most common wet cell is the lead-acid cell.

Cells are further classified as primary and secondary cells.

Primary cells: Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharge is not reversed. The chemicals used in the reactions are all converted when the cell is fully discharged. It must then be replaced by a new cell.

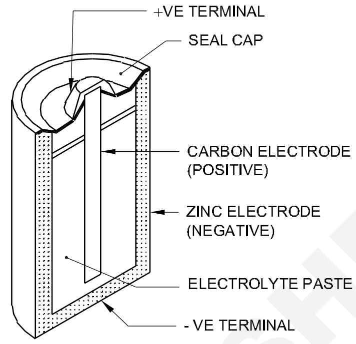
Types of primary cells:

- Voltaic cell
- Carbon-zinc cell (Leclanche cell and Dry cell)
- Alkaline cell
- Mercury cell
- Silver oxide cell
- Lithium cell

Dry cell (Carbon-Zinc cell): The danger of spilling the liquid electrolyte from a Leclanche type of cell led to the invention of another class of cells called dry cells.

The most common and least expensive type of a dry cell is the carbon-zinc type (Fig 1). This cell consists of a zinc container which acts as the negative electrode. In the centre is a carbon rod which is the positive electrode. The electrolyte takes the form of a moist paste made up of a solution containing ammonium chloride.

Fig 1



CARBON-ZINC DRY CELL

ELN216516

As with all primary cells, one of the electrodes becomes decomposed as part of the chemical reaction. In this cell the negative zinc container electrode is the one that is used up. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the neighbouring parts.

Carbon-zinc cells are produced in a range of common standard sizes. These include 1.5 V AA,C and D cells .(AA Pen type cell, `C' medium size and 'D' large/economy size).

Uses: Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemakers, torches, hearing aids, transistor radios etc.

Internal resistance: The output voltage from a cell varies as the load on the cell changes. Load on a cell refers to the amount of current drawn from the cell. As the load increases, the voltage output drops. The change in output voltage is caused by the internal resistance of the cell. Since materials from which the cell is made are not perfect conductors, they have resistance. Current flowing through the external circuit also flows through the internal resistance of the cell.

Defects of a simple cell: With a simple voltaic cell, the strength of current gradually diminishes after some time. This defect is mainly due to two causes.

- Local action
- Polarisation

Local action: In a simple voltaic cell, bubbles of hydrogen are seen to evolve from the zinc plate even on open circuit. This effect is termed local action. This is due to the presence of impurities like carbon, iron, lead, etc. in the commercial zinc. This forms small local cells on the zinc plate and reduces the strength of current of the cell.

The local action is prevented by amalgamating the zinc plate with mercury. To do so, the zinc plate is immersed in dilute sulphuric acid for a short time, and afterwards, mercury is rubbed over its surface.

Polarisation: As current flows, bubbles of H_2 evolve at the copper plate on which they gradually form a thin layer. Due to this the current strength falls and finally stops altogether. This effect is called the polarization of the cell.

Polarisation can be prevented by using some chemicals which will oxidize the hydrogen to water before it can accumulate on the plate. The chemicals used to remove polarisation are called de-polarisers.

Secondary cell: A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell.

The secondary cell is also called a storage cell since after it is charged it stores the energy until it is used up or discharged.

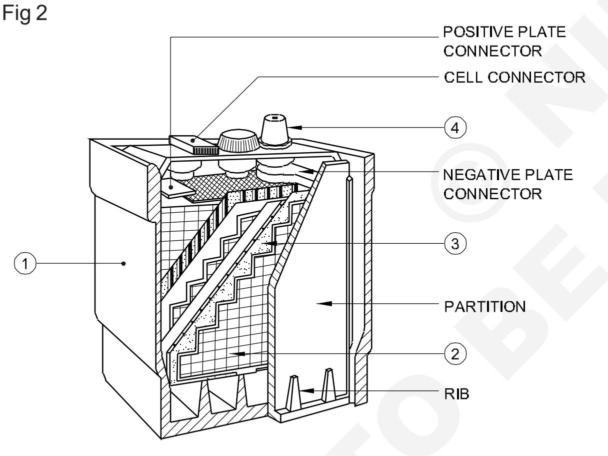
Types of secondary cells

– Lead acid cell

– Alkaline cell or nickel-iron cell

Parts of Lead acid cell (Fig 2)

Fig 2



PARTS OF LEAD ACID CELL

1 Container

2 Plates

3 Separators

4 Post terminals

Container: The container is made of hard rubber, glass or celluloid to accommodate the active plates, separators and the electrolyte. The plates rest on ribs provided at the bottom of the container and the space between ribs is known as sediment chamber.

Plates: Positive plates are of two types.

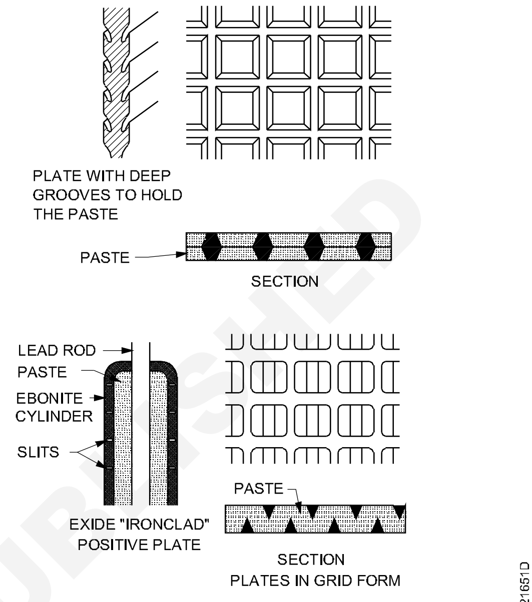
– Plante plate or formed plates

– Faure plate

Plante plates: These are prepared by the process of repeated charging and discharging. They are made of pure lead at the beginning which changes to lead peroxide after charge.

Faure plate: Pasted or Faure plates are made of rectangular lead grid into which the active material i.e. lead peroxide (Pb O_2) is filled in the form of a paste (Fig 3).

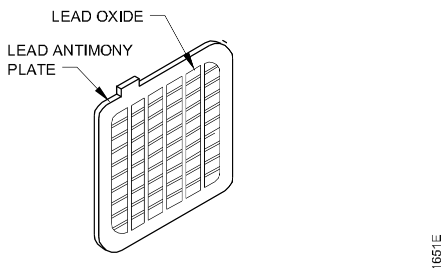
Fig 3



CONSTRUCTION OF PASTED-TYPE ACCUMULATOR PLATES

Negative plates are made of rectangular lead grid, and the active material is spongy lead (Pb) which is in the form of a paste (Fig 4).

Fig 4



SINGLE LEAD PLATE

Separators: These are made of thin sheets of chemically treated porous wood or rubber. They are used to avoid short in between the positive and negative plates (Fig 5).

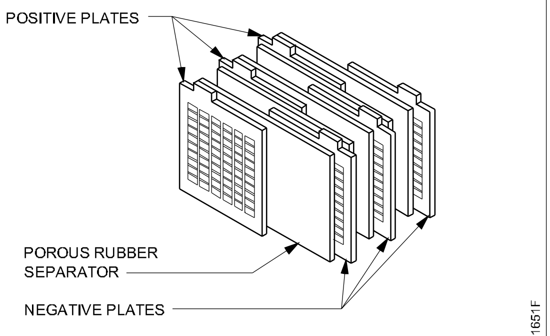
Post terminal: A small pole extended upward from each group of welded plates from the plate connecter (Fig 6) forms the post terminal.

Electrolyte: The electrolyte used in a lead acid cell is dilute sulphuric acid (H_2SO_4). The specific gravity of the electrolyte is 1.24 to 1.28. It varies according to the manufacturer's specification.

Working principle

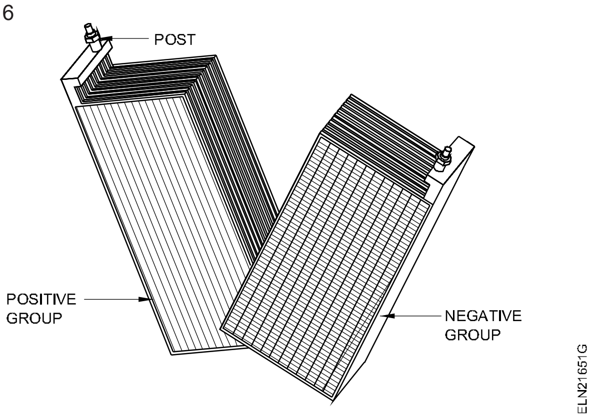
The secondary cell has no significant electrochemical energy at the start. The energy must first be charged into secondary cell. Then the cell retains the stored energy until

Fig 5



ARRANGEMENT OF PLATES AND SEPARATORS

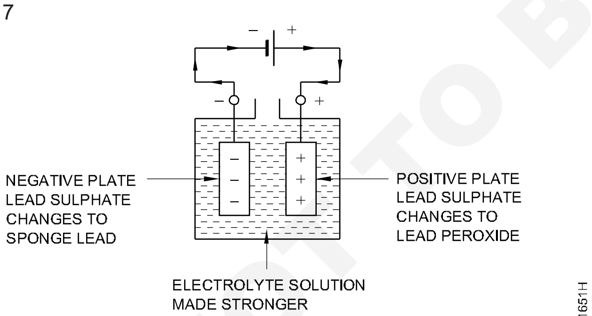
Fig 6



it is used up. That is,both cell electrodes are basically lead sulphate(Pb SO_4).When the cell is charged, due to chemical reaction taking place in it, the lead sulphate eletctrode change to soft or sponge lead,(Pb - negative plate) and the other electrode changes to lead peroxided(Pb O_2 - positive plate).

At the same time the electrolyte solution is strengthened and becomes strong sulphuric acid (H_2SO_4) (Fig 7).

Fig 7



DURING CHARGING PROCESS

Voltage of a fully charged cell is 2.1 to 2.6V and the voltage falls to 1.8V after discharge.

Capacity: The unit of capacity of a storage cell is ampere-hour (AH). It is the product of the rated current of a cell/battery in amperes and the time in hours at which it can discharge that rated current,

Capacity = Current x Time - AH

Temperature and specific gravity: The temperature of the electrolyte must be kept at 27°C and the specific gravity at 1.250 ± 0.010.

Excess temperature will cause more sulphation and buckling of the positive plate.

Defects

- Hard sulphation
- Buckling
- Partial short

Hard sulphation: Over discharging or the cell being left in a discharged condition for a long time cause sulphation on both electrodes and offers high internal resistance. The sulphation (hard) can be removed by recharging the cell for a longer period at a low rate called a trickle charge.

Buckling: The bending of electrodes due to overcharging and discharging, improper electrolyte and temperature is known as buckling.

Partial short: The sediments falling from the plates (electrodes) short- circuiting the positive and negative electrodes cause overheating of the particular cell during both charging and discharging periods. Such a cell may be replaced with a new one.

Efficiency: It is considered in two ways.

- Ampere-hour (AH) efficiency
- Watt-hour (WH) efficiency

$$\text{AH efficiency} = \frac{\text{Output in AH discharge}}{\text{Input in AH charge}}$$

The watt-hour efficiency is always less than the ampere-hour efficiency because the potential difference during discharge is less than that during charge.

Watt - hour efficiency

$$= \frac{\text{AH efficiency} \times \text{Average volts on discharge}}{\text{Average volts on charge}}$$

The chemical action which takes place in the cell during charge and discharge cycle is given below for your reference.

During discharge

positive plate

Lead peroxide	+	Hydrogen	+	Sulphuric Acid	→	Lead sulphate	+	water
PbO_2	+	H_2	+	H_2SO_4	→	$PbSO_4$	+	$2H_2O$

Negative plate

Pure lead	+	Sulphate	=	Lead sulphate
Pb	+	SO_4	=	$PbSO_4$

During charge

positive plate

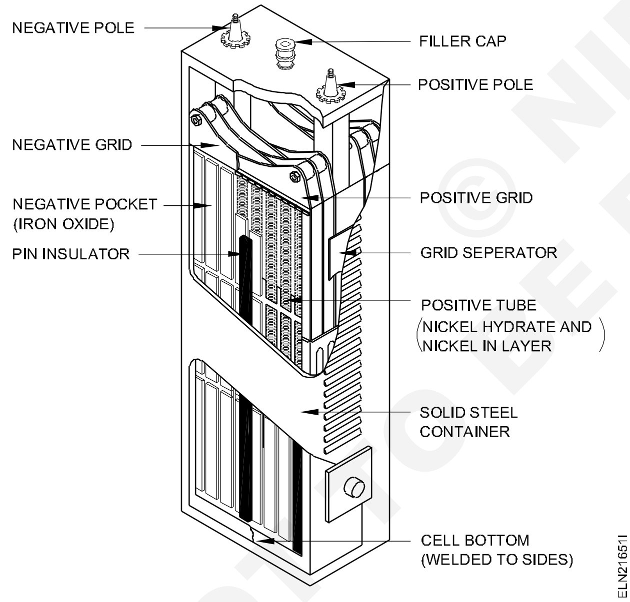
Lead sulphate	+	Sulphate	+	Water	→	Lead peroxide	+	Sulphuric acid
$PbSO_4$	+	SO_4	+	$2H_2O$	→	PbO_2	+	$2H_2SO_4$

Negative plate

Lead sulphate	+	Hydrogen	→	Lead	+	Sulphuric acid
$PbSO_4$	+	H_2	→	Pb	+	H_2SO_4

The nickel iron cell (Fig 8)

Fig 8



Parts

- Positive plate
- Negative plate
- Electrolyte
- Container
- Separators

The positive plate is made of Nickel hydroxide($Ni(OH)_4$) tubes and perforated steel ribbon wound spirally and held together by steel ribs, and the whole lot is nickel-plated.

The negative plate is made of a nickel steel strip with fine perforation.The electrolyte is 21% solution of potassium hydroxide (KOH) along with some quantity of lithium hydrate(LiOH).

The container is made of nickel-plated steel. The separators are made of hard rubber strips and held in the nickel-plated container.

Chemical changes: On discharge, potassium hydroxide (KOH) splits up into K and (OH)ions. i.e. into potassium and hydroxide ions. OH ions travel towards the negative and oxidise the iron. K ions go to the anode and reduce Ni $(OH)_1$ to Ni $(OH)_2$. During charging, the opposite reactions take place. The chemical changes during charging and discharging can be represented by a reversible equation.

It is seen from the equation that the electrolyte acts merely as a source for transfer of OH ions from one plate to another. It does not take part in any chemical change. As a result the density does not change to the same extent as in an ordinary lead acid cell. Thus, the density of the electrolyte remains almost the same during the action.

Charactereristics: The emf of the cell when fully charged is 1.4V, and it reaches to 1.2 on discharge. If the voltage falls below 1.15, the cell is fullly discharged.

- The mechanical strength of plates is good since they are made of steel.
- The cell can withstand heavy charge and discharge currents, and does not deteriorate even if left discharged.
- It is superior to a lead acid cell in mechanical strength, durability and robustness.

Moreover, as compared to lead-acid cells, the alkaline cells operate much better at low temperatures, do not emit obnoxious fumes, have very small self-discharge and their plates do not buckle or smell.

Chemical action

$Ni(OH)_4$	+	KOH	+	Fe	$\rightleftharpoons$	$Ni(OH)_2$	+	KOH	+	$Fe(OH)_2$
Hydrated Ferrous		Potassium		Ferrous		Nickel				

Comparison : Lead-acid cell and Edison cell

Sl.No.	Particulars	Lead-acid cell	Nickel iron cell
1	Positive plate	PbO, lead peroxide	Nickel hydroxide $Ni(OH)_4$ or Nickel oxide (NiO_2)
2	Negative plate	Sponge lead	Iron
3	Electrolyte	Diluted H_2SO_4	KOH
4	Average emf	2.1 V/cell	1.2 V/cell
5	Internal resistance	Comparatively low	Comparatively higher resistance
6	Efficiency: Amp-hour Watt-hour	 90 - 95% 72 - 80%	 Nearly 80% About 60%
7	Cost	Comparatively less than alkaline cell	Almost twice that of Pb-acid cell (Easy maintenance)
8	Life	Gives nearly 1250 charges and discharges	Five years atleast
9	Strength	Needs much care and maintenance.Sulphation occurs often due to incomplete charge or discharge.	Robust, mechanically strong, can withstand vibration, light, unlimited rates of charge and discharge. Can be left discharged, free from corrosive liquids and fumes.

Advantages and disadvantages of nickel iron cell

A Advantages

i It can withstand heavy charge and discharge current and does not deteriorate.

ii It is robust in construction and thus it can be used even roughly.

iii It is light in weight and thus it is portable.

iv It can be left discharged for a long time.

v It can work on higher temperatures also.

vi It is used on higher temperatures also.

vii It is used in electric operated vehicles, switch-gear operations etc.

B Disadvantages

i Its EMF does not remain constant.

ii Its efficiency is lower than lead-acid cell.

iii It has a high internal resistance.

iv Its EMF is low in comparison to lead acid cell.

v If temperature is increased, its EMF will slightly reduce.

Grouping of cells

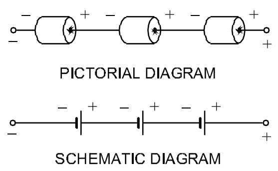
Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **state the purpose of cells connected in series and parallel**
- **explain series connections, parallel connection and series-parallel connection of cells.**

Grouping of cells: Often an electric circuit requires a voltage or current that a single cell is not capable of supplying alone. In this case it is necessary to connect groups of cells in various series and parallel arrangements.

Series connections: Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell (Fig 1).

Fig 1

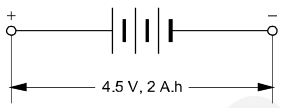


SERIES CONNECTION

Identical cells are connected in series to obtain a higher voltage than is available from a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages of all the cells. However, the ampere hour (AH) rating remains equal to that of a single cell.

Example: Suppose three `D' flashlight cells are connected in series (Fig 2). Each cell has a rating of 1.5 V and 2 AH The voltage and ampere hour rating of this battery would be:

Fig 2



CIRCUIT SCHEMATIC

V Battery = V per cell x No.of cells

= (1.5V) (3)

= 4.5 V

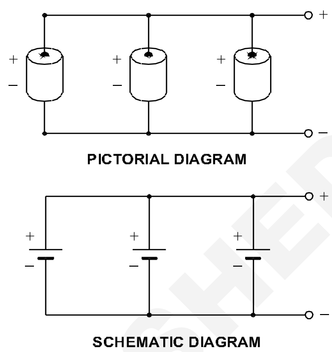
AH Battery rating = AH rating of 1 cell

= 2 AH

Parallel connection: Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together (Fig 3).

Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere hour rating is equal to the sum of the ampere hour ratings of all the cells. However, the output voltage remains the same as the voltage of a single cell.

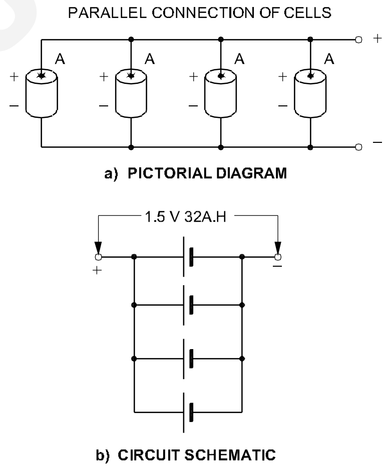
Fig 3



PARALLEL CONNECTION

Assignment : Suppose four cells are connected in parallel (Fig 4). Each cell has a rating of 1.5 V and 8 AH. The voltage and ampere-hour rating of this battery would be:

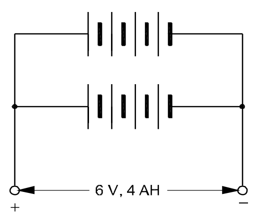
Fig 4



Series-parallel connection: Sometimes the requirements of a piece of equipment exceed both voltage and ampere hour rating of a single cell. In this case a series-parallel grouping of cells must be used (Fig 5).

The number of cells that must be connected in series to have voltage rating is calculated first and then the number of parallel rows of series connected cells is calculated for required ampere-hour rating.

Fig 5



SERIES-PARALLEL CONNECTION

Battery charging method - Battery charger

Objectives: At the end of this lesson you shall be able to
- **state the necessity of charging a battery**
- **describe the preparation of electolyte**
- **describe the use of a hydrometer and high rate discharge tester**
- **state the precautions to be followed while charging and discharging a battery**
- **describe the different types of charging methods of secondary cells**
- **explain the purpose, construction and working principle of battery charger.**

Scan the QR Code to view the video for this exercise

Necessity of charging: During discharge, due to chemical reaction, the active electrodes become smaller and the internal resistance becomes high causing a low output. To reverse the action, send a current (DC) through the battery or cell in the opposite direction to that of the discharge. This process is called charging. The charging can be done through a battery charger.

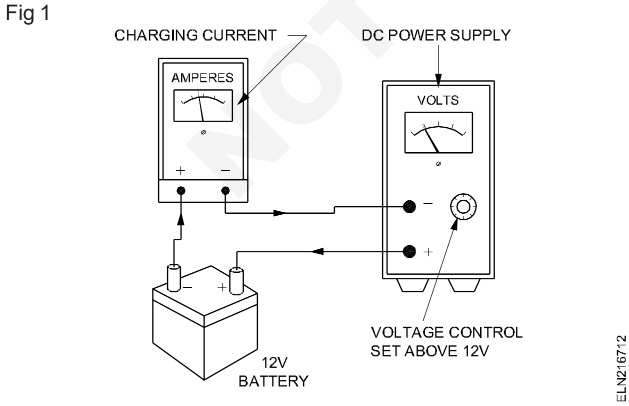
Battery chargers: When the chemical reaction in a rechargeable battery has ended, the battery is said to be discharged and can no longer produce the rated flow of electric current. This battery can be recharged, however, by passing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery.

When charging a battery, the negative lead of the charger must connect to the negative lead of the battery and the positive lead of the charger to the positive lead of the battery

A simple variable-voltage DC power supply works well as a battery charger.

Charging current: When charging any battery, it is important to set the charging current to a value recommended by the manufacturer. This current is set by adjustment of the output voltage on the charger and read by an ammeter connected in series with the charger and battery (Fig 1). When the battery and charger are at the same voltage, no current flows. The charger voltage is set to a value higher than that of the battery to produce a current flow.

Fig 1



Before charging the battery or cell the following points are to be observed to ascertain the condition of the battery.

1 Specific gravity of the electrolyte

2 Voltage of each cell of the battery

3 Ampere hour capacity of each cell.

Electrolyte

The electrolyte used in a cell is dilute sulphuric acid having a specific gravity between 1.21 and 1.3.

Specific gravity

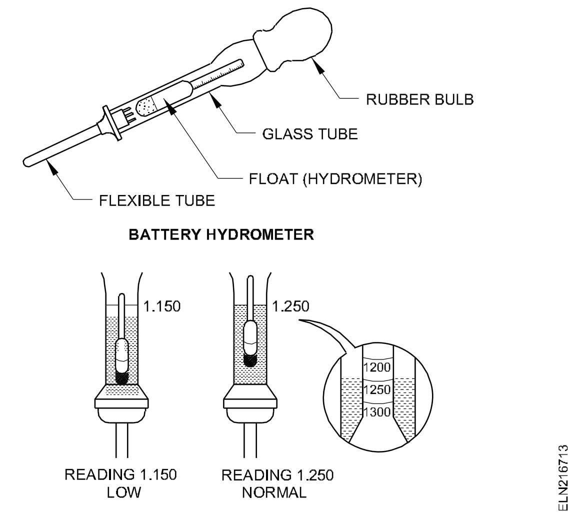
The ratio of the mass of a given volume of liquid to the mass of the same volume of the water at 4°C, is known as specific gravity of the liquid.

$$\text{Specific gravity} = \frac{\text{(mass of given volume of liquid)}}{\text{(Mass of the same volume of water at 4°C)}}$$

Instrument for testing the condition of cells:

Hydrometer : The specific gravity of an electrolyte is measured with a hydrometer (Fig 2).

Fig 2

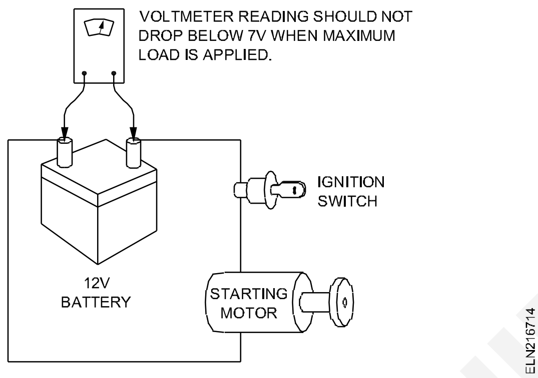


The charged condition of battery can be tested by means of a battery hydrometer. This instrument measures the relative density of the battery electrolyte. Since the strength of the electrolyte varies directly with the state of charge of each cell, you need only to find what specific gravity of sulphuric acid remains in each cell electrolyte to determine how much energy is available.

Cell condition	Hydrometer reading
Full charge	1.26
50% charge	1.20
Discharged	1.15

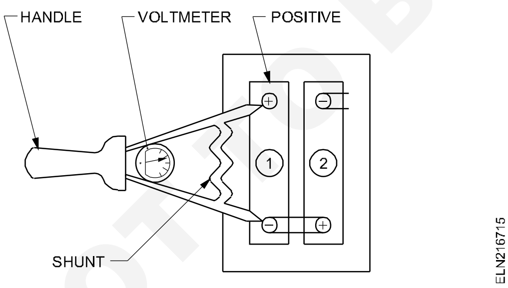
Voltage tests of lead-acid batteries, like primary cells, should be conducted under load. To make a simple light load voltage test of a car battery, check the value of the battery output voltage with and without the headlights on. A maximum load voltage test can be made by metering the battery voltage while operating the starting motor (Fig 3). In the case of a 12V battery, a drop of battery output voltage below 7V indicates the battery is defective or not fully charged.

Fig 3



High rate discharge tester: The internal condition of the cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance (Fig 4). The two terminal prods are pressed on to the terminals of a cell for testing. A fully charged cell which is in good condition reads in the range of full charge.

Fig 4



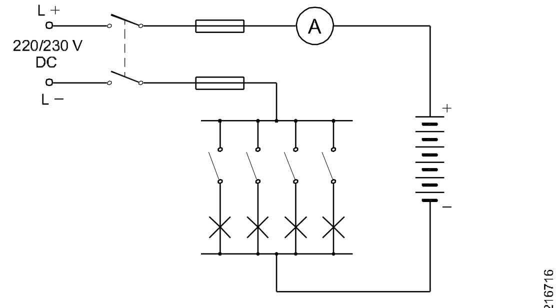
The meter is having three colours red, yellow and green - red for fully discharged, yellow for half charge, green for fully charged condition of the cell respectively.

The methods of charging the secondary cells are:

- constant current method
- constant potential method
- rectifier method.

Constant current method: This method is used where the supply is high voltage DC 220 V, 110 V, etc. but the battery is of low voltage 6 V, 12 V, etc. The emf of the battery is small in comparison to the supply voltage so a lamp-load or a variable resistor is connected in series with the battery (Fig 5). This causes a loss of energy, so, the method is inefficient.

Fig 5

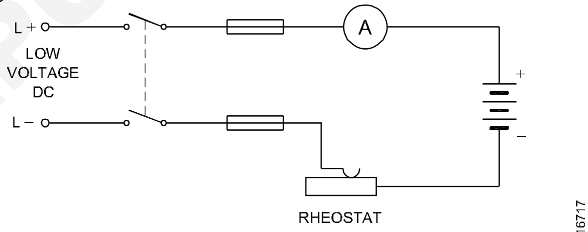


CONSTANT CURRENT METHOD

Use: For charging more number of cells at constant current rating.

Constant potential method: In this method, the voltage is maintained at a fixed value about 2.3 V per cell; the current decreases as the charging proceeds. A variable resistor is connected in series, so a voltage source of 2.5 to 2.6 V per cell is required. For a 12 V motor car battery, the charging dynamo is of about 15 V. In comparison to the constant current method less power is wasted for charging and less time is taken. Fig 6 shows the connections for a constant potential method of charging batteries.

Fig 6

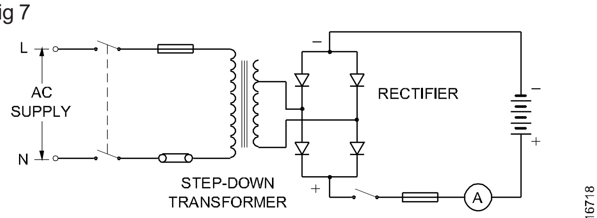


CONSTANT VOLTAGE METHOD

Use: For charging batteries of constant voltage rating.

Rectifier method: A rectifier for battery charging is generally made of diodes connected in the form of a bridge (Fig 7). A transformer is used to step down the AC voltage to that suitable for diodes. Ammeter, voltmeter, switches and fuses are also used in the rectifier set.

Fig 7



RECTIFIER METHOD

Trickle charge: When the battery is charged at a very low rate, that is 2 to 3% of the normal rate for a long period, it is said to be a trickle charge.

Use: For central or sub-station batteries and for emergency lighting systems.

Care and maintenance of batteries

Objectives: At the end of this lesson you shall be able to
- **state the guidelines for care and maintenance of batteries and installation**
- **state the precaution to be followed while charging and discharging of battery.**

Scan the QR Code to view the video for this exercise

Guidlines for installation of batteries

The following guide lines to be followed during installation of batteries at residential building

- Location of battery installed should be free from heat sources and flame.
- Battery connection cables should be as short as possible to prevent excessive voltage drop.
- Before connecting the battery the positive and negative poles must be carefully checked to ensure correct installation.
- Authorised and trained person must only be allowed for installation.
- If the batteries to be installed in the accessories like remote controls first open the battery cover, insert the batteries correctly into +ve and -ve ends then close the battery cover and press it to close.
- Do not expose the batteries to heat (or) flame.
- Manufacturer's instruction must be followed when installing the batteries.
- Follow the local, state and National electricity code.
- When installing a battery bank always be careful, since shock hazard may be present.

Care and maintenance of batteries : The lead acid batteries must be operated under the right conditions if they are to function properly. Regular maintenance is necessary in order to maintain proper conditions and thus prolong the life of the battery.

The battery should not be discharged beyond the minimum value of voltage say, 1.75 V for 2V battery.

The battery should not be kept under a discharged condition for a long time.

The level of the electrolyte should always be kept to a minimum of 10 to 15 mm above the plates by adding distilled water only.

The battery should never be charged and discharged at a higher rate which weakens the plate structure. It should be done as per the manufacturer's instructions.

The battery should be recharged as early as possible after discharge.

A discharged battery should never be tested with a high rate discharge tester.

The high rate discharge tester should be used only on charged batteries and for less than ten seconds.

The specific gravity of the electrolyte should be checked regularly before and after a battery is put on charge.

The battery charging room should always be well ventilated for the gases to escape freely.

The battery terminals must be free from corrosion. The terminals must always be kept clean and petroleum jelly should be applied on them.

The spilling of the electrolyte over the battery causes corrosion and it should be cleaned with soda water or ammonia water.

If the battery has not been used for a long period then the battery should be put on a trickle charge.

The vent plugs should be kept open while charging, for free liberation of gases.

Avoid overcharging and discharging at a high rate. This causes the plates to bend from their position and buckle.

Precautions : Make sure the cell temperature during charge does not exceed the limit specified (43°C) as per the manufacturer's instruction.

A fully charged battery stored at 100°F (38°C) will loose almost all its charge in 90 days. The same battery stored at 60°F(15°C) will loose a little of its charge in the same period of 90 days. High temperature decreases the charging rate and shortens the life.

The rate of charging at the end of the period called finish rate is most important. It must not exceed the value recommended by the manufacturer.

During recharging, the lead acid battery produces flammable gases. An accidental spark can ignite these gases, causing an explosion inside the battery. Such an explosion can break the battery case and throw acid on the people and equipment in the area.

Do not top up the cell with improper water such as tap water, well water, mineral water or acids which will cause hard sulphation and increase the internal resistance.

Avoid improper cleaning agents for terminal posts and metal parts of the battery like emery or sandpaper. Use only the recommended cleaning agents such as baking soda water(warm), ammonia water, and wipe with cotton cloth or with an old brush.

Always wear safety glasses when working with lead acid cells and batteries. If acid does come in contact with clothing or with the skin, immediately flush with clean water. Then wash with soap and water except for eyes. Wash your hands in soap and water after handling batteries.

Solar cells

Objectives: At the end of this lesson you shall be able to
- **state the necessity of tapping natural resources for energy**
- **state about the solar cell /photo voltaic cell**
- **explain the basic principle, construction and characteristics of the solar cell.**

Heat energy

Heat energy is the most sought energy for human being to cook the food as well as to keep warm in cold climate. However the use of wood as the fuel for fire, has ended up in deforestation and resulted in drought.

Search of fuel led the man to use coal and then oil. However these commodities are fast dwindling and after few hundred years both may completely vanish from earth. As such it is essential that human race should find alternative source of energy from nature.

Hence the use of natural resources like heat from sun thought by several scientists and one of the solutions to the energy crisis is the invention of solar cells.

Solar cell / Photovoltaic cell

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. They are used as a photo-detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

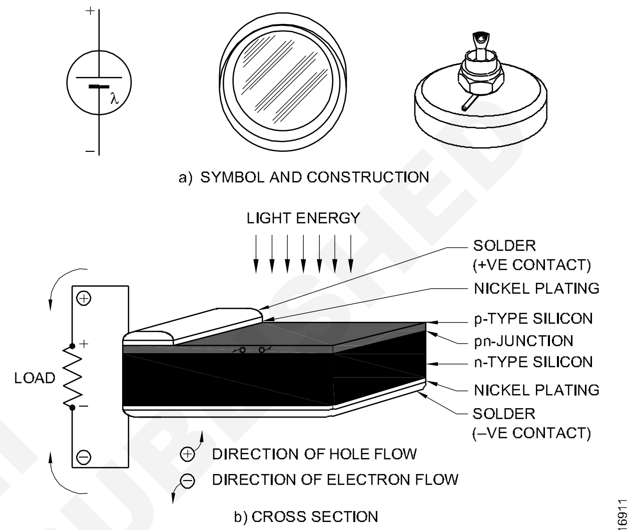
The operation of a photovoltaic (PV) cell requires 3 basic attributes:

- The absorption of light, generating electron-hole pairs extraction.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

The solar cells is essentially a large photo diode designed to operate as photo voltaic device and to give as much output power as possible. When these cells are under the influence of light rays from sun, they give out about 100 mw/cm^2 power.

Fig 1 shows the construction, symbol and cross section of a typical power solar cell. The top surface consist of a extremely thin layer of P-type material through which light can penetrate to the junction.

Fig 1



CONSTRUCTION AND CROSS SECTION OF A SOLAR CELL.

The nickel plated ring around the P-type material is the positive output terminal, and the bottom plating is the negative output terminal. Commercially produced solar cells will be available in flat strip form for efficient coverage of available surface areas.

According to different manufacturing standards, the output power varies from 50mw/cm^2 to 125mw/cm^2 . The graph shows the characteristic of a solar cell which gives 100mw/cm^2. Considering the characteristic curve it is apparent that the cell will deliver an output current of 50mA when the output terminals are short circuited then the output voltage will be zero.

On the other hand open circuited voltage of the cell will be 0.55mv but the output current is zero. Therefore again the output power is zero. For maximum output power the device must be operated at the knee of the characteristic. In solar cells the output power decreases at high temperature.

Several cells must be connected in series to produce the required output voltage, and number of parallel groups to be provided as per the required output current.

B.I.S. Symbols used for electrical accessories

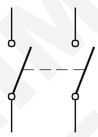
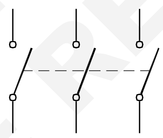
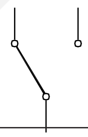
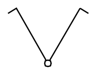
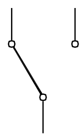
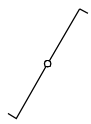
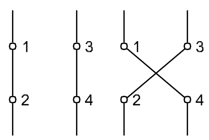
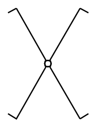
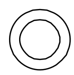
Objectives: At the end of this lesson you shall be able to
- **interpret the various BIS symbols used in electrical wiring diagrams.**

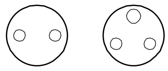
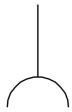
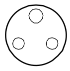
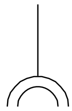
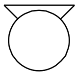
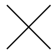
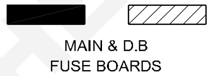
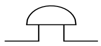
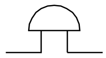
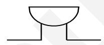
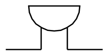
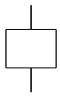
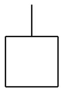
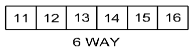
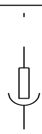
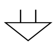
In electrotechnical engineering the symbols are used in layouts and wiring circuits to represent the electrical parts or the function of the circuit.

Since the drawing of the actual device is very laborious and would be drawn by each person differently, standardised symbols are used. With the help of the symbols, an electric circuit can be represented easily and can be described precisely as well.

A few examples of standard symbols recommended by B.I.S. 2032 (different parts) used for wiring are given here.

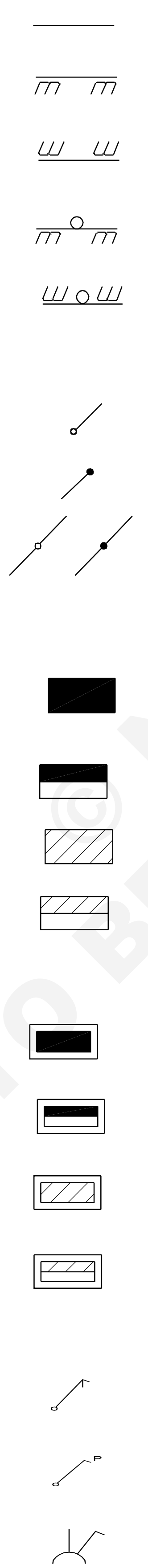
B.I.S. SYMBOLS FOR WIRING SCHEMES

Sl.No.	Description	Symbols used in the circuit diagram	Symbols used in layout
1	One-way switch, single pole		
2	One-way switch, two poles		
3	One-way switch, three poles		
4	Multi-position switch single pole		
5	Two-way switch		
6	Intermediate switch		
7	Push-button or bell-push		

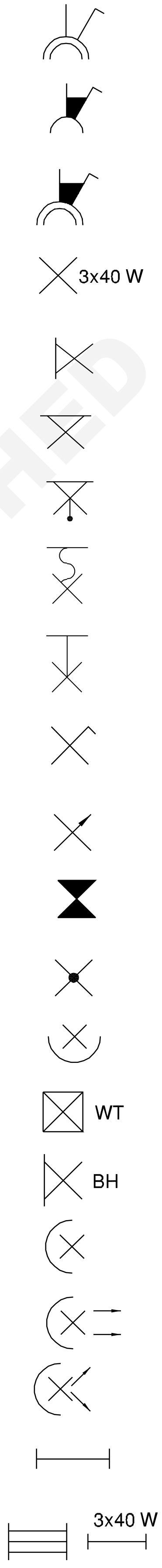
Sl.No.	Description	Symbols used in the circuit diagram	Symbols used in layout
8	Socket outlets, 6A		
9	Socket outlets, 16A		
10	Lamp or outlet for lamp		
11	Fuse		
12	Bell		
13	Buzzer		
14	Earth point		
15	Circuit breaker		
16	Terminal strip		N.A
17	Link (closed)		N.A
18	Plug and socket (male and female)		N.A
19	Ceiling rose		N.A
	N.A: Not applicable		

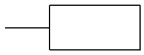
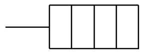
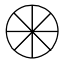
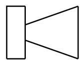
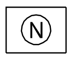
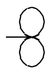
The B.I.S. Symbols used in the wiring is given here.

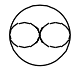
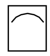
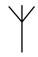
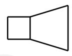
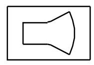
ITEMS	SYMBOLS
I Wiring	
1 General wiring	
2 Wiring on the surface	
3 Wiring under the surface	
4 Wiring in conduit	
a Conduit on the surface	
b Conduit concealed	
The type of conduit may be indicated, if necessary.	
5 Wiring going upwards	
6 Wiring going downwards	
7 Wiring passing vertically through a room	
II Fuse-boards	
1 Lighting circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
2 Power circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
III Switches and switch outlets	
1 Single pole pull-switch	
2 Pendent switch	
IV Socket outlets	
1 Combined switch and socket outlet, 6A	



ITEMS	SYMBOLS
2 Combined switch and socket outlet, 16A	
3 Interlocking switch and socket outlet, 6A	
4 Interlocking switch and socket outlet 16A	
V Lamps	
1 Group of three 40 W lamps	3x40 W
2 Lamp,mounted on a wall or light bracket	
3 Lamp, mounted on ceiling	
4 Counterweight lamp fixture	
5 Chain lamp fixture	
6 Pendent lamp fixture	
7 Lamp fixture with built-in switch	
8 Lamp fed from variable voltage supply	
9 Emergency lamp	
10 Panic lamp	
11 Bulk-head lamp	
12 Watertight light fitting	WT
13 Batten lamp-holder (Mounted on the wall)	BH
14 Projector	
15 Spotlight	
16 Floodlight	
17 Fluorescent lamp	
18 Group of three 40W fluorescent lamps	3x40 W



ITEMS	SYMBOLS
VI Electrical appliances	
1 General If necessary, use designation to specify.	
2 Heater	
VII Bells, buzzers and sirens	
1 Siren	
2 Horn or hooter	
3 Indicator (at `N' insert number of ways)	
VIII Fans	
1 Ceiling fan	
2 Bracket fan	

ITEMS	SYMBOLS
3 Exhaust fan	
4 Fan regulator	
IX Telecommunication apparatus	
1 Aerial	
2 Loudspeaker	
3 Radio receiving set	
4 Television receiving set	

Wiring accessories, IE Rules

Objectives: At the end of this lesson you shall be able to
- **classify, specify, identify and state the uses of the accessories employed in domestic wiring**
- **state the IE rules related to safety and electric supply.**

Electrical accessories: An electrical domestic accessory is a basic part used in wiring either for protection and adjustment or for the control of the electrical circuits or for a combination of these functions.

Rating of accessories: The standard current ratings of the accessories are 6, 16 and 32 amps. The voltage rating is 240V AC as per B.I.S. 1293-1988.

Mounting of accessories: The accessories are designed to mount either on the surface or concealed (flush type).

Surface mounting type: Accessories are provided with a seating so that when mounted they project wholly above the surface on which they are mounted.

Flush-mounting type: These accessories are designed to mount behind or incorporated with a switch plate, the back of the plate being flush with the surface of the wall or switch box.

The electrical accessories used in wiring installation, are classified according to their uses.

– Controlling accessories

– Holding accessories

– Safety accessories

– Outlet accessories

– General accessories

Types of switches according to their function and place of use

1 Single pole, one-way switch

2 Single pole, two-way switch

3 Intermediate switch

4 Bell-push or push-button switch

5 Pull or ceiling switch

6 Double pole switch (DP switches)

7 Iron clad double pole, (ICDP) switch.

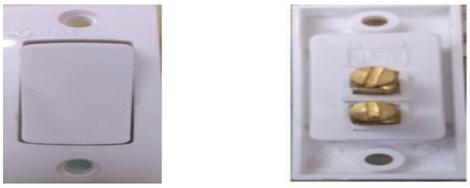
8 Iron clad triple - pole (ICTP) switch.

Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Single pole, one-way switch: This is a two terminal device, capable of making and breaking a single circuit only. It is used for controlling light or fan or 6 amps socket. (Fig 1)

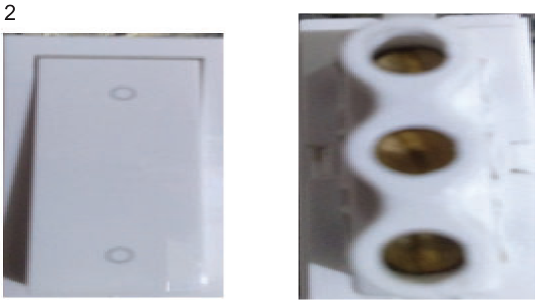
Two-way switch: This is a three terminal device capable of making or breaking two connections from a single position (Fig 2). These switches are used in staircase lighting where one lamp is controlled from two different places.

Fig 1



6 AMPS single pole one way flush switch

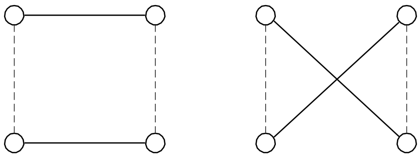
Fig 2



6 AMPS two way flush type switch

Intermediate switch: This is a four-terminal device capable of making or breaking two connections from two positions (Fig 3). This switch is used along with 2 way switches to control a lamp from three or more positions.

Fig 3



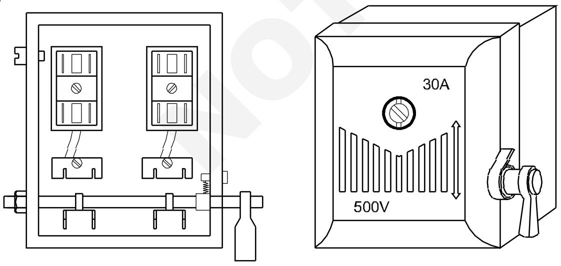
INTERMEDIATE SWITCH CONNECTIONS

ELN227023

Bell-push or push-button switch: This is a two-terminal device having a spring-loaded button. When pushed it `makes' the circuit temporarily and attains `break' position when released.

Iron - Clad Double pole (ICDP) main switch : This switch is also referred to as DPIC switch and is mainly used for single phase domestic installations, to control the main supply. It controls phase and neutral of the supply simultaneously (Fig 4).

Fig 4



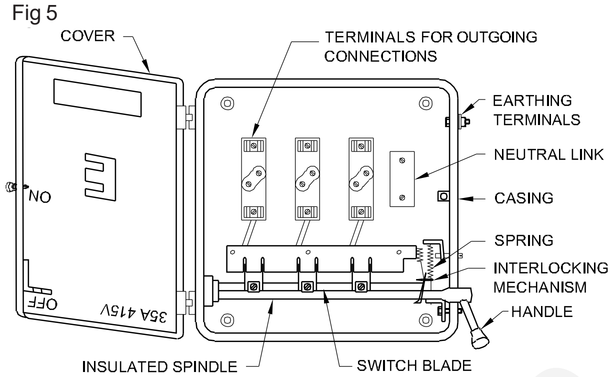
DPIC MAIN SWITCH

ELN227025

The current rating of the switch varies from 16 amps to 32 amperes.

Iron - Clad Triple pole (ICTP) main switch: This is also referred to as TPIC switch and is used in large domestic installation and also in 3-phase power circuits, the switch consists of 3 fuse carriers, one for each phase. Neutral connection is also possible as some switches are provided with a neutral link inside the casing (Fig 5).

Fig 5



FUSED ICTP `N' SWITCH

ELN227026

The current rating of the switch varies from 16 to 400 amps.

Holding accessories

Lamp-holders : A lamp-holder is used to hold a lamp. Earlier, brass holders were most commonly used but nowadays these have been replaced by bakelite holders. These may contain solid or hollow spring contact terminals. Four types of lamp-holders are mainly available.

– Bayonet cap lamp-holders

– Screw type holders

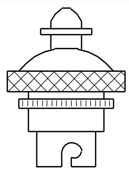
– Edison screw type lamp-holders

– Goliath Edison screw type lamp-holders

Bayonet cap (BC) lamp-holders: In this type,the bulb is fitted into the slot, and is held in position by means of two pins in the lamp cap. It has solid or hollow spring contact terminals, and the supply mains through the switch are connected to these contacts. In BC types there are two grooves on the circular construction of all types of holders.

Pendent lamp-holders: This holder (Fig 6) is used in places where the lamps are required in a hanging position. These holders are made of either brass or bakelite. An exploded view of this holder shows the parts of the holder. These holders are used along with ceiling roses for suspending the lamps from the ceiling.

Fig 6



EXPLODED VIEW OF PENDENT HOLDER

ELN227027

Batten lamp-holders: The straight batten holder (Fig 7a) is used on a flat surface on the round block, wooden board etc. These holders are made of either brass or bakelite.

Angle holders: The angle bottom holder, (Fig 7b) is to hold the lamp in a particular angle. These are made of either brass or bakelite. These are used for advertising boards, window display, kitchens etc.

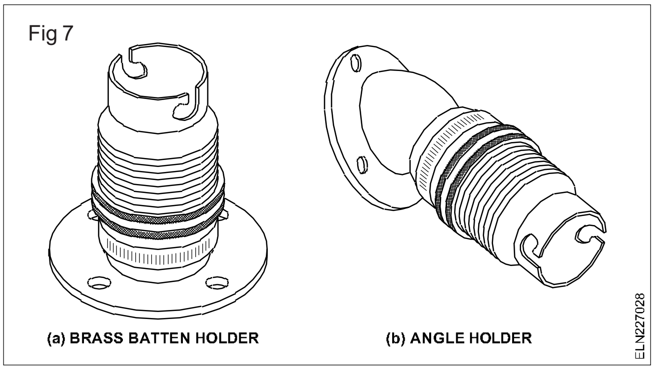


Fig 7

Edison screw-type lamp-holders: In this type, the holder is provided with inner screw threads and the lamp is fitted in it by screwing. It has a centre contact which is connected to the live wire and the screwed cap is connected to the neutral wire.

For lamps with wattage above 200W and not exceeding 300W, Edison screw-type holders are used. (Fig 8).

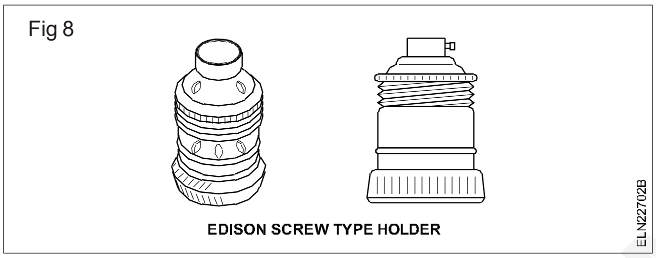


Fig 8

EDISON SCREW TYPE HOLDER

Goliath Edison screw (GES) type holders (Fig 9): The cover of this type of holder is made of porcelain. Such holders are used in studios, headlights, floodlights, focussing lights etc.

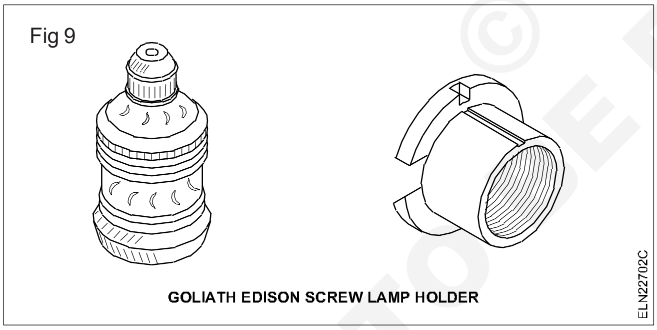


Fig 9

GOLIATH EDISON SCREW LAMP HOLDER

These holders are used for more than 300W lamps.

Specification of a lamp-holder: While specifying the lamp-holders, the type of material used for construction, type of gripping, type of mounting, working current and voltages should also be specified.

Socket outlet current rating: The standard ratings shall be 6,16 and 32 amperes and 240 volts.

Two-pin socket: This socket is rated as 6A, 250V, having only two pins without earth connection. These are suitable only for double insulated appliances (having PVC or insulated body).

Two-pin plug top: It is used for taking the supply from the socket. It has got two pins of the same size.

Three-pin socket: This type of socket is suitable for light and power circuits. These sockets are rated as 6A, 250V or 16A, 250V, and are available as surface-mounting type and flush type (Fig 10). There are three terminals marked as Line (L) Neutral (N) and Earth (E).

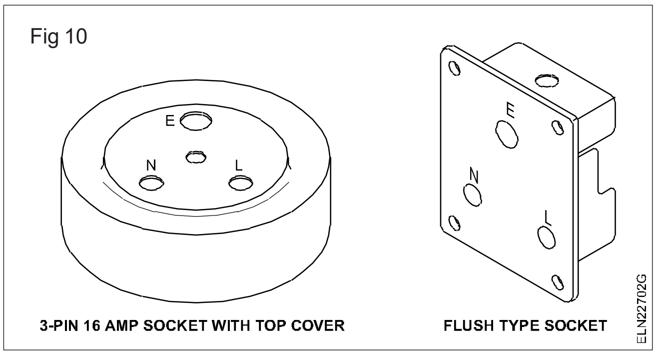


Fig 10

Three-pin plug top : It is used for taking the supply from the socket. It has three pins. Two are similar in size and the third one is bigger and longer which is for earth (Fig 11). These are also rated as 6A,250V or 16A, 250V. These are made of bakelite, PVC materials.

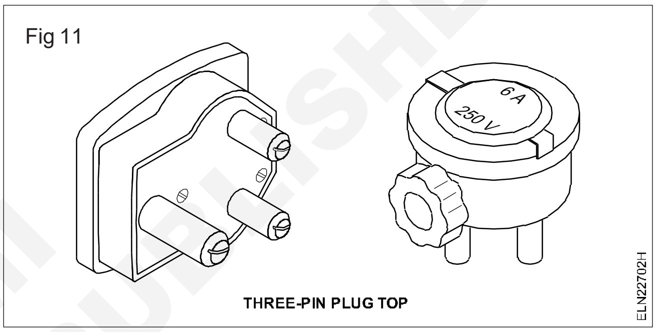


Fig 11

THREE-PIN PLUG TOP

General accessories : Some accessories are used for general and special purposes such as:

– appliance connectors (or) iron connectors
– adapters
– ceiling roses
  a two-plate
  b three-plate
– connectors
– distribution board
– neutral links.

Appliance connectors or iron connectors : These are used as female connectors to supply current to electric kettles, electric iron, hotplate, heaters etc. It is made of bakelite or porcelain. These are rated as 16A, 250V (Fig 12).

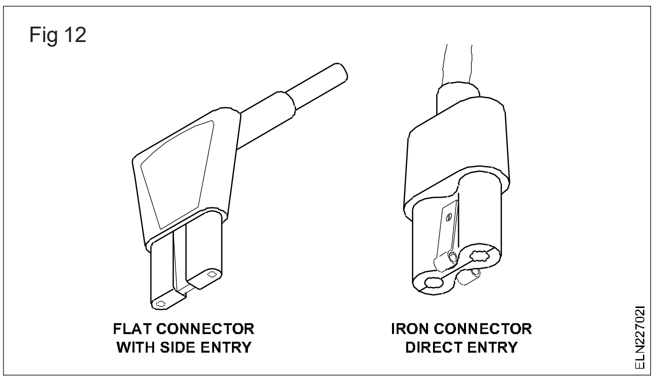
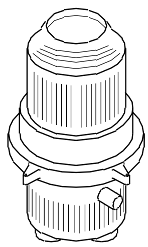


Fig 12

Adaptor (Fig 13)**:** They are used for taking supply from a lamp holder for small appliances. They are made out of bakelite. They are available in ratings up to 6 A 250 V.

Fig 13

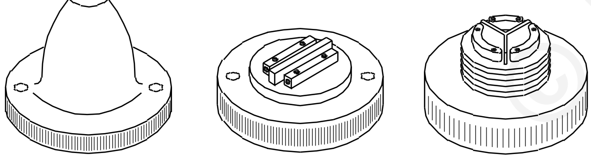


Ceiling roses: Ceiling roses are used to provide tapping points from the wiring for supplying power to fans, pendent-holders, tube lights etc. Normally flexible wires are used for tapping from the ceiling roses.

Two-plate ceiling rose (Fig 14a & b)**:** This is made of bakelite and it has 2 terminals (phase & neutral) which are separated from each other by a bakelite bridge. The two-plate ceiling rose is used for 6A, 250V current capacity.

Three-plate ceiling rose: This type of ceiling rose has 3 terminals which are separated from each other by a bakelite bridge. It can be used for two purposes. (Fig 14c)

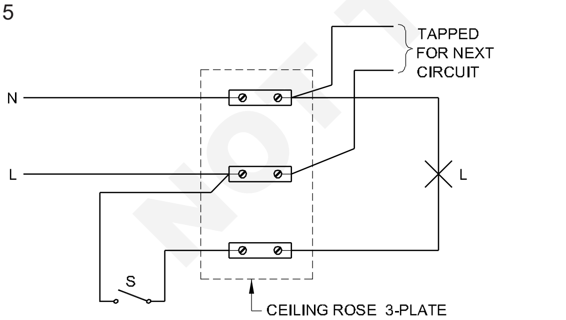
Fig 14



– Bunch light control

– To provide tapping for phase wire (Fig 15).

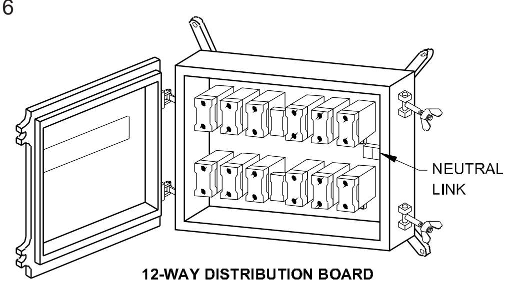
Fig 15



These ceiling roses are available in the rating of 6A, 250V

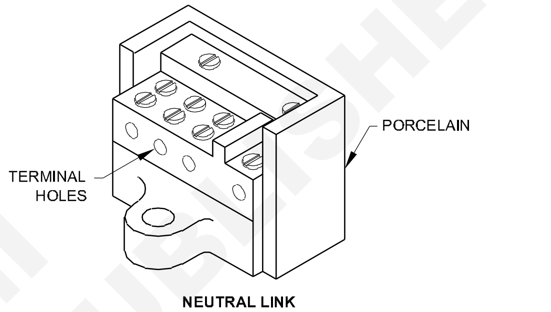
Distribution board (Fig 16): These are used where the total load is high and is to be divided into a number of circuits. These are used where the load is more than 800W. The number of fuses in the board is according to the number of circuits, and a neutral link is also provided so that the neutral wire can be taken for different circuits. All these branch fuses are enclosed in a metal box. These boards are available as two-way, three-way, 4,6,12-way types.

Fig 16



Neutral link: In a three-phase system of wiring installations, the phases are controlled through switches, and the neutral is tapped through a link called neutral link. (Fig 17). The ratings are 16A, 32A, 63A, 100A neutral link.

Fig 17

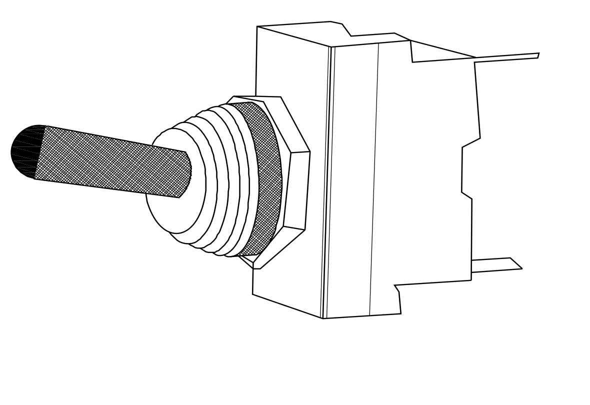


The accessories' rating shall be 240V and 6 or 16 amps from the year 1991, instead of 250V and 5 or 15 amps as per BIS 1293-1988.

Toggle switches (Fig 18)

It is an electric switch operated by means of a projecting lever that can be moved upward and downward and is also called as snap switches .

Fig 18



Modular switches (Fig 19)

The latest version of modular switch of different sizes and colours along with sockets combined and switches with indicators are available in market

Indian Electricity Rules - Safety Requirements

The IE rules 1956 was made under sections 37 of Indian Electricity Act 1910. Now it is redefined after the enactment of the Electricity Act 2003. The Central Electricity Authority (measures relating to safety and electric supply) Regulation (CEAR) 2010 which came into effect from 20th September 2010, in place of Indian Electricity Rules 1956.

Fig 19

Modular switch

ELN22702Q

SAFETY RULES: Among safety rules, the following are important and indeed requires attention. Every rule in the Indian Electricity Rules 1956 is related either directly or indirectly to safety.

Rule 32: Switches shall be on the live conductor. No cutout, link or switch other than gang switch shall be inserted in the neutral conductor. Code of Practice of wiring shall be followed while marking the conductors.

Rule 50: Energy shall not be supplied, transformed,converted or used unless the following provisions are observed. A suitable linked switch or circuit breaker is erected at the secondary side of the transformer. Every circuit is protected by a suitable cut-out. Supply to each motor or group of motors is controlled by a linked switch or circuit breaker. Adequate precautions are taken to ensure that no live parts are exposed.

Special provisions in respect of high and extra high voltage installations

Rule 63: Approval of Inspector is necessary before energising any high voltage installations.

Rule 65: The installation must be subjected to the prescribed testing before energizing.

Rule 66: Conductors shall be enclosed in a metallic covering and suitable circuit breakers shall be provided to protect the equipment from overloading.

Rule 68: Incase of outdoor type of sub-station a metallic fencing of not less than 1.8 m height shall be erected around the transformer.

Provisions in terms of OH line

Rule 77: Clearance of lowest conductor above ground across street.

- Low and Medium Voltage lines - 5.8 m.
- High voltage Lines - 6.1 m.
- Clearance of lowest conductor above ground along a street. Low and Medium Voltage lines - 5.5 m.
- High voltage lines - 5.8 m.
- Clearance of lowest conductor above ground other than along or across the street. Low, Medium and High Voltage lines upto 11 KV if bare - 4.6m .
- Low, Medium and High upto and including 11KV, if insulated - 4.0m.
- High Voltage above 11 KV - 5.2 m.

Rule 79: Clearance of low and medium voltage lines from building,

- Vertical Clearance - 2.5 m.
- Horizontal clearance - 1.2 m.

Rule 80: Clearance from building of high and extra high voltage. Vertical Clearance High Voltage upto 33KV - 3.7m.

- Extra High Voltage above 33KV - 3.7 m, plus 0.3 m for every 33KV part there of.
- Clearance from building of high and extra high voltage - Pitched Roof . Vertical Clearance upto 11KV - 1.2m.
- Above 11KV upto 33KV - 2.2 m.
- Above 33KV - 2m. plus 0.3m for every 33KV part there of.

Rule 85: Maximum interval between supports. It shall not exceed 65 m except by prior approval of inspector.

Indian electricity rules regarding to internal wiring:

1 The minimum size of conductor used in domestic wiring must not be of size less than 1/1.12mm in copper or 1/1.40mm (1.5mm) in aluminium wire.

2 For flexible wires the minimum size is 14/0.193mm.

3 The height at which meter board, Main switch board are to be fitted 1.5 meters from ground level.

4 The casing will be run at a height of 3.0 meters from the ground level.

5 The light brackets should be fixed at a height of 2 to 2.5 meters from ground level.

6 The maximum number of points in a sub circuit is 10.

7 The maximum load in a sub circuit is 800W.

I.E. Rules regarding - Voltage drop concept:

1 **I.E. Rule 48:** The insulation resistance between the wiring of an installation and earth should be of such a value that the leakage current may not exceed 1/50000 the part or 0.02 percent of the F.L. current.

2 The permissible voltage drop in a lighting circuit is 2% of the supply voltage plus one volt.

3 The maximum permissible voltage drop in a power industrial circuit should not be more than 5% of the declared supply voltage.

4 The insulation resistance of any wiring installation should not be less than 1MΩ .

5 The earth resistance should not exceed the value of one ohm.

I.E. Rules regarding to power wiring:

1 In a power sub circuit the load is normally restricted to 3000 watts and number of outlets to two in each sub circuit.

2 All equipment used in power wiring shall be iron clad construction and wiring shall be of the armoured cable or conduit type.

3 The length of flexible conduit used for connections between the terminal boxes of motors and starters, switches and motors shall not exceed 1.25 meters

4 Every motor, regardless of its size shall be provided with a switch fuse placed near it.

5 The minimum cross-sectional area of conductor, that can be used for power mining of 1.25 mm for copper conductor cables and 1.50 mm for Aluminium conductor cables (refer ISI recommendations). Hence VIR or PVC cables of size lower than 3/0.915 mm copper or 1/1.80 mm Aluminium can not be used for motor wiring.

Circuit Breaker (CB) - Miniature Circuit Breaker (MCB)- Moulded Case Circuit Breaker (MCCB)

Objectives: At the end of this lesson you shall be able to
- **explain the types, working principle and parts of a miniature circuit breaker.**
- **state the advantages and disadvantages of MCB**
- **state the categories and applications of MCBs**
- **state the application, advantage and disadvantage of MCCBs.**

Circuit Breaker

A circuit breaker is a mechanical switching device capable of making, carrying and breaking the currents under normal condition and breaking the currents under abnormal conditions like a short circuit.

Miniature circuit breaker (MCB)

A miniature circuit breaker is a compact mechanical device for making and breaking a circuit both in normal condition and in abnormal conditions such as those of over current and short circuit.

Types of MCB's

MCBs are manufactured with three different principles of operation namely

a Thermal Magnetic

b Magnetic hydraulic and

c Assisted bimetallic

Out of three MCB's thermal magnetic MCB is discussed below

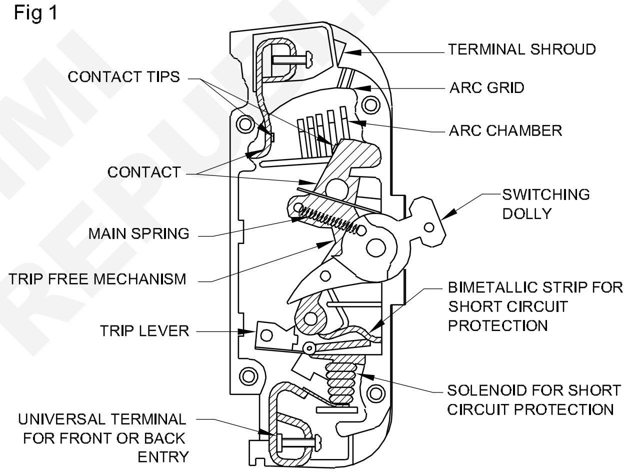
Thermal magnetic MCB

The switching mechanism is housed in a moulded housing with phenolic moulded high mechanically strong switching dolly. This type of MCB is also provided with bimetallic overload release (Fig 1).

The electric current gets through two contact tips one each on moving and fixed contact of silver graphite.

An arcing chamber incorporating de-ionising arc chutes for control and quick suppression of the arc is provided in the gap between two contacts. It has a ribbed opening closed by metal grid which allows ventilation and escape of gases.

Fig 1



NOTE: THE HATCHED PORTION SHOWS THE PATH OF CURRENT FROM TOP TERMINAL TO BOTTOM

THERMAL MAGNETIC TYPE MCB

ELN227031

For protection against over-load and short circuit, MCB's have thermal magnetic release unit. The overload is taken care of by bimetallic strip, short circuit currents and over loads of more than 100% are taken care by solenoid.

Working

The bimetallic strip when flexing due to temperature rise caused by increasing normal rated current beyond 130% rotates a trip lever carrying an armature to which it is to brought into field of a solenoid. The solenoid is designed to attract the armature to full position at about 700% overload or instantaneous short circuit current.

For initial portion of current wise (130% to 400%) tripping of circuit breaker is due to thermal action, between 400 to 700% tripping is due to combined thermal and magnetic action and beyond 700% due to fully magnetic action.

Categories of MCBs

Certain manufacturers like Indo Kopp manufacture the MCBs in three different categories namely ‘L’ series, ‘G’ series, and ‘DC’ series.

‘L’ series MCBs

‘L’ series MCBs are designed to protect circuits with resistive loads. They are ideal for protection of equipment like Geysers, ovens and general lighting systems.

‘G’ series MCBs

‘G’ series MCBs are designed to protect circuits with inductive loads. G series MCBs are suitable for protection of motors, air conditioners, hand tools, halogen lamps etc.,

‘DC’ series MCBs

‘DC’ series MCBs are suitable for voltage upto 220V DC and have a breaking capacity up to 6kA.

The tripping characteristics are similar to ‘L’ an ‘G’ series. They find extensive application in DC controls, locomotives, diesel generator sets etc.,

Advantages of MCB

1 Tripping characteristic setting can be done during manufacture and it cannot be altered.

2 They will trip for a sustained overload but not for transient overload.

3 Faulty circuit is easily identified.

4 Supply can be quickly restored.

5 Tamper proof.

6 Multiple units are available.

Disadvantages

1 Expensive.

2 More mechanically moving parts.

3 They require regular testing to ensure satisfactory operation.

4 Their characteristics are affected by the ambient temperature.

Moulded Case Circuit Breakers (MCCB)

Moulded case circuit breakers are similar to thermo magnetic type MCBs except that these are available in higher ratings of 100 to 800amp at 500V 3-phase.

In MCCB, thermal and magnetic releases are adjustable. A shunt release is also incorporated for remote tripping and interlocking at MCCB. MCCBs are provided with under voltages release. There are two types of MCCB.

1 Thermal magnetic type.

2 Fully magnetic type (Fig 2).

Advantages of MCCB

1 MCCBs occupy much less space in comparison to fuse switch units.

2 MCCBs provide equal amount of protection against high faults as switch gears having HRC fuses.

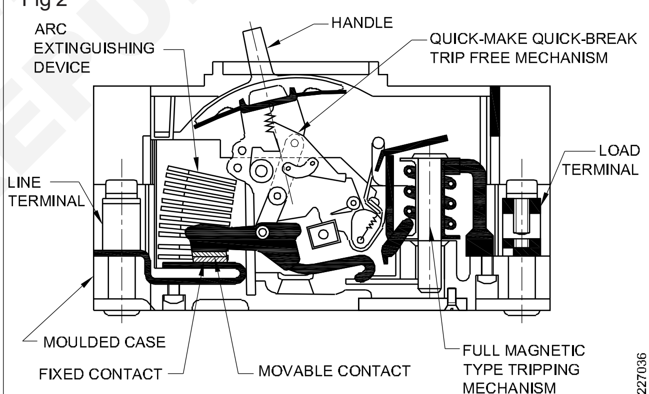
Disadvantages

1 MCCBs are much costlier.

2 Leak proof situation required.

3 Sensitivity to insulation resistance low.

Fig 2



FULLY MAGNETIC TYPE M.C.C.B

ELCB - types - working principle - specification

Objectives : At the end of this exercise you shall be able to
- **explain the working principle, different types and construction of an earth leakage circuit breaker (ELCB)**
- **explain the technical specifications of ELCB’s.**

Introduction

The sensation of electric shock is caused by the flow of electric current through the human body to earth. When a person comes in contact with electrically live objects like water heaters, washing machines electric iron etc., the extent of damages caused by this current depends on its magnitude and duration.

This kind of current is called the leakage current which comes in milli-amps. These leakage current being very small in magnitude, hence undetected by the fuses/MCBs are the major cause for the fires due to electricity.

The leakage current to earth also results in the wastage of energy and excessive billing for electricity not actually used.

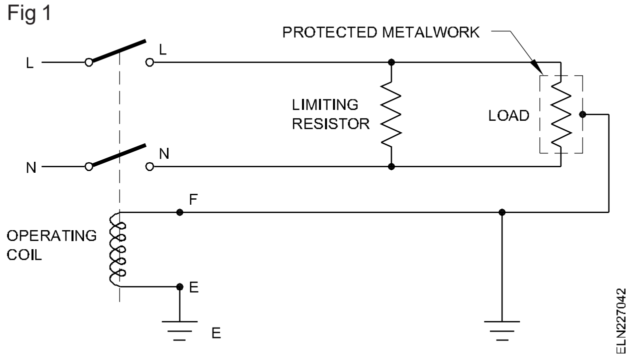
These residual current circuit breakers (RCCB) are popularly called as Earth leakage circuit breakers (ELCB).

Basically ELCBs are of two types namely voltage operated ELCBs and the current operated ELCBs.

Voltage operated ELCB

This device is used for making and breaking a circuit. It automatically trips or breaks the circuit when the potential difference between the protected metal work of the installation and the general mass of earth exceeds 24V. This voltage signal will cause the relay to operate (Fig 1).

Fig 1



Voltage operated ELCBs are meant to be used where it is not practicable to meet the requirements of IEE wiring regulation by direct earthing or where additional protection is desirable.

Current operated ELCB

This device is used for making and breaking a circuit and for breaking a circuit automatically when the vector sum of current in all conductors differs from zero by a predetermined amount. Current operated ELCBs are much more reliable in operation, easier to install and maintain.

Construction of current operated ELCB

It consists of a Torroid ring made of high permeability magnetic material. It has two primary windings each carrying the current flowing through phase and neutral of the installation. The secondary winding is connected to a highly sensitive electro - magnetic trip relay which operates the trip mechanism.

Working principle

The residual current device (RCD) is a circuit breaker which continuously compares the current in the phase with that in the neutral. The difference between the two is called as the residual current which is flowing to earth.

The purpose of the residual current device is to monitor the residual current and to switch off the circuit if it rises from a preset level (Fig 2&3).

Fig 2

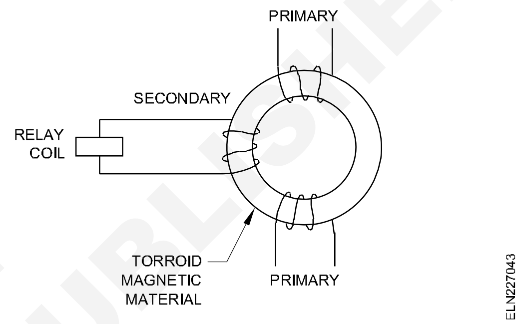
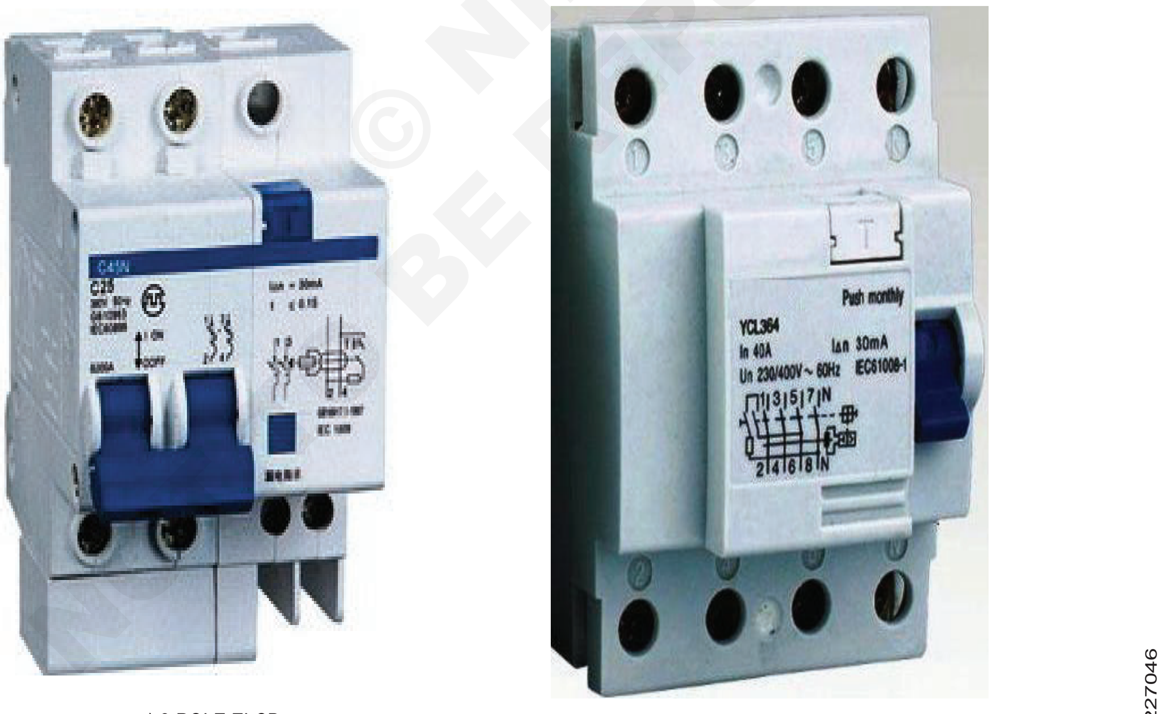


Fig 3



a) 2-POLE ELCB

b) 4-POLE ELCB

The main contacts are closed against the pressure of a spring which, provides the energy to open them when the device trips. Phase and neutral current pass through identical coils wound in opposing direction on a magnetic circuit, so that each coil will provide equal but opposing numbers of ampere turns when there is no residual current.

The opposing ampere turns will cancel and no magnetic flux will be set up in the magnetic circuit.

In a healthy circuit the sum of the current in phases is equal to the current in the neutral and vector sum of all the current is equal to zero. If there is any insulation fault in the circuit then leakage current flows to earth. This residual current passes to the circuit through the phase coil but returns through the earth path and avoids the neutral coil, which will therefore carry less current.

So the phase ampere turns exceeds neutral ampere turns and an alternating magnetic flux results in the core. The flux links with the secondary coil wound on the same magnetic circuit inducing an emf into it. The value of this emf depends on the residual current, so it drives a current to the tripping system which depends on the difference between them and neutral current.

When tripping current reaches a predetermined level the circuit breaker trips and open the main contacts and thus interrupts the circuit.

Fuses

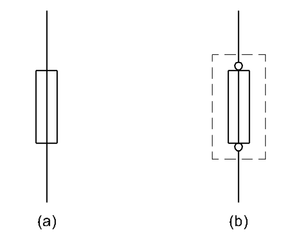
Objectives: At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **classify the different types of fuses and their uses.**

Purpose of fuses: A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols: These are the graphical symbols used to illustrate an electrical fuse in electro-technical diagrams.

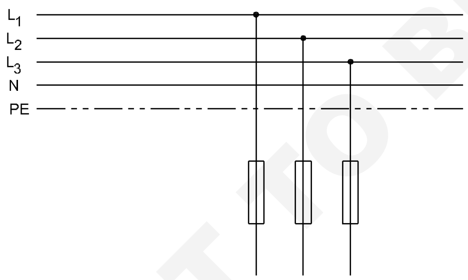
- General symbols of a fuse (Fig 1)

Fig 1



Placement of fuses: In electrical installations, the fuses are always connected into the live wires (Fig 2) and never into the neutral N.

Fig 2



Types of fuses used in domestic wiring:

- Re-wirable type (up to 200A)
- Cartridge type (up to 1250A)

Rewirable type fuse (Fig 3): The fuse element in this type of fuse consists of a wire which may be replaced when necessary. These fuses are simple in construction and the initial cost as well as the renewal cost is very low.

The fuse elements used in this type are tinned copper wire, lead and tin alloy or aluminium wire (Table 1).

The fuse element will melt after approximately 2 minutes when carrying a current equal to twice the current rating.

Fig 3

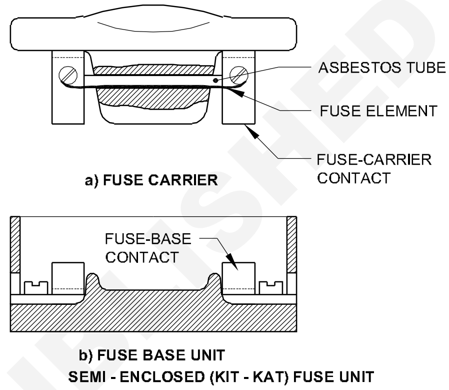


Table 1

Current rating for	Approximate fusing current Amp	Tinned copper wire		Aluminium wire dia. in mm
		S.W.G.	Diameter in mm	
1.5	3	40	.12192	--
2.5	4	39	.13208	–
3.0	5	38	.1524	.195
4.0	6	37	.17272	–
5.0	8	35	.21336	–
5.5	9	34	.23368	–
6.0	10	33	.254	.307
7.0	11	32	.27432	–
8.0	12	31	.29464	–
8.5	13	30	.31496	–
9.5	15	–	––	.400
10.0	16	29	.34544	–
12.0	18	28	.37592	–
13.0	20	–	––	.475
13.5	25	–	––	.560
14.0	28	26	.4572	–
15.0	30	25	.508	.630

Disadvantages of rewirable type fuse:

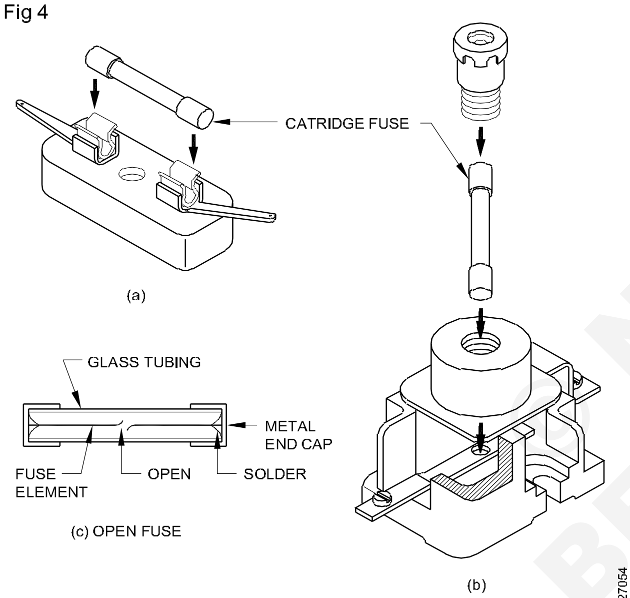
- Effected by the fluctuation of the ambient temperature.
- External flash or arc on blowing.
- Poor rupturing capacity (under short-circuit condition).
- Wrong rating possible by human error.

Rewirable-type fuses up to 16A rated current should not be used in locations where short circuit level exceeds 2 KA, (I.S. 2086-963).

Cartridge fuses: Cartridge fuses are developed to overcome the disadvantages of the rewirable fuses. As cartridge fuse elements are enclosed in an air tight chamber, deterioration does not take place. Further the rating of a cartridge fuse could be accurately determined from its marking. However, the cost of replacement of cartridge fuses is more than that of rewirable fuses.

- Ferrule-contact cartridge fuses (Fig 4).

Fig 4



FERRULE - CONTACT CATRIDGE FUSE UNIT

Ferrule-contact cartridge fuses: This type, is used for protecting electrical and electronic circuits. These are available in 25, 50, 100, 200, 250, 500 milliamperes, and also in 1,2,5,6,10,16 & 32 amperes capacity.

Normally the current rating is written on one side of the cap, and while replacing, the same capacity fuse should be used. Its body is made of glass and the fuse wire is connected between two metallic caps.

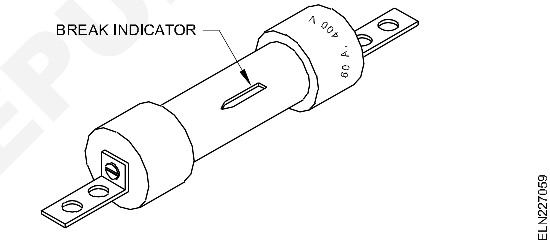
This fuse can be plugged into the fuse socket (Fig 4a) or it can be fitted into a fuse base with a screw, type fuse- holder (Fig 4b).

High rupturing capacity (HRC) fuses (Fig 5): They are cylindrical in shape and are made of a ceramic body filled in with a chemically treated filling powder or silica to quench the arcing quickly without any fire hazard.

Normally a silver alloy is used as the fusing element and when it melts due to the excessive current, it combines with the surrounded sand/powder, and forms small globules without making an arc, spark or gas. HRC fuses can open a short-circuited circuit within 0.013 second. It has an indicator to show the fuse has blown.

As HRC fuses are capable of opening circuits having very high faulty currents, these are preferred in high power circuits even though the replacement cost is high.

Fig 5



Relays - types - symbols

Objectives: At the end of this lesson you shall be able to
- **define a relay and classify the relays**
- **classify relays according to the operating force and function**
- **state the causes of the failure of the relay.**

Relay: A relay is a device which opens or closes an auxiliary circuit under predetermined conditions in the main circuit.

Relays are extensively used in electronics, electrical engineering and many other fields.

There are relays that are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

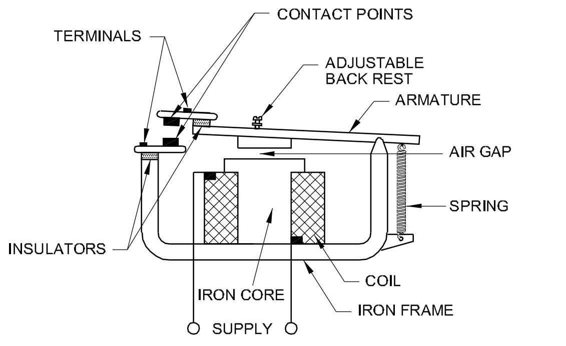
Relays are also classified according to their main operating force as stated under.

- Electromagnetic relays
- Thermal relays

Electromagnetic relay: A relay switch assembly is a combination of movable and fixed low-resistance contacts that open or close a circuit. The fixed contacts are mounted on springs or brackets, which have some flexibility. The movable contacts are mounted on a spring or a hinged arm that is moved by the electromagnet in the relay (Fig 1).

The other types of relays coming under this group are as follows.

Fig 1



ELECTRO MAGNETIC RELAY

Current sensing relay: A current sensing relay functions whenever the current in the coil reaches an upper limit. The difference between the current specified for pick up (must operate) and non-pick up (must not operate) is usually closely controlled. The difference in current may also be closely controlled for drop out (must release) and non-drop out (must not release).

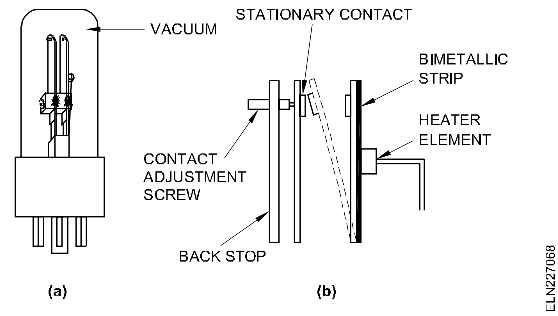
Under-current relay: Under-current relay is an alarm or protective relay. It is specifically designed to operate when the current falls below a predetermined value.

Voltage sensing relay: A voltage sensing relay is used where a condition of under-voltage or over-voltage may cause a damage to the equipment. For example, these types of relays are used in voltage stabilizers. Either a proportional AC voltage derived from a transformer or a proportional DC derived from a transformer and rectifier used for this purpose.

Thermal relay: A thermal relay (Fig 2) is one that operates by changes in temperature. Most of the bimetallic relays where the bimetallic element changes its shape, in response to changes in temperature comes under this group.

It takes time for the heating element to reach the necessary temperature and more time to raise the temperature of the bimetallic element. Therefore, thermal relays are often used as time-delay relays.

Fig 2



Causes of relay failures: Relay failures are usually caused by the gradual deterioration of the parts. This deterioration can be electrical, mechanical or chemical in nature.

The environmental shirks that contribute to physical breakdown include large temperature changes, shock, vibration and voltage or current changes. Therefore, it is important that these factors are taken into consideration to ensure reliable performance of relays.

In general, when a relay fails, look for the following.

1 Improper control voltage.

2 Dirt, grease or gum on contacts or moving parts.

3 Excessive heating of parts: discolouration or charred insulation on coil or base.

4 Bending of moving parts.

5 Corrosion or deposits on metal parts.

6 Excessive wear on moving parts.

7 Loose connections.

8 Improper spring tension.

9 Improper control pressure.

10 Improper functioning of the time delay device.

Types domestic wiring

Objectives: At the end of this lesson you shall be able to
- **state the types wiring used in domestic installations**.

Introduction

The type of wiring to be adopted is dependent on various factors viz. location durability, safety, appearance, cost and consumer's budget etc.

Types of wiring

The following are the types of internal wiring used in domestic installations.

- Cleat wiring (for temporary wiring only)
- CTS/TRS (batten) wiring
- Metal/PVC conduit wiring, either on surface or concealed in the wall.
- PVC casing & capping wiring

Cleat wiring

This system uses insulated cables supported in porcelain cleats (Fig 1).

Cleat wiring is recommended only for temporary installations. These cleats are made in pairs having bottom and top halves (Fig 2). Bottom half is grooved to receive the wire and the top half is for cable grip.

Initially the bottom and top cleats are fixed on the wall loosely according to the layout. Then the cable is drawn through the cleat grooves, and it is tensioned by pulling and the cleats are tightened by the screw.

The cleats are of three types, having one, two or three grooves, so as to receive one, two or three wires.

Fig 1

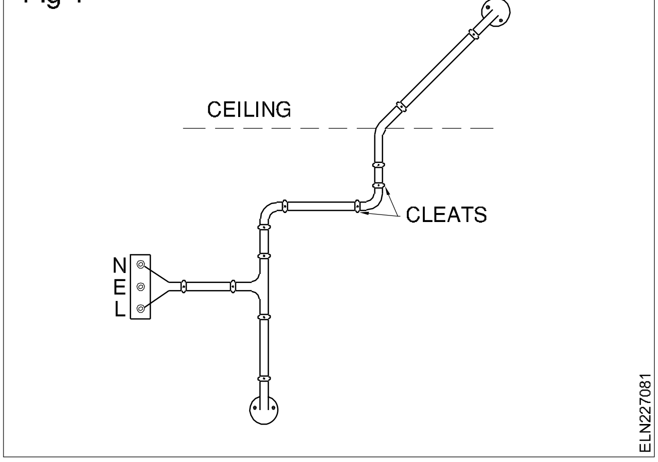
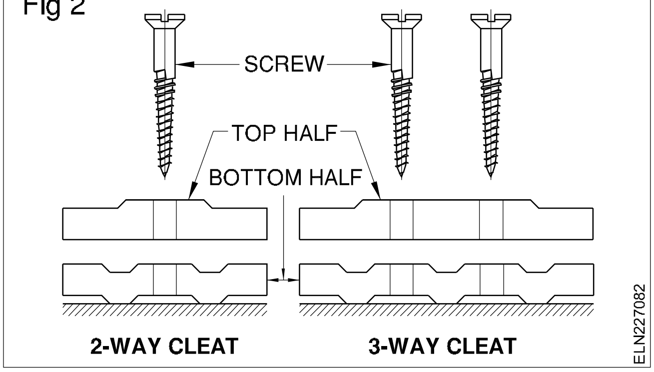


Fig 2



Cleat wiring is one of the cheapest wirings considering the initial cost and labour, and is most suitable for temporary wiring. This wiring can be quickly installed, easily inspected and altered. When not required this wiring could be dismantled without damage to the cables, cleats and accessories. This type of wiring may be done by semi-skilled persons.

Types of Power wiring

Objectives: At the end of this lesson you shall be able to
- **explain the types of electrical wiring and their application**
- **state the advantages and disadvantages of each types.**

Many wiring systems are developed to meet the safety requirements, economy of cost, easy maintenance and trouble shooting. A particular system can be chosen according to technical requirements but the system needs to be approved by the local electricity authorities. The following are the fundamental requirements for any wiring system. They are:

i For safety, switches should control the live phase wire. The second terminal of the switch called as half wire should be connected to the appliance or socket through the wire. The neutral can be connected directly to the appliance, socket or lamp.

ii For safety, fuses should be placed in the live/phase wire only.

iii To supply the rated voltage, parallel connections should be given to all lamps and appliances.

Types of wiring system: There are three types of wiring systems used for tapping supply from mains to the different branches. They are as follows.

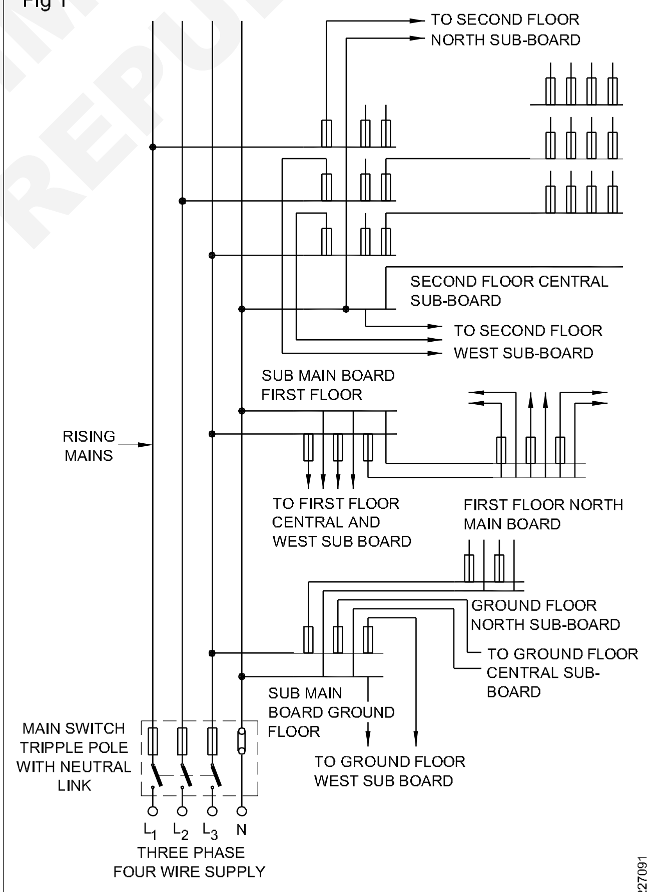
1 Tree system

2 Ring main system

3 Distribution board system

Tree system: In this system, copper or aluminium strips in the form of bus bars are used to connect the main supply to the raising mains (Fig1). This system is suitable for multi-story buildings and the bus bar trunking space is provided in the building at a convenient location and at load centres for the purpose of economy.

Fig 1



WIRING OF BUILDING BY TREE SYSTEM

At each floor the running main is connected to the sub-main board through proper cable terminations. If there are more than one flat in each floor the individual main switches for the flat get their supply from the sub-main board through a distribution network which may include an energy meter for each flat.

However the system adopted within the flat will be the distribution board system.

Advantages

1 The length of the cables required for installation will become less. Hence, the cost is less.

2 This system is suitable for high rise buildings.

Disadvantages

1 The voltage across the appliances which are at the farthest end of the tree system may be less when compared to the one connected to the nearest end if the bus bars size is not of sufficient size.

2 As fuses are located at different places, fault location becomes troublesome.

Ring main system: This system consists of two pairs of cables of size 4 or 6sq.mm which run through the rooms and are brought back to the main or sub-board (Fig 2&3). Tappings are taken for sockets or ceiling roses from the pair of cables through fuses and controlling switches. There may be saving of copper used because the current can be fed from both sides. As this system requires special sockets or plugs with fuses it becomes costly; and hence rarely used in India.

Fig 2

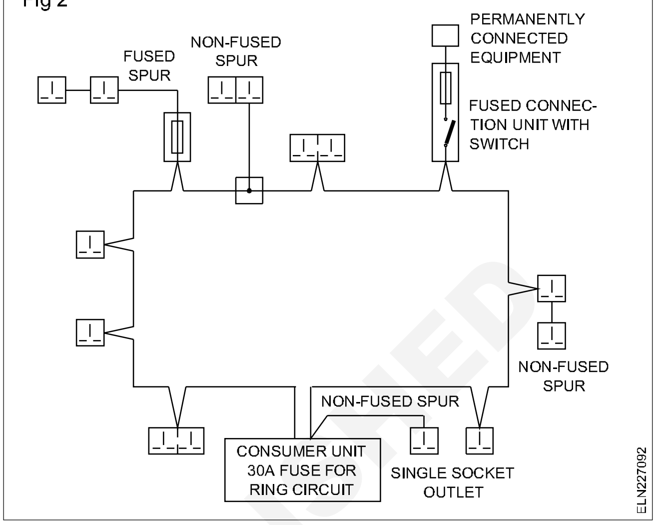
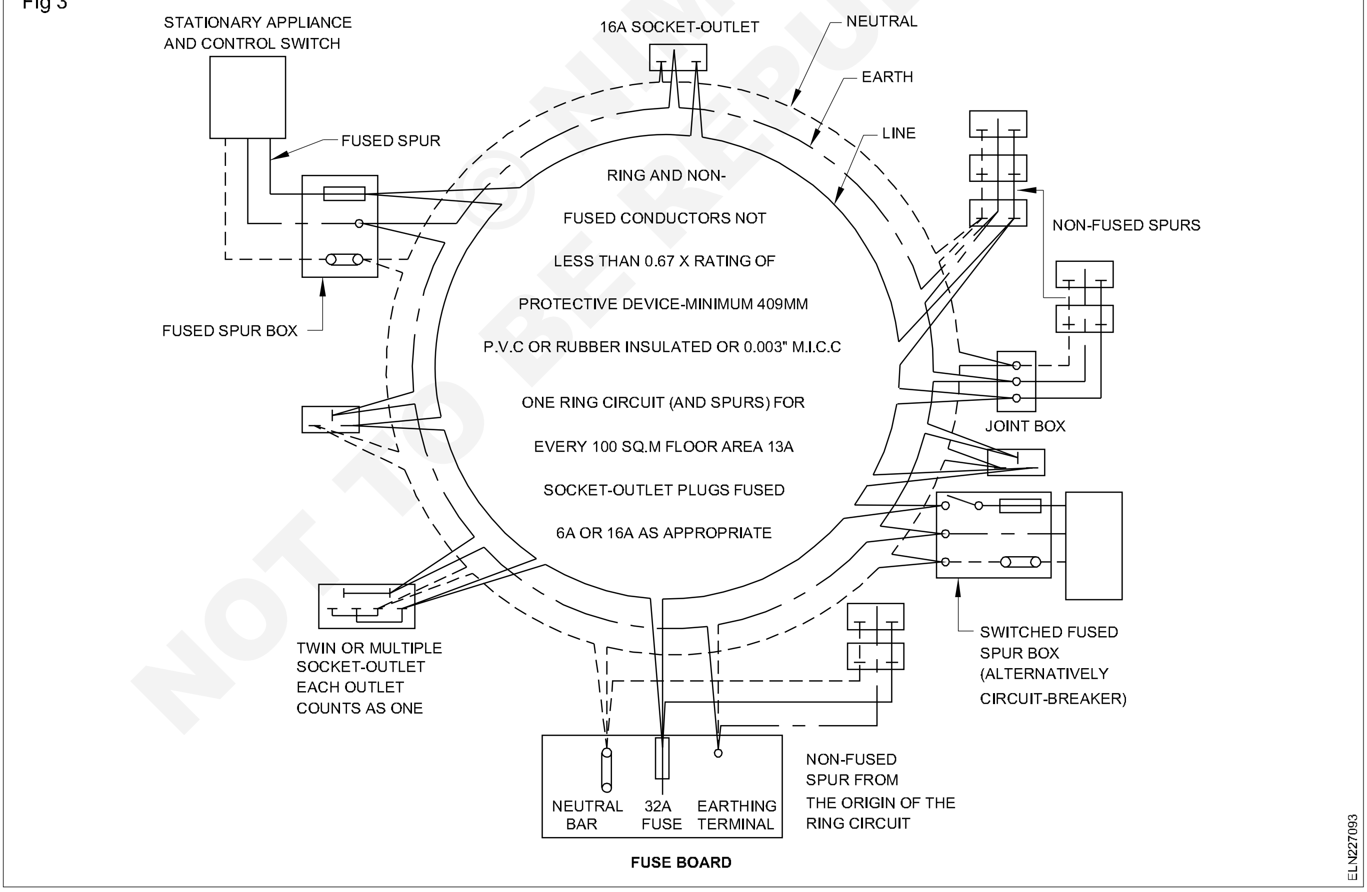


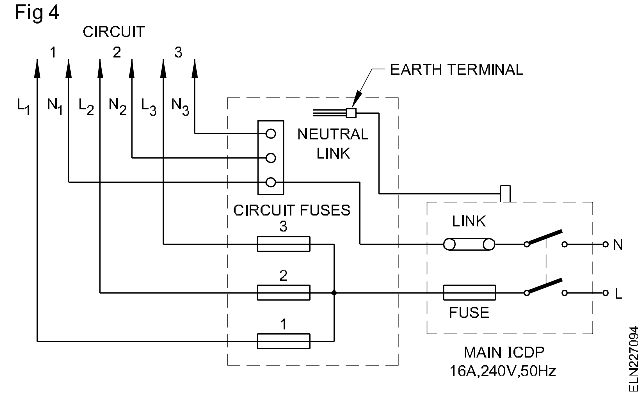
Fig 3



As per IEE regulations one ring circuit has to be there for every 100 sq metres of the floor area or part thereof. The number of power plugs fed from branch lines (spurs) should not exceed two and the total current should not exceed 30 amps. Protection for individual power plug can be provided by having built-in-fuses with the individual power plugs or by having MCB type switch and socket arrangement.

Distribution board system: This is the most commonly used system. This system enables the appliances connected to the system to have the same voltage. The main switch is connected to the distribution board through suitable cables. The distribution board has a number of fuses depending upon the number of circuits required in the installation, and the phase and neutral cable of each phase are taken from the distribution board (Fig 4).

Fig 4

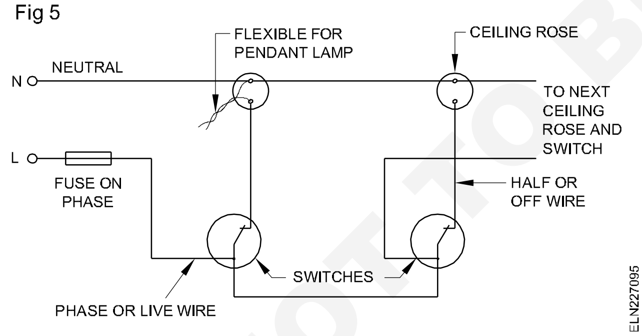


As each circuit can have power up to 800 watt, the phase wire which is taken from the circuit fuse of the distribution board is looped to the other light switches or fan switches of the same circuit by any one of the following ways.

No joint is allowed in the cable route except in switches, ceiling roses and joint boxes.

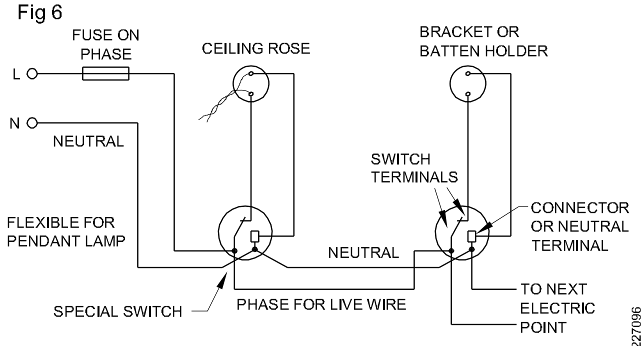
a **Looping out from switch and ceiling rose:** Fig 5 shows the simple looping in method which is commonly employed. The phase wire which is connected to the terminals of the switch is looped out to the next switch and so on, whereas the neutral wires are looped together from ceiling roses (Fig 5). Cable consumed in this system is very high.

Fig 5



b **Looping out from switch:** This system employs special switches having two terminals and one connector (Fig 6). Both the phase and neutral cables are taken to the switch for looping the cables. As these accessories are not commonly manufactured in India such a system is not used.

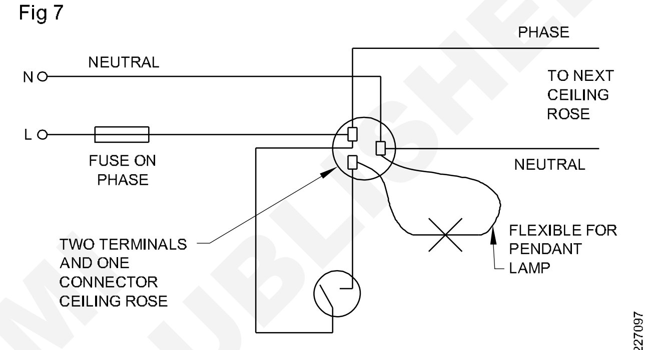
Fig 6



WIRING WITH TWO TERMINALS AND ONE CONNECTOR SWITCH

c **Looping out from 3-plate Ceiling roses:** In this type of system, three terminal ceiling roses need to be used. As this system uses less cables when compared to (a), this system is in use in some parts of India. (Fig 7)

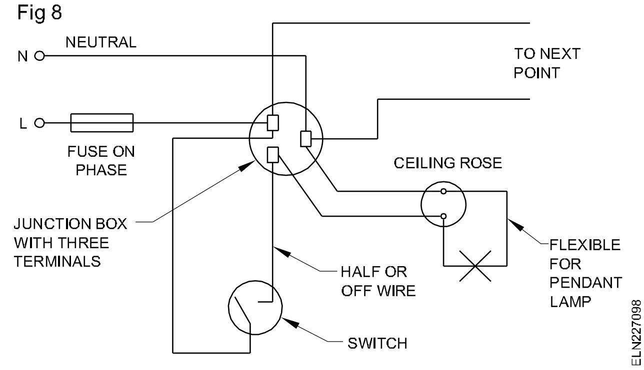
Fig 7



WIRING WITH THREE TERMINALS CEILING ROSE

d **Looping out with junction box:** In this system a pair of conductors from the distribution board is brought to the junction box and tappings are taken to switches, two plate ceiling roses as well as other points from the junction box. This method may be economical for lodges where a row of rooms are constructed on either side of a common corridor. (Fig 8)

Fig 8



Principle of laying out of domestic wiring

Objectives: At the end of this lesson you shall be able to
- **explain the layout, installation plan, circuit -diagram, wiring diagram and state their uses**
- **state the B.I.S. regulation pertaining to wiring installation.**

In electrical wiring work, the electrician is supplied with a layout of wiring installation and an installation plan initially.

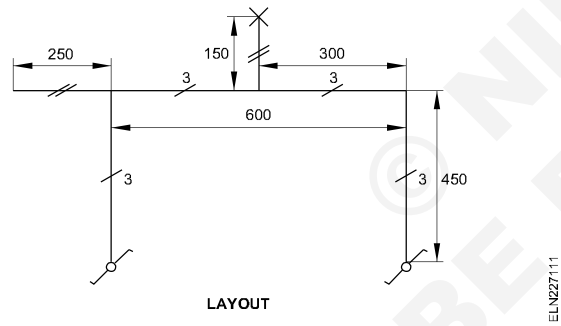
On the basis of the layout and installation plan, the electrician should draw the circuit and wiring diagrams before the commencement of work for systematic execution of the work.

The terms used in wiring installation drawings are explained here.

Layout diagram: Some customers give their requirements in writing. But a few can give them in the form of a layout diagram to the electrician.

The layout diagram (Fig 1) is a simplified version of the wiring diagram. Its purpose is to inform the reader quickly and exactly, what the circuit is designed for without giving any information on the circuit itself.

Fig 1



This type of layout diagram is used for preparing architectural diagrams, plans, etc. of a building.

In a layout diagram, it is necessary to indicate with symbols details like whether the wiring is on the surface or concealed, and the run `up' or `down', the number of wires in run, dimensions, and accessories with appropriate I.S. symbols.

Installation plan (Fig 2): This plan shows the physical position of accessories in an installation, and also gives the final appearance of the installation.

Circuit diagram (Fig 3): This shows the schematic connections of the circuit for a specific task in the simplest form, incorporating the graphical symbols.

The purpose of a circuit diagram is to explain the function of the various accessories in the circuit. Fig 3 is an example of a circuit diagram for controlling a lamp from two different places.

Wiring diagram (Fig 4): This is the diagram in which the position of the components in the diagram bears a resemblance to their actual physical position.

Fig 2

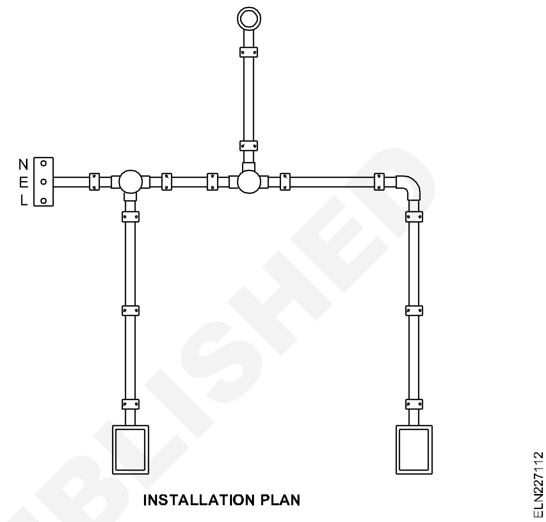


Fig 3

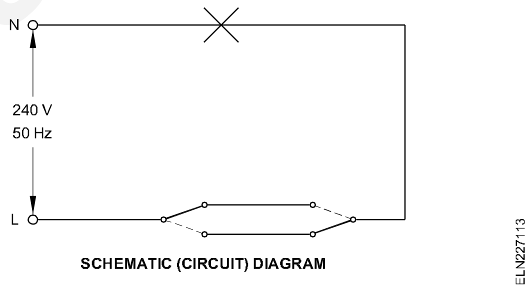
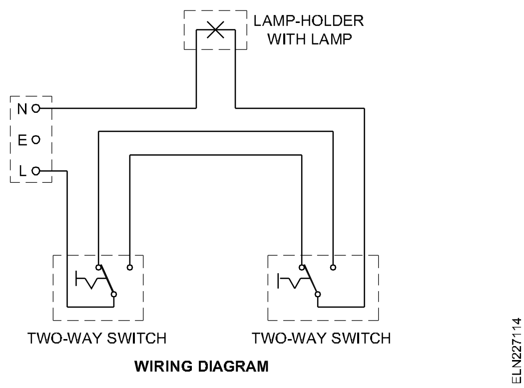


Fig 4 also shows the wiring plan for controlling a lamp from two different places with their actual locations.

Fig 4



For his own good and to facilitate quick location of faults at a later stage, the customer should insist on the electrician giving him a copy of the wiring diagram soon after the completion of wiring.

B.I.S. Regulations and the N .E. code pertaining to wiring installations

The wiring installation shell generally be carried out in conformity with the requirements of the Indian Electricity Act 1910, as updated from time to time and the Indian Electricity Rules 1956, framed thereunder, and also the relevant regulations of the electric supply authority of the concerned area (State Government).

The following are some of the extracts of B.I.S. (Bureau of Indian Standards) regulations pertaining to wiring installations. All the B.I.S. regulations are recommended by the National Electrical Code (NEC).

B.I.S. regulations pertaining to wiring installations

Wiring: Any one of the following types of wiring may be used in a residential building.

- Tough rubber-sheathed or PVC-sheathed or batten wiring.
- Metal-sheathed wiring system
- Conduit wiring system:

  a rigid steel conduit wiring

  b rigid non-metallic conduit wiring
- Wood casing wiring

Permissible load in sub circuit and power circuit

Sub-circuits - different types: The sub-circuits may be divided into the following two groups:

- Light and fan sub-circuit
- Power sub-circuit.

After the main switch, the supply shall be brought to a distribution board. Separate distribution boards shall be used for light and power circuits.

Light and fan sub-circuits: Lights and fans may be wired on a common circuit. Each sub-circuit shall have not more than a total of ten points of lights, fans and 6A socket-outlets. The load on each sub-circuit shall be restricted to 800 watts. If a separate circuit is installed for fans, the number of fans in that circuit shall not exceed ten.

Power sub-circuits: The load on each power sub-circuit should normally be restricted to 3000 watts. In no case shall there be more than two outlets on each sub-circuit.

If the load on any power sub-circuit exceeds 3000 watts, the wiring for that sub-circuit shall be done in consultation with the supply authority.

Lighting : A switch shall be provided adjacent to the normal entrance to any area for controlling the general lighting in that area. The switches should be fixed on a usable wall space and should not be obstructed by a door or window in its fully open position. They may be installed at any height up to 1.3m above the floor level.

The light fittings in kitchens should be so placed that all working surfaces are well illuminated and no shadow falls on them when in normal use.

For bathrooms, it is recommended to use ceiling lighting with the switch located outside the bathroom.

It is recommended that lighting facilities be provided for lighting of all steps, walkways, driveways, porch, carport, terrace, etc, with switches for each provided inside the house at a convenient place. If the switches are installed outdoors, they should be weatherproof.

Waterproof lighting fittings should be used for outdoor lighting.

Socket-outlets: All plugs and socket-outlets shall be of 3-pin type, the appropriate pin of the socket being connected permanently to the earthing system.

An adequate number of socket-outlets shall be placed suitably in all rooms so as to avoid the use of long lengths of flexible cords.

Only 3-pin, 6A socket-outlets shall be used in all light and fan sub-circuits. 3 pin, 16A socket-outlets shall be controlled by individual switches which shall be located immediately adjacent to it. For 6A socket-outlets, if installed at a height of 130 cm above the floor level, in situations where a socket-outlet is accessible to children, it is recommended to use shuttered or interlocked socket-outlets.

Dining rooms, bedrooms, living rooms, and study rooms, if required, shall each be provided with atleast one 3-pin, 16A socket outlet.

No socket-outlet shall be provided in the bathroom at a height less than 130 cm.

Fans: Ceiling fans shall be wired to ceiling roses or to special connector boxes. All ceiling fans shall be provided with a switch besides its regulator.

Fans shall be suspended from hooks or shackles with insulators between the hooks or shackles and also with insulators between the hooks and suspension rods.

Unless otherwise specified, all ceiling fans shall be hung not less than 2.75 m above the floor.

Flexible cords: Flexible cords shall be used only for the following purposes.

- For pendents
- For wiring of fixtures
- For connection of transportable and hand-held appliances

Mounting levels of the accessories and cables as recommended in B.I.S. and N.E.C.

Height of main and branch distribution boards should be not more than 2m from the floor level. A front clearance of 1 m should also be provided.

All the lighting fittings shall be at a height of not less than 2.25 m from the floor.

A switch shall be installed at any height 1.3 m above the floor level.

Socket-outlets shall be installed either 0.25 or 1.3 m above the floor as desired.

The clearance between the bottom point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades of the fan shall not be less than 300 mm.

The cables shall be run at any desired height from the ground level, and while passing through the floors in the case of wood casing and capping and T.R.S. wiring, it shall be carried in heavy gauge conduit 1.5 m above floor level.

References

I.S. 732-1963

I.S. 4648-1968

N.E. Code

Selection of the type and size of cable for a given wiring installation and voltage drop concept

Objectives: At the end of this lesson you will be able to
- **state the factors to be considered for selecting the cable for a circuit**
- **apply the factors and select the cable.**

In order to determine the type and size of the cable for a given circuit, the following points should be taken into account.

- Suitability of the type of cable for the location of the circuit and the type of wiring.
- Size of the cable depending upon the current carrying capacity of the cable.
- Size of the cable depending upon the length of the wiring and permissible voltage drop in the cable.
- Minimum size of the cable based on the economy.

Location of the circuit and the type of wiring decide the type of cable.

It is necessary to consider whether the installation is for industry or domestic use and whether the atmosphere is damp or corrosive. Accordingly the type of cable has to be chosen.

Further the type of wiring determines the type of cable suitable for the installations.

The current carrying capacity of the cable decides the size of the cable.

In this, the first step is to find out the current expected to flow in the circuit when the total connected load is fully switched on. This current is the maximum current that would flow through the circuit in case all the loads are working at the same time. But this is not the case in actual situations.

Diversity factor

In the case of lighting installation all the lamps in a domestic installation may not be switched 'on' at the same time. Hence, it is assumed only two thirds of the lights (say 66%) only will be 'on' at a given time. This introduces a factor called 'diversity factor'.

When the connected load is multiplied by the diversity factor you get a load value which can be said as normal working load. Use of this diversity factor enables the technician to use a lesser size cable than the one calculated, based on the connected load.

Based on the working load the current in each circuit is to be calculated and the size of the cable suitable to carry the current has to be chosen.

Voltage drop in the cable

In any current carrying conductor, voltage drop takes place due to its internal resistance. This voltage drop in a premises as per BIS 732 should not be more than 3 percent of the standard supply voltage when measured between the consumer supply point and any point of the installation when the conductors are carrying the maximum current under the normal conditions of service.

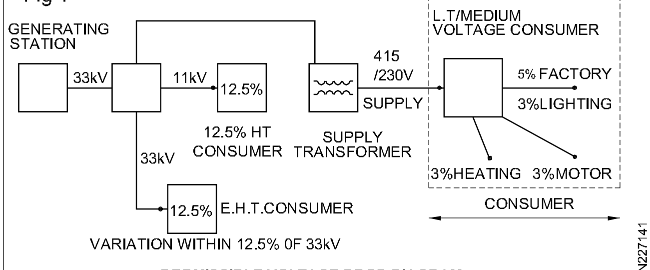
Tables 3 and 4 for aluminium cable and 5 for copper cable give the relation between voltage drop and length of the cable run for various cables. In case the voltage drop found in the cable exceeds the stipulated limit of 3% voltage drop, the technician has to choose the next bigger sized cable to maintain the voltage drop within limits.

If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the load or the cable rating whichever is minimum, to ensure the desired protection (BIS 732).

Declared voltage of supply to consumer

On the other hand according to IE Rule No.54, the voltage at the point of commencement of supply at the consumer should not vary from the declared voltage by more than 5 percent in the case of low or medium voltage or by more than 12 percent in the case of high or extra high voltage (Fig 1).

Fig 1



PERMISSIBLE VOLTAGE DROP-DIAGRAM

At this stage it is better to remember that when current flows through a conductor, the resistance offered by the conductor produces heat. The increase in heat is proportional to the cable resistance which in turn depends upon the cross-sectional area of the cable. Since overheating damages the insulation, the conductor size must be adequate to prevent this from occurring.

While choosing the cable size, voltage drop is a more severe limitation than any other criterion. Hence, it is advisable to select the cable size only after ascertaining the permissible voltage drop. Excessive voltage drop impairs the performance of heating appliances, lights and the electric motors.

Calculation of voltage drop

In DC and single phase AC two-wire circuits

Voltage drop = Current x Total resistance of cables

= 2 IR

where I is the current and

R is the resistance of one conductor only

Wherever voltage drop is given as 1 volt drop per metre run of cable, we have to assume that both (lead and return) cables are taken into account and the cable carries its rated current. In such cases the voltage drop for X metre length of cable for a current of Y amps is calculated as given.

$$\left\{\begin{matrix}\text{Voltage} \\ \text{drop}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{Length of} \\ \text{the cable}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Actual current} \\ \text{of the load}\end{matrix}\right\}}{\left\{\begin{matrix}\text{Metre length of} \\ \text{the cable per one} \\ \text{volt drop}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Rated current} \\ \text{of the cable}\end{matrix}\right\}}$$

$$= \frac{\text{XY}}{\left\{\begin{matrix}\text{Metre length of} \\ \text{the cable per one} \\ \text{volt drop}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Rated current} \\ \text{of the cable}\end{matrix}\right\}}$$

3-phase circuits

$$\text{Voltage drop} = 1.73 \text{ x I R} = \sqrt{3}\,\text{IR}$$

where I is the line current

R is the resistance of one core only.

The above points could be explained through the following set of examples.

Example 1

A guest house installation has the following loads connected to the three phase 415 V supply with neutral. Select a proper size of cable for this installation.

1 Lighting - 3 circuits of tungsten lighting total 2860 watts

2 Power from 3 x 30A ring circuits to 16A socket outlets for

a 1 x 7 KW Water heater (Instant)

b 2 x 3 KW Immersion heater (Thermostatically controlled)

c Cooking appliances: 1 x 3 KW cooker

1 x 10.7 KW cooker

Current demand in amperes in each of the circuit is calculated by referring the Table 1. Calculate current taking account into the diversity factor.

Assuming the declared voltage as 240 volts and the length of the longest run in a circuit as 50 metres

Permissible voltage drop at the rate of 3%

$$= \frac{3 \text{ x } 240}{100} = 7.2 \text{ Volts}$$

If the size of the conductor selected is 35.0 sq.mm which can carry 69 amps, the voltage drop at 69 amperes rating will be 1 volt for every 7.2 metres cable run.

For 50 metres cable run the voltage drop at 69 amps current rating = 50 / 7.2 volts.

Voltage drop for 65 amps

$$= \frac{50 \text{ x } 65}{7.2 \text{ x } 69} = 6.54 \text{ Volts}$$

As the actual voltage drop in the circuit, that is 6.54 volts, is well within the permissible value, of 7.2 volts, the cable selected is suitable for the installation.

Table 1

Sl. No	Demand description	Current Demand (Ampere)	Diversity Factor (Table 2)	Current allowing for Diversity (Ampere)
1	Lighting	11.9	75%	9.00
2	Power i ii iii	30 30 30	100% 80% 60%	30 24 } 72.00 18
3	Water heaters (inst)	29.2	100%	29.2
4	Water heaters (thermo)	25.00	100%	25.00
5	Cooker i ii	12.5 44.5	80% 100%	10.00 44.5
Total current		= 213.1		189.7

Total current demand (allowing diversity) = 189.7 amps
Load spread over 3 phases = 189.7/3 = 63.23 amps, say 65 amps per phase.

Metal conduit pipe - methods of cutting, threading and bending

Objectives: At the end of this lesson you shall be able to
- **state the methods of cutting a metal conduit pipe**
- **state the purpose and process of threading and list out the precautions of conduit pipes**
- **list the different accessories used in conduit installation**
- **state the purpose and methods of bending the conduit pipes and list out the precautions.**

Cutting: Rigid and intermediate conduits may be cut with a hacksaw (Fig 1) or a pipe cutter (Fig 2) . With either method, the conduit must be locked in a pipe vice before making the cut.

After cutting (Figs 1 and 2) the inside edge of the conduit must be smoothed with a half round file (Fig 3) or a pipe reamer mounted in a brace.

Fig 1

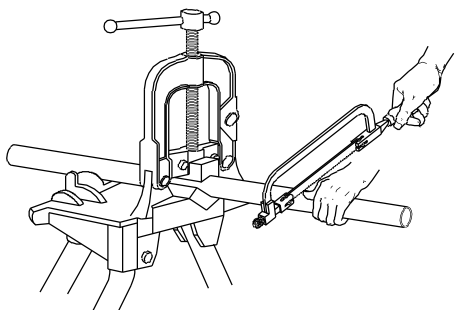
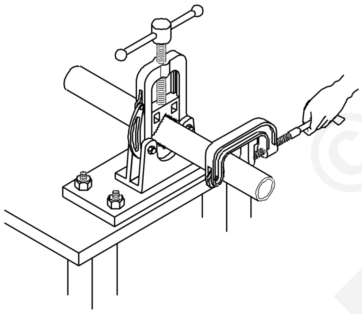
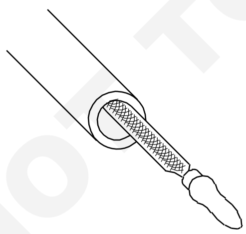


Fig 2



CUTTING A PIPE USING A PIPE CUTTER

Fig 3



DEBURRING PROCESS

Threading: Conduit is threaded by using dies and a die stock. Apply cutting oil to the end of the conduit before starting to cut threads. Cutting the threads longer than necessary will leave the exposed threads subject to corrosion.

Do not use any lubricant which is an electrical insulator, as this may increase the resistance of the conduit assembly and affect its use as the circuit protective earthing conductor.

Precautions to be observed while threading conduit pipes

1 Chamfer the end of the conduit to be threaded.

2 Apply a lubricant frequently while threading the conduit pipe. It helps the die to cut more easily and the die to stay sharp.

3 Reverse turnings of the die stock are necessary to break off cut chips and to clear the cutting edges of the die.

4 Use only a brush to remove the metal burrs from the die. Do not use your hand.

Conduit fittings like elbows, bends and Tees: All these fittings are available in two categories.

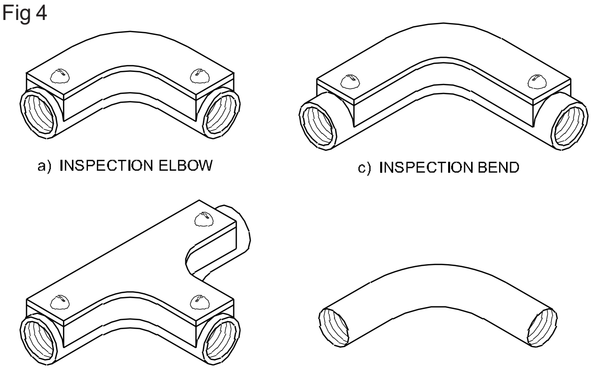
- Normal
- Inspection type

They are made from cast iron.

Elbows are suitable for short bends whereas bends are suitable for long bends. In general where a conduit runs between the wall and the ceiling, elbows are used. (Fig 4a,b & d)

Tees are used in switch-drops and diversions. Various types of these accessories (Fig 4c).

Fig 4



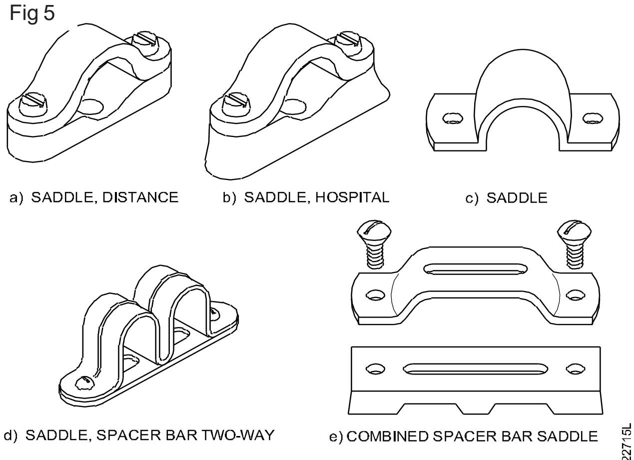
CONDUIT ACCESSORIES

Conduit saddles are used to fasten the conduit on the surface of the walls. These saddles could be used along with any one of the following bases. They are:

- spacers made from sheet metal
- distance piece made from wood or PVC
- hospital piece made from wood or PVC.

Various types of these base fittings along with the saddles are shown in Fig 5.

Fig 5

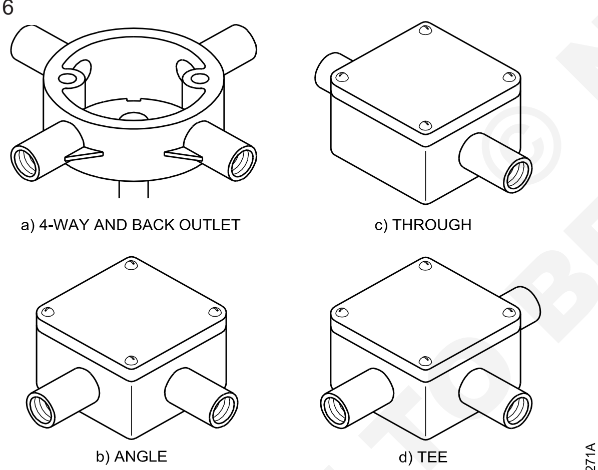


CONDUIT SADDLE ASSEMBLY

Metal conduit boxes: Termination of rigid conduits is done at metal conduit boxes of either cast iron or sheet metal. Various shapes and sizes of boxes are commercially available in the market. Junction boxes of round, square, rectangular and hexagonal shapes are manufactured for one-way, 2-way, 3-way and 4-way outlets.

These outlets may be straight, angular or tangential as required for the situation. When ordering, the specification should contain the material with which the box is to be made, the size of the conduit to be fitted, the number of ways, shape and the position of outlets. (Fig 6)

Fig 6



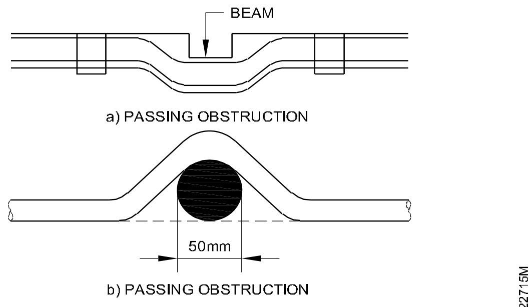
CONDUIT OUTLET BOXES

Conduit pipe bending: It is often necessary to set or bend the conduit to enable it to pass over an obstruction (Fig 7) or to turn a corner which is less or more than 90^0 (Fig 8). The bending may be a little offset to the line of conduit installation. This can be manipulated by proper bending as required.

The bending may be done by using a simple bending block or by a hickey or with the help of a bending machine. Further, in concealed conduit wiring, the B.I.S. recommends bending of conduit pipes in preference to the use of bends and elbows.

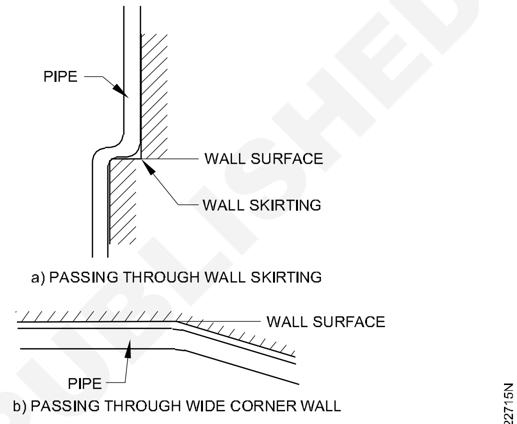
Using bending block for bending conduit: The bending block (Fig 9) is made preferably with teak wood or strong country wood, and should have holes suitable for the conduit to be bent. Edges are chamferred to avoid kinks in the bent portion of the conduit. Light gauge conduits need to be filled with sand and heated before bending to have smooth bends.

Fig 7



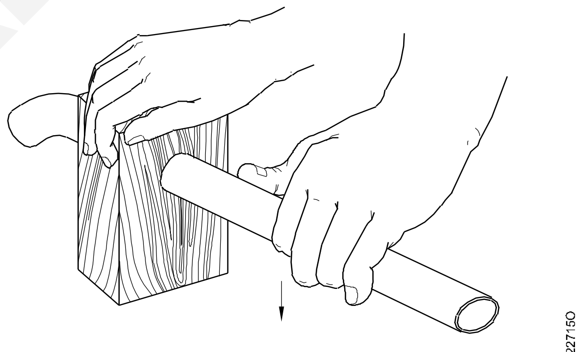
OFFSETTING THE CONDUIT RUN

Fig 8



CONDUIT RUN THROUGH OFFSET WALL SURFACE

Fig 9



BENDING CONDUIT WITH THE BENDING BLOCK

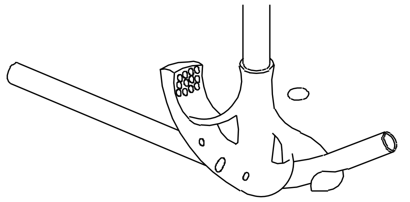
Using hickey for bending conduits: A hickey is a special bending tool (Fig 10) and is made of forged steel or alloy steel. A particular size of pipe requires that size of hickey. Bending of pipes could be performed cold or hot by using a hickey.

Using bending machine for bending conduit: Various types of bending machines are available in the market. They can either be operated by hand (Fig 11) or by hydraulic pressure. For each size of conduit, the guide and collet need to be changed.

Precautions to be observed while bending

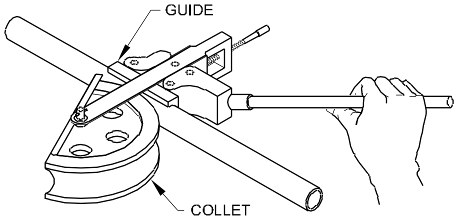
- The pipe used should be mechanically strong to withstand the pressure while bending.

Fig 10



BENDING CONDUIT WITH THE HICKEY

Fig 11



BENDING CONDUIT WITH THE BENDING MACHINE

- Poorly seam-welded pipes are not suitable for bending as they may split while bending.
- One of the easy methods of bending is to draw the bending curve on the floor and bend the pipe accordingly.
- When a wooden block is used for bending, chamfer both sides of the hole opening in the block.
- Ensure that the conduit does not twist while bending.
- Use a proper size of hickey according to the dia. of the pipe to be bent.
- While doing manual hot bending do not use wet sand as the steam generated during heating may cause an explosion.

Test board, Extension board and colour code of cables

Objectives: At the end of this lesson you shall be able to
- **explain the method of using a test board**
- **state the general colour codes used in cables.**

Test board: A test board is an electric switch board, used for conducting the following tests.

- **Continuity test** (Load connected in series with a lamp)

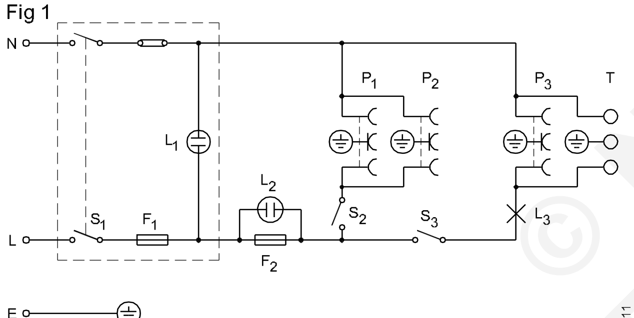
  Example: Testing of fan winding, condition of choke and tube light starter etc.

- **Direct test**

  Example : Testing electrical appliances of 1000 watts or lower rating for proper functioning.

Fig 1 source the schematic diagram of a test board with all the outlets and controls. Sockets P_1 and P_2 provide direct, single-phase supply whereas socket P_3 and terminal block T provide a single-phase supply in series with the lamp L_3.

Fig 1



TEST BOARD
SCHEMATIC DIAGRAM

Continuity test: While performing a continuity test, the appliance to be tested is connected to the socket P_3 or to the terminal T which are in series with the lamp L_3 and are controlled by switch S_3. Normally this test is conducted by the electrician to ascertain whether the appliance is open-circuited or short-circuited. A low wattage, appliance when connected, will make the lamp L_3 to burn dim, and a high wattage appliance will make the lamp to burn bright.

According to the brightness of the lamp, the behaviour of the appliance, as well as the wattage of the appliance and the lamp and the condition of the appliance could be judged. `No light' indicates either open circuit or high resistance in the appliance. In the same way, a choke coil and a starter of a tube light can be checked. (The flickering of the lamp L_3 with the starter indicates that the starter is good.)

Thus the testing board also works as a continuity tester.

Direct testing: By connecting the appliance direct to the socket P_1 or P_2, the performance of the appliance can be verified after repair.

Fuses: If the indicator lamp L_1 does not burn, it indicates no supply. On the other hand, in normal conditions, the indicator lamp L_2 will not burn, and it burns only when the fuse F_2 is open.

Thus the test board is a cheap and handy test set which is easy to use by an electrician to carry out his routine checks in the course of his work.

Colour identification of cables: The colour of the cables indicates their function. Table 1 gives the colour code and the alpha-numeric notation as recommended by N.E.Code.

The rules apply for marking conductors in equipment/ apparatus/installation.

Table 1

Alpha-numeric notation and colours

Designation of		Identification by	
		alpha	colour
Supply AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Apparatus AC system	Phase 1	U	Red
	Phase 2	V	Yellow
	Phase 3	W	Blue
	Neutral	N	Black
Supply DC system	Positive	L+	Red
	Negative	L-	Blue
	Mid-wire	M	Black
Supply AC system (Single phase)	Phase	L	Red
	Neutral	N	Black
Protective Earth conductor		PE	Green and yellow
Earth		E	Colour of the bare conductor.

Extension board (Fig 2)

Extension boards are used to operate portable electrical appliances/ machines. It is also used where more number of sockets are required at a time.

Extension boards are available in different shapes with PVC (or) plastic boxes provided with 2 core (or) 3 core cables and moulded plugs. Extension boards are available in 6A and 16A ratings.

Fig 2

EXTENSION BOARDS

ELN227212

Conduit wiring - types of conduits - non-metallic conduits (PVC)

Objectives: At the end of this lesson you shall be able to
- **distinguish between the different types of conduits used in wiring**
- **state the different types of accessories used in non-metallic conduits wiring.**

In general, conduit is defined as a tube or channel, which is the most commonly used in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

Types of conduits

There are four types of conduits used for wiring.

- Rigid steel conduits
- Rigid non-metallic conduits
- Flexible conduits
- Flexible non-metallic conduits.

Non-metallic conduits

These are made of fibres, asbestos, polyvinyl chloride (PVC), high density polyethylene (HDP) or poly vinyl (PV). Of the above, PVC conduits are popular owing to their high resistance to moisture and chemical atmosphere, high dielectric strength, low weight and low cost. These conduits may be buried in lime, concrete or plaster without harmful effects.

However, light gauge (lower than 1.5 mm wall thickness) PVC pipes are not as strong as metal conduits against mechanical impact. Special PVC pipes which are heavy gauge and high impact resistance are available in the market which can withstand heavy mechanical impact as the thickness of the pipe is more than 2 mm.

There are some PVC heavy gauge conduits having special base material made to withstand temperatures up to 85°C. These PVC conduits are available in 3 m length.

Variation in conduit wiring systems

There are two types of conduit wiring systems as stated below, for either metallic or non-metallic types.

- Surface conduit wiring system done on wall surfaces.
- Concealed (recessed) conduit wiring system done inside the concrete, plaster or wall.

Selection of the type of conduit

Metallic or PVC conduits are equally popular in electrical installations. Selection of the type of conduit depends upon the following criteria.

- Type of location, outdoor or indoor
- Type of atmosphere, dry or damp or explosive or corrosive
- Expected working temperature
- Exposure to physical damage due to mechanical impact
- Allowable weight of conduit runs
- Estimated cost.

Special precautions with non- metallic conduits

1 If the conduits are liable to mechanical damages they should be adequately protected.

2 Non-metallic conduits shall not be used for the following applications.

3 In concealed/inaccessible places of combustible construction where the ambient temperature exceeds 60°C.

4 In places where the ambient temperature is less than 5°C.

5 For suspension of fluorescent fittings and other fixtures

6 In areas exposed to sunlight.

PVC fittings and accessories

Couplers (Fig 1)

Normally push type couplers are used and the conduit shall be pushed right through to the interior of the fittings. Inspection type couplers are used in straight conduit runs to assist in the inspection of the cables.

Fig 1

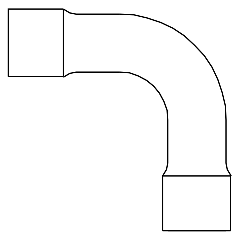
TYPES OF COUPLERS

ELN227221

Elbow (Fig 2)

The axis of any elbow shall be a quadrant of a circle plus a straight portion of each end. Elbows are used at sharp ends of nearby walls or roof and wall.

Fig 2



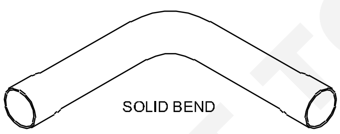
ELBOWS

ELN227222

Bends (Fig 3)

A bend gives a diversion of 90ºC in the turn of a conduit, and a normal bend shall be a large sweep. Inspection type bends are used to assist in the inspection at the corners and for drawing cables.

Fig 3



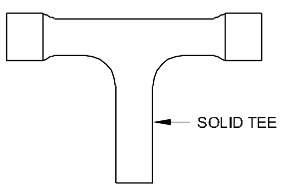
BENDS

ELN227223

Tees (Fig 4)

Tees are used to take diversion from the main line either to the switch points or the light points. It may be either an ordinary type or an inspection type. Inspection type tees are used to assist in the inspection in case there is a need.

Fig 4

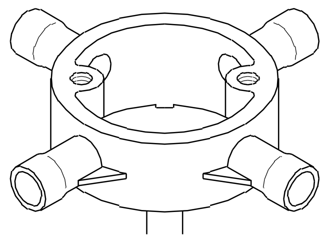


TEE

ELN227224

Circular boxes (Fig 5)

Fig 5



CIRCULAR BOXES

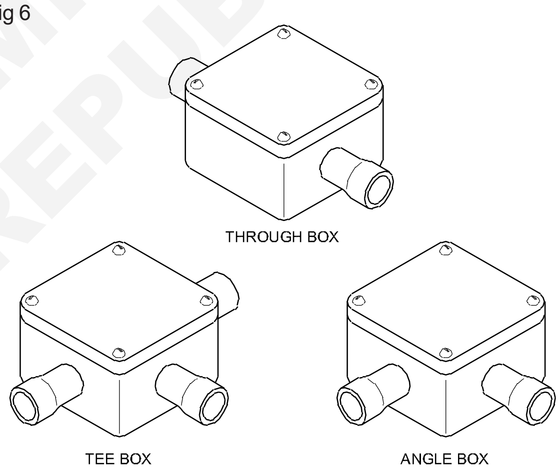
ELN227225

Small circular boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the covers. Large circular boxes have four machine screws of not less than 4 mm diameter having not less than 10mm threaded portion for fixing the cover.

They are available in a single-way, two-way, three-way and four-way as well as back outlet types which can be used as per necessity in wiring. The minimum depth of junction boxes used in roof slabs shall be 65 mm. The cover of the circular box shall be made of the same material as that of the the box, and have a minimum thickness of 1.6 mm.

Apart from the above various other types are used as junction boxes. (Fig 6)

Fig 6



TYPES OF BOXES (JUNCTION BOXES)

ELN227227

Method of cutting, joining and bending PVC conduit pipes

While doing the conduit wiring, it becomes essential, that the length has to be increased or decreased. Further the conduit is to be bent according to the required situation.

Cutting PVC conduit

A PVC conduit is easily cut by holding at the corner of a bench and using a hacksaw. Any roughness of cut and burrs should be removed with the aid of a knife blade/emery sheet, or sometimes by using a reamer. Before installing the PVC conduit pipe great care should be taken to remove the burrs inside the pipes to avoid damage to the cables during the cable drawing process.

Joining conduit with fittings

The most common jointing procedure uses a PVC solvent adhesive. Before applying the adhesive the inner surface of the accessory and the outer surface of the PVC pipe shall be cleaned with emery sheet to have a better grip. The adhesive should be applied to the receiving portion of the conduit fitting, and the conduit twisted into it to ensure a total coverage.

Generally, the joint is solid enough for use after two minutes although complete adhesion takes several hours. In order to ensure a sound joint, the tube and fittings must be clean and free from dust and oil.

Where expansion is likely and adjustments become necessary a mastic adhesive should be used. This is a flexible adhesive which makes a weatherproof joint, ideal for surface installations and in conditions of wide temperature variation. It is also advisable to use the mastic adhesive where there are straight runs on the surface exceeding 8 metres in length.

Conduit fittings should be best avoided, as far as possible, on outdoor systems.

Bends in conduit

All bends in the non-metallic system shall be formed either by bending the pipes by proper heating or by inserting suitable accessories such as bends elbows or similar fittings. Solid type fittings shall be used for recessed wiring. Solid type/inspection type of fittings shall be used for surface conduit wiring.

The minimum bending radius of conduits shall be 7.5 cm. Care should be taken while bending the pipes to ensure that conduit pipes are not damaged or cracked and the internal diameter is not effectively reduced.

In recessed conduit wiring, conduit bending, other than at the ends, shall be made by bending the pipes to the required angle and clamping at short intervals. In the case of conduits laid in the roof slab, it can be clamped or tied to steel reinforcement bars with suitable metallic clamps.

In the case of conduits recessed on walls, the chasis shall be made in the required shape and conduit fixed in the groove with suitable clamps. In the case of bending for surface conduit system, bending can be done either at cold state or by proper heating.

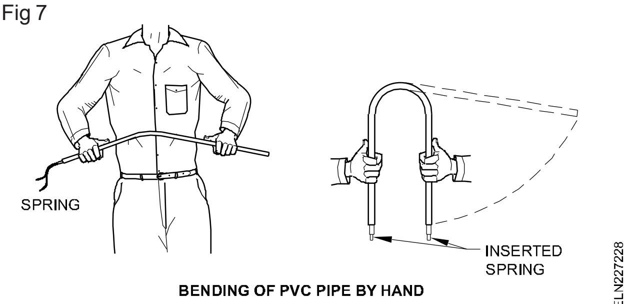
Bending PVC conduit in cold weather (Fig 7)

In cold weather it may become necessary to warm the conduit slightly at the point where the bend is required. One of the simplest ways to do this is to rub the conduit with the hand or a cloth. The PVC will retain the heat created long enough for the bend to be made. In order that the bend is maintained at the correct angle, the conduit should be saddled as quickly as possible.

Bending of conduit by heating

The piece of conduit to be bent is first cut and inspected for any sharp edges or burrs left out. In such cases it shall be made smooth by using suitable emery sheet. The conduit is then filled with river sand. The ends are sealed with suitable dummy covers. The portion where the bend is to be made shall be heated uniformly (Fig 8a) to a temperature below its melting point.

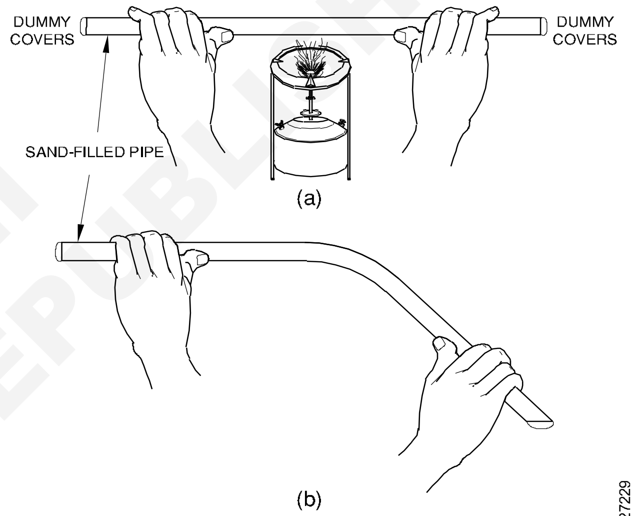
Fig 7



BENDING OF PVC PIPE BY HAND

Then bend the required angle is made by holding both sides, with sufficient gap from the heated portion to avoid burning of hands, and applying uniform pressure (Fig 8b). Care shall be taken to avoid kinks on the conduits while bending.

Fig 8



HOT BENDING OF THE PVC PIPE

In PVC conduit wiring the first step is to select the correct size of conduit. The conduit size is determined by the size of cables and the number of cables to be drawn in a particular section. This information can be obtained from the wiring layout and the wiring diagram.

Selection of conduit size

A non-metallic conduit pipe, used in wiring, should have a minimum size of 20 mm in diameter. Where a large number of conductors are to be drawn, the size of the diameter depends on the size of the conductor and the number of conductors. Table 1 gives details of the numbers and the sizes of conductors that can be drawn in each size of a non-metallic conduit.

When 2.5 sq mm 650 V grade single core cables of six numbers are to be drawn in a single run, we can use 25 mm non-metallic conduit as per the table.

When 6 sq mm. 650 V single core 6 cables are to be drawn in a single pipe we can use 32 mm PVC pipe. The following are the maximum permissible number of 650/1100V volts grade single core cables that may be drawn into rigid non-metallic conduits (Table 1).

TABLE 1

Maximum number of PVC insulated 650 V/1100 V grade aluminium/copper conductor cable drawing through conduits conforming to IS: 694-1990.												
Nominal Cross- sectional area of condutor in sq.mm	**20 mm**		**25 mm**		**32 mm**		**38 mm**		**51 mm**		**70 mm**	
	S*	B*	S	B	S	B	S	B	S	B	S	B
1.50	5	4	10	8	18	12	–	–	–	–	–	–
2.50	5	3	8	6	12	10	–	–	–	–	–	–
4	3	2	6	5	10	8	–	–	–	–	–	–
6	2	–	5	4	8	7	–	–	–	–	–	–
10	2	–	4	3	6	5	8	6	–	–	–	–
16	–	–	2	2	3	3	6	5	10	7	12	8
25	–	–	–	–	3	2	5	3	8	6	9	7
35	–	–	–	–	–	–	3	2	6	5	8	6
50	–	–	–	–	–	–	–	–	5	3	6	5
70	–	–	–	–	–	–	–	–	4	3	5	4

* **The above table shows the maximum capacity of conduits for a simultaneous drawing in of cables.**

* **The columns headed 'S' apply to runs of conduits which have a distance not exceeding 4.25 m between draw in boxes and which do not deflect from the straight by an angle of more than 15 degrees. The columns headed 'B' apply to runs of conduit which deflect from the straight by an angle of more than 15 degrees.**

* **Conduit sizes are the nominal external diameters.**

PVC Channel (casing and capping) wiring

Objectives: At the end of this lesson you shall be able to
- **state the use limitation and rules of channel wiring system**
- **select the channel size according to size and number of cables from the chart**
- **explain the method of fabricating neutral, bend, and junction in PVC channel .**

Introduction : Channel (Casing and Capping) wiring is a system of wiring in which PVC/metallic channels with covers are used for drawing wires. This system of wiring is suitable for indoor surface wiring works. This system is adopted to give a good appearance and for extension of existing wiring installation. PVC insulated cables are generally used for wiring in casing and capping system. This is otherwise called 'wireways'.

The channel and top cover shall be of the same material either PVC or anodised aluminium. The casing is square or rectangular in shape. The capping shall be slide in type with double grooving in the case of PVC wire ways. Plain type capping are used for metallic wireways.

The only disadvantage in a channel wiring is that it is inflammable and risk of fire.

Dimensions : The sizes of channel, the maximum number of wires which can be drawn in each size are given in the table 1 below.

The thickness of channel should be 1.2mm ± 0.1mm.

Table 1

Nominal cross sectional area of conductor in sq.mm	**10/15mm x 10mm size channel**	**20mm x 10mm size channel**	**25mm x 10mm size channel**	**30mm x 10mm size channel**	**40mm x 20mm size channel**	**50mm x 20mm size channel**
	No. of wires	**No. of wires**	**No. of wires**	**No. of wires**	**No. of wires**	**No. of wires**
1.5	3	5	6	8	12	18
2.5	2	4	5	6	9	15

4	2	3	4	5	8	12
6	-	2	3	4	6	9
10	-	1	2	3	5	8
16	-	-	1	2	4	6
25	-	-	-	1	3	5
35	-	-	-	-	2	4
50	-	-	-	-	1	3
70	-	-	-	-	1	2

Precautions

1 Neutral (Negative) cables should be carried in top channel and phase (Positive) in the bottom channel.

2 Crossing of cables between phase (Positive) and neutral (Negative) should be avoided.

3 Porcelain or PVC pipe should be used for crossing the cables through the walls.

Installation of PVC channel : The channel should be fixed to wall/ceiling with flat headed screws and rawlplugs. These screws shall be fixed at an interval of 60cm. On either side of joints this distance shall not exceed 15cm from the end point. Channel under steel joints shall be fixed with MS clips of not less than 1.2mm (18SWG) thickness and width not less than 19mm.

Floor/Wall crossings : When conductor pass through floors/wall the same should be carried in a steel conduit/ PVC conduits properly bushed at both ends. The conduits shall be carried 20cm above floor level and 2.5cm below ceiling level and properly terminated into the channel.

Joints in PVC/Metal channel : As far as possible wireways in straight runs should be single piece. All joints shall be scarfed or cut diagonally in longitudinal section. The section ends shall be filed smoothly but joined without any gap. Care shall be taken to see that the joints in PVC cover does not overlap those channel.

Joints shall also be done using standard accessories like elbows, tees, 3 ways/4 ways junction box etc of high grade PVC/Aluminium alloy. In PVC channel separate channel cover for joint, elbows, tees, cross etc are available. These can be fixed after fixing the channel to give a good appearance. The radius of curvature of the cables inside a bend should be more than 6 times its over all diameter.

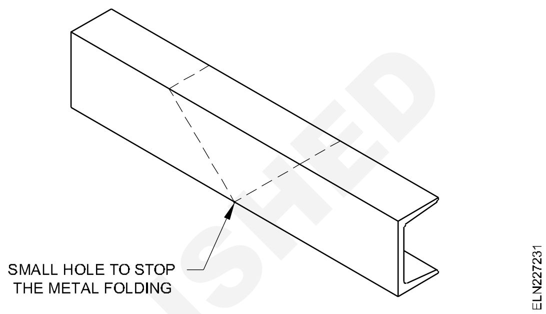
In the case of PVC channel, making joints is comparatively easy. Mark the joints by placing the two pieces in required angle. Identify the position to be cut and remove on each pieces. Cut through the lines and file the edges to get gapless joint.

Fabricating a right-angled vertical bend

1 Mark out the position of bend of all sides as shown in Fig 1. the width 'Y' must be made equal to the diagonal length 'Y' to be cut.

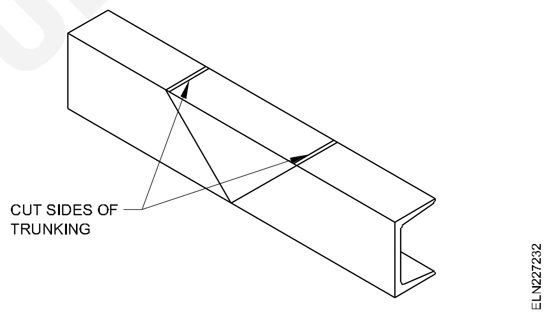
2 Drill small holes in corners at point of bend to stop channel folding (Fig 1).

Fig 1



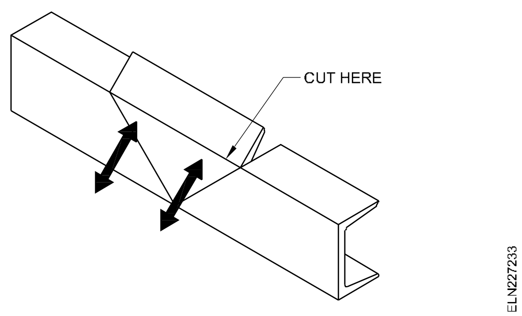
3 Place wood blocks inside trunking for support. Cut sides of trunking (Fig 2).

Fig 2



4 Cut, file and break-off waste (Fig 3).

Fig 3



5 File all the edges smooth in order to bend to shape (Fig 4).

6 Make 'L' plates out of PVC scrap (Fig 5).

7 Make and secure assembly with 'L' plates and paste it with suitable adhesive (Fig 6).

Fabricating 90° bend

1 Mark out the position of bend (Fig 7a & b).

Fig 4

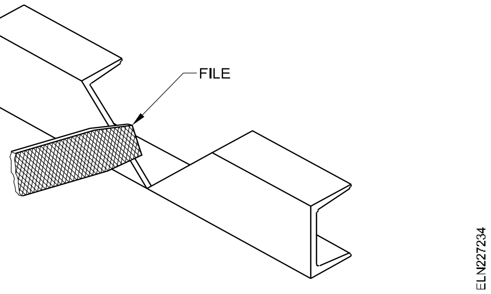


Fig 5

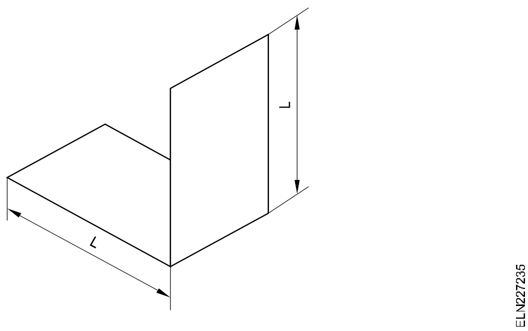


Fig 6

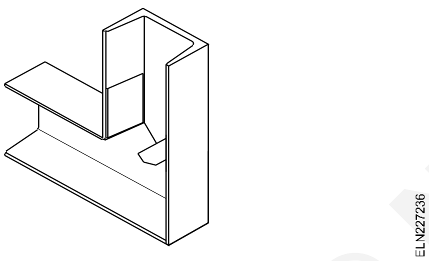
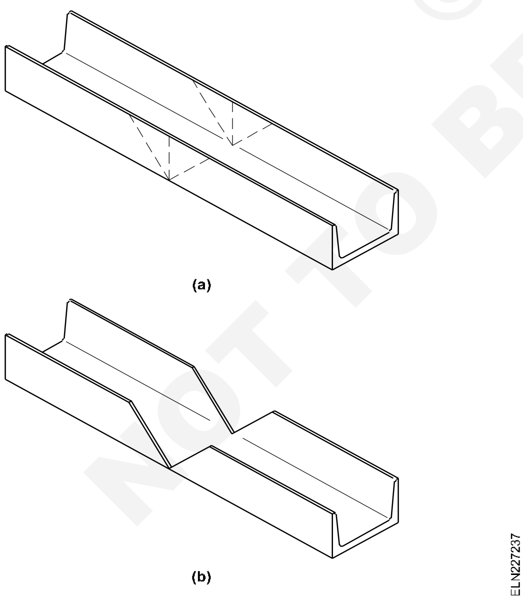


Fig 7



2 Place wood blocks in trunking for support and make cuts with hacksaw.

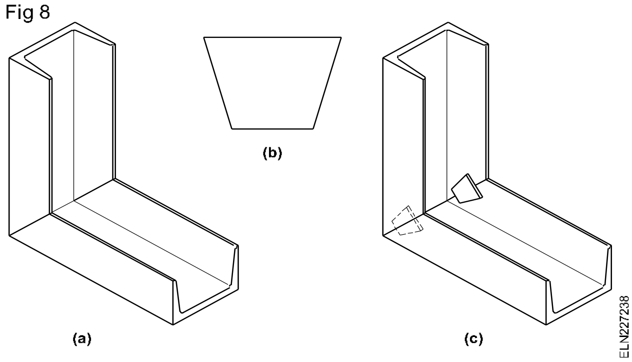
3 Remove sections and file smoothly.

4 Bend shape and adjust the fit as required (Fig 8a, b & c).

5 Make fish plates from PVC scrap (Fig 8b).

6 Make and secure the assembly with fish plate (Fig 8).

Fig 8



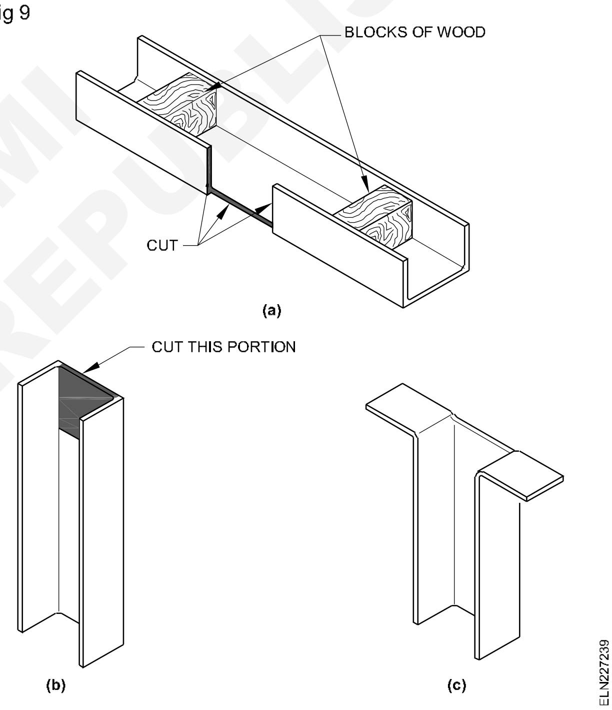
Fabricating a Tee junction

1 Mark out the position of tee using another piece of trunking to gauge width

2 Cut out the space for the tee (Fig 9a). Blocks of wood should be used to support section being cut.

3 In another piece cut away the section (Fig 9b) to form two legs (Fig 9c).

Fig 9

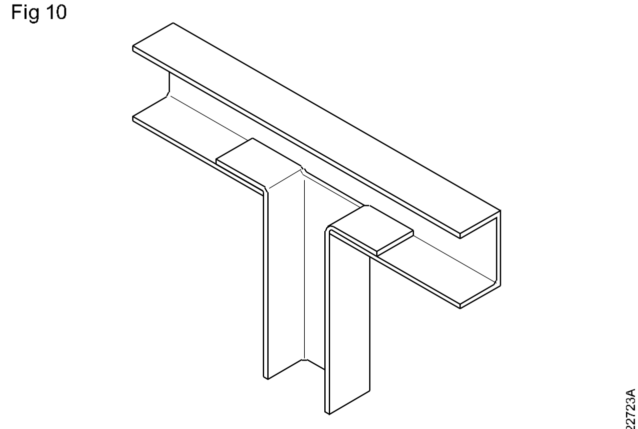


4 File edges smooth and remove burrs. Check fit and adjust as necessary.

5 Make, assemble and secure the Tee junction using suitable adhesive (Fig 10).

Installation of cables : Cables carrying the direct current or alternate current shall always be bunched seperately so that the outgoing and return cables are drawn in the same channel. Clamps shall be provided to hold the wires inside the channel at suitable intervals, so at the time of opening of the cover of channel, the wires do not fall out.

Fig 10



ASSEMBLEDTEE JUNCTION

Attachment of cover : Cover should be attached to channel in individual sections after drawing all wires inside. No screws or nails shall be used for fixing PVC capping (cover) to the casing (channel). The capping (cover) should be slided in through the grooves. Metallic capping (cover) shall be fixed by using cadmium plated screws in a staggered manner with axial spacing not exceeding 30cm.

Earth continuity conductor : Earth continuity conductor shall be drawn inside the casing and capping (channel) for earthing of all metallic boxes of the installation as well as for connecting to earthpin of the socket.

Power wiring

Objectives: At the end of this lesson you shall be able to
- **state the power, control, communication and entertainment wiring.**

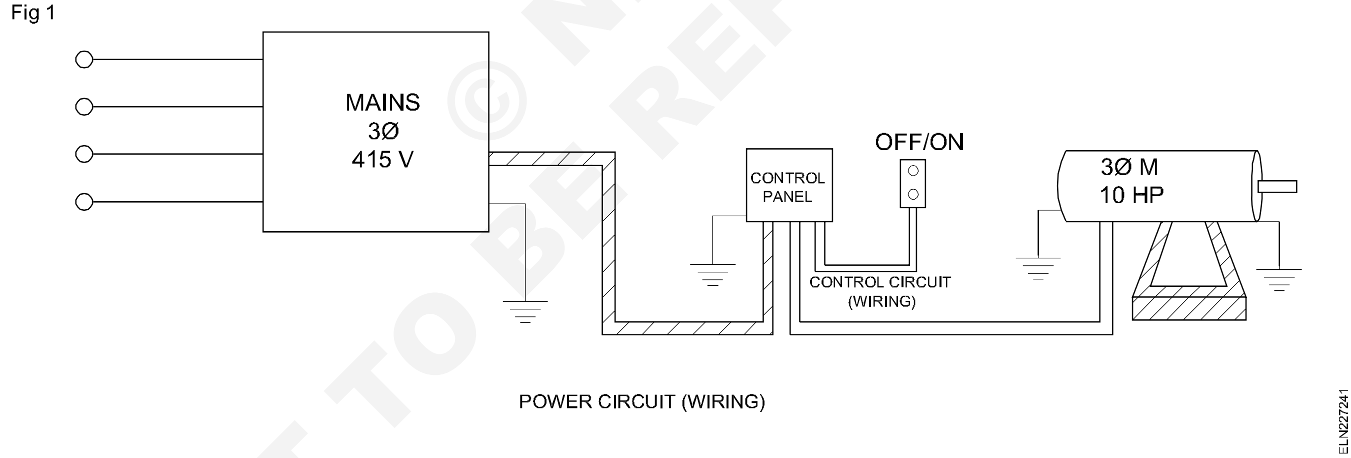
A panel wiring diagram usually gives information about the relative position and arrangement of devices and terminals of the devices to help in installing or servicing the device.

Generally all the control panel / commercial / industrial wiring invariably consists of two sections viz control wiring and power wiring.

Fig 1 shows the typical layout diagram of a motor wiring. The control panel consisting of all the control and protective devices installed near to the power source and the load like, furnace, compressor etc, are installed away from the power source / panel boards.

Power wiring is a high current carrying circuit which is wired to connect / disconnect the load like motors/ furnace through the protective devices like OLR and fuses etc..

Fig 1



Power wiring has to be done as per the guideline and rules specified in IE rules. The cable size depends on the load current and it varies according to the load.

The power and control cable should not be run into single conduit. As the current radiation influences the control cable, a seperate conduit to be provided for control and power cables.

Control wiring

Control wiring is a circuit which is wired to communicate the commands and other information between control devices and lighting.

Control wiring enables the control circuit for various control purpose. In a motor control unit the control circuit is wired and kept near to motor. In other system such as fire alarm, fire detector etc. The control circuit is wired seperately with low current carrying condutors and drawn seperately for easy maintenance.

Fire alarm

The purpose of fire alarm system is to provide an immediate alarm in case of any fire and to prevent loss of life, also to secure the immediate attention of fire fighting staff.

Fire detectors

The three principal fire detection method involve sensing the heat, presence of flame or smoke. The third method identifies the pre - fire condition that is a flammable gas detector, which is techniclaly not a fire detector and its use is limited to places where flammable gases are likely to be present.

I Heat detector

The three basic operating principles for heat detection are:

a Fusion detector (melting of a metal)

b Thermal expansion detector

c Electrical sensing

II Smoke detectors

There are three types of smoke detectors namely

1 Ionisation detector

2 Light - scattering smoke detector

3 Obscuration smoke detector.

III Flammable gas detector

A flammable gas detector is designed to measure the amount of flammable gas in the atmosphere. The gas mixture is drawn over a catalytic surface where oxidation i.e. combustion takes place. The combustion causes a rise in temperature of the surface which is measured by a decrease in its electrical resistance. The instruments are calibrated by considering pentane or heptane as reference gas. The readings are displayed in terms of percentage of lower explosive limit.

Control panel for fire alarm system

The control panel is the heart of the system through which the fire alarm system is monitored and alarm is initiated if any indication/signal is conveyed to the panel.

The working of the fire alarm system should be checked once in a month regularly.

The features of the control panel are the power supply, battery charging unit and control card.

Communication wiring

It is type of wiring which is used to transmit the voice, data, images and video etc to the desired places.

Some of examples are

- Telephone wiring
- Internet / LAN network wiring
- Cable TV and other entertainment wiring
- Data and security services wiring
- Telex/ Fax machines wiring

Faster and more reliable than ordinary phone wiring, low-cost, high-tech copper wiring should serve every room in the modern home. Its is required to carry voice, data and other services from where they enter the house to every room, and from any one room to any other.

Necessity of communication wiring

Unshielded twisted pair (UTP) copper information wiring often called structured wiring is used today for offices, schools and factories to provide local area networks (LANs), which allow computers to talk to one another and to receive and send Internet and high-speed computer data outside the facility.

Educated homebuyers-and homebuilders realize it is better to use the most advanced wiring technology up front, when installation is economical.

It's better to anticipate the homeowner's future needs by wiring the house with a state-of-the-art system while it is being built, and at the same time equip yourself with a powerful marketing tool.

The phone wiring of the past, often referred to as quad wiring because it has four copper wires, is now obsolete. Cat 5 or higher speed wiring has four twisted wire pairs, or eight wires.

Copper UTP Wiring

Copper UTP wiring contains eight color-coded conductors (four twisted pairs of copper wires). It offers greatly increased bandwidth compared with old-fashioned quad wiring.

The cable is small (roughly 3/16 inch in diameter), inexpensive and easy to pull, although it must be handled with care.

Advantages

Modern copper UTP wiring offers the following advantages:

Diversity

The Internet and computer communications, as well as ordinary phone signals, can be carried throughout the home on modern, inexpensive, high-speed, UTP cables. (To service a large number of TV channels, it is recommended to also run high-quality coaxial cable, such as quad-shielded RG-6.)

More phone numbers

Several phone numbers can be made available throughout the house. Actually, voice service requires very little bandwidth, and the addition of separate numbers is almost trivial.

Fig 1 is a simplified plan of a small, two-bedroom, single-story house. Note that all the wiring radiates from a single distribution device the star pattern and there are multiple outlets in each major room, including the kitchen and the porch.

Entertainment wiring

It is a type of wiring which is mainly used for entertainment or relaxation purpose.Example Home theatre wiring.

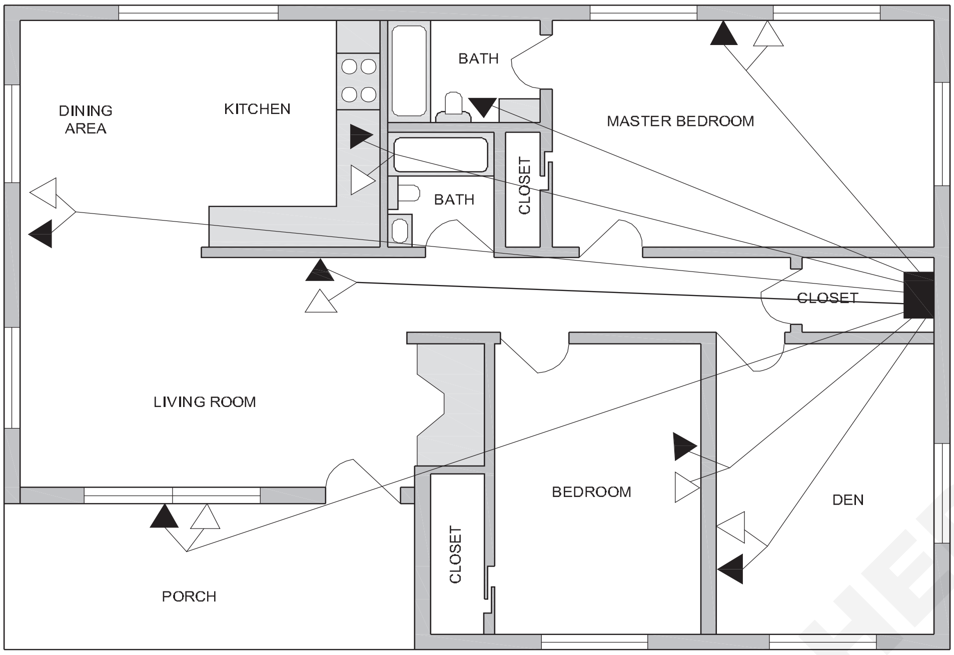
The nature and quality of wiring will not only determine the level of safety in home theatre room, but equally important, will have a noticeable impact on the video and sound quality of your system components.

Home Theatre Wiring Basics: Safety, planning, budgeting

When it comes to home theatre wiring, the guiding principle is...

- Do it safe
- Do it once
- Do it right

Fig 1



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Safety: This is a most important aspect in any installation. Do not save on the wiring by using sub-standard cables.

With in-wall installations, Specially certified wires (UL-rated CL3 wires) should be used that comply with national standards for resistance to fire, chemicals, abrasion, and temperature extremes.

Planning: Planning is the key to future proofing the installation while avoiding costly alterations later on.

AV (Audio Video) equipment and speaker placement the room lighting requirements, networking, possible future additions, etc. are to be taken care of these will determine the quantity and placement of the various audio/video points in the room as well as the electrical needs for home theatre installation.

Finally, when it comes to estimating the required cable lengths, do not just calculate the linear lengths to complete your cable runs; allow for at least 20% extra to cover for possible errors and slack for terminations.

Home Theatre Speaker Wiring

Many fail to realize that home theatre wiring can have a noticeable impact on speaker performance. The greatest speakers will not sound their best with the use of inappropriate speaker wires or an incorrect wiring installation. In particular, selecting the correct speaker wire thickness is essential for the best speaker performance.

At the same time, keep in mind that some speaker manufacturers use non-standard connectors with their speakers; in these circumstances, use of optional third-part speaker wire and connectors may not always be an option unless you take the extreme route of splice your wiring.

Speaker Wire Size

Selecting the correct thickness for your home theater wiring is important as it affects the speakers' performance; it will impact the speakers' ability to deliver the explosive effects in home theatre sound.

Single Room Installation

The thicker wire will help bring out fine musical detail in quality music systems, as well as deliver the explosive effects of surround sound.

In those situations where long speaker wire runs cannot be avoided, thicker wire helps reduce the overall resistance, and therefore amplifier load - leading to lower operating temperatures. This will result in improved sound quality and long-term stability.

After setting up a modestly priced home-theatre-in-a-box package, do not go for the more expensive thicker wire unless you plan an upgrade sometime in the future; using of gauge 16 speaker wire should suffice in this case.

Connection Basics

Speakers and amplifiers/receivers normally come equipped with one of two types of connectors - spring terminals or binding post connectors.

Each speaker connection have two such terminals marked (+) and (-) to help you distinguish the two leads. Maintaining correct polarity all along your home theater wiring is important. For this reason, speaker wire and terminals are normally color coded black for the -ve terminal and red for +ve side.

Spring terminals will only accept pin connectors or tinned base wire ends. Instead, binding posts accept many types of connection, including pin, banana plug or spade.

Guidelines for Home theatre wiring & installation

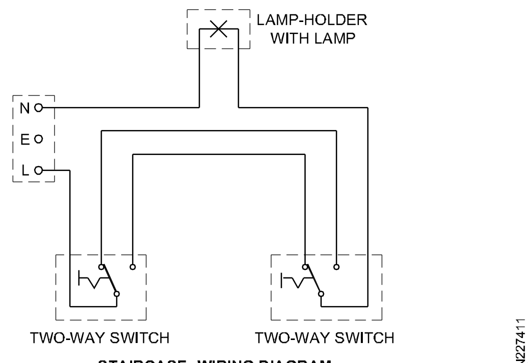
- Do not run home theatre cables in close proximity or parallel to other electrical lines, nor run your wiring around power supplies as these can lead to interference issues with both your audio and video system components.

Special wiring circuits - Tunnel, corridor, godown and hostel wiring

Objectives: At the end of this lesson you shall be able to
- **state the difference between godown, tunnel and corridor, bank/hostel wirings**
- **draw the tunnel lighting / corridor / bank / hostel circuits**
- **prepare the mode chart for the above circuits.**

Staircase wiring: In wiring one lamp controlled with one switch in a simple wiring circuit to begin with. However,one lamp controlled with two switches from two different places, known an staircase wiring in the very basic wiring. Fig 1 shows such a wiring where two double pole switches are used to control one lamp individually.

Fig 1



STAIRCASE–WIRING DIAGRAM

In the case of **godown wiring** we have seen that as you move inside the godown, you can switch on a lamp ahead of you while the light behind you is put off. The same process in the reverse order takes place while moving out of the godown.

But one light will not be sufficient to give enough illumination in the case of **tunnels** where darkness is more. Hence, the wiring circuit for a tunnel needs at least two lights to be 'ON' at a time while a person moves inside a tunnel and goes out.

Whereas in the case of **corridor wiring** the corridor may have a number of rooms occupied by different persons. When one moves toward his room, he needs a forward light to do so. The moment he finds the room and opens it, he may not need the corridor light. Then there should be an arrangement to switch off the light left behind the forward moving person and at the same time there should be a provision to switch off the light in front of his room. Such an arrangement is incorporated in corridor wiring.

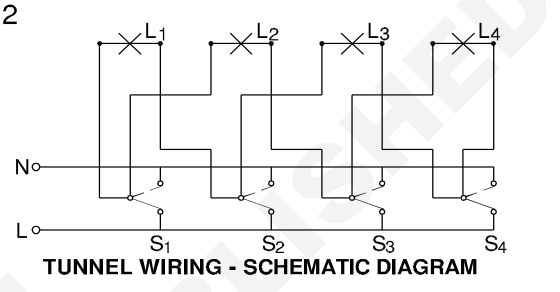
Tunnel lighting circuit (Fig 2)

In tunnel wiring a person walking along the tunnel can successively light behind two lamps ahead and put off a lamp behind with one switch.

All switches are two-way switches.

Caution: This circuit is not in accordance with IE rules as the phase and neutral come in the same switch. So care should be taken while connecting the wires.

Fig 2



TUNNEL WIRING - SCHEMATIC DIAGRAM

The mode of operation of the switches and the consequent lighting position are shown below.

Mode chart for tunnel wiring

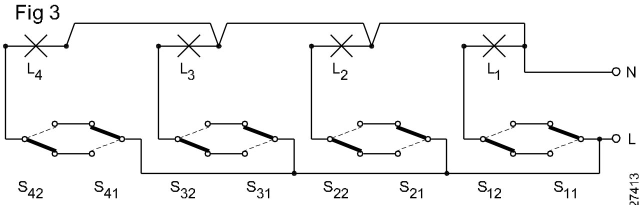
SWITCHES				LIGHTS			
S_1	S_2	S_3	S_4	L_1	L_2	L_3	L_4
✓	✗	✗	✗	✓	✓	✗	✗
✓	✓	✗	✗	✗	✓	✓	✗
✓	✓	✓	✗	✗	✗	✓	✓
✓	✓	✓	✓	✗	✗	✗	✗

MODE CHART FOR TUNNEL WIRING

Corridor wiring (Fig 3)

In this circuit, operating the first switch in one set makes the first light to switch on while operating the 2nd switch in the first set switches off the first light. This sequence goes on as explained in the mode chart.

Fig 3



SCHEMATIC DIAGRAM OF CORRIDOR WIRING

Switch lamps chart

SWITCHES								LAMPS			
Ist SET		2nd SET		3rd SET		4th SET		L_1	L_2	L_3	L_4
S_{11}	S_{12}	S_{21}	S_{22}	S_{31}	S_{32}	S_{41}	S_{42}				
ON	–	–	–	–	–	–	–	✓	✗	✗	✗
ON	OFF	–	–	–	–	–	–	✗	✗	✗	✗
ON	OFF	ON	–	–	–	–	–	✗	✓	✗	✗
ON	OFF	ON	OFF	–	–	–	–	✗	✗	✗	✗
ON	OFF	ON	OFF	ON	–	–	–	✗	✗	✓	✗
ON	OFF	ON	OFF	ON	OFF	–	–	✗	✗	✗	✗
ON	OFF	ON	OFF	ON	OFF	ON	–	✗	✗	✗	✓
ON	OFF	ON	OFF	ON	OFF	ON	OFF	✗	✗	✗	✗

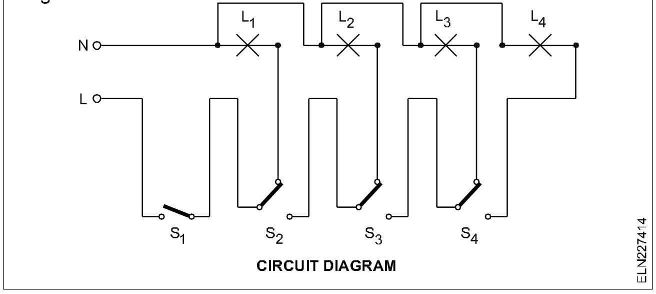
MODE CHART FOR CORRIDOR WIRING

Godown lighting circuit

Let us consider a godown lighting circuit (Fig 4) having four lamps L_1, L_2, L_3 and L_4 which are to be controlled such that if one moves in a godown in either direction he can switch ON one light after the other in the forward direction while the lamp which was lighted earlier gets switched OFF. In an arrangement. S_1 is a one way switch, S_2, S_3 and S_4 are two-way switches.

While coming back from the godown when the person switches off the light 4, then the light 3 will be on and give light for his return movement. When he leaves the godown all the lights could be switched 'off' by operating switch S_1.

Fig 4



The following chart gives the mode of operation of the switches and lights. Trainees are advised to make the return mode chart.

Mode chart for godown wiring

Switches				Lights			
S_1	S_2	S_3	S_4	L_1	L_2	L_3	L_4
ON	OFF	OFF	OFF	ON	-	-	-
ON	ON	OFF	OFF	-	ON	-	-
ON	ON	ON	OFF	-	-	ON	-
ON	ON	ON	ON	-	-	-	ON

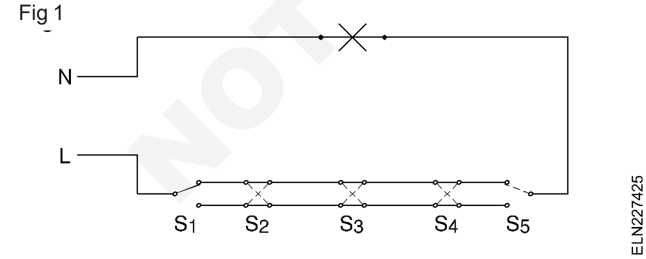
Intermediate switch - Application in lighting circuit

Objectives: At the end of this lesson you shall be able to
- **draw diagrams of a lighting circuit using intermediate switches.**

An intermediate switch is a special type of switch having four terminals for connection. This switch is commonly used to control a lamp or load from three or more positions as encountered in the lighting of staircases, corridors, bedrooms.

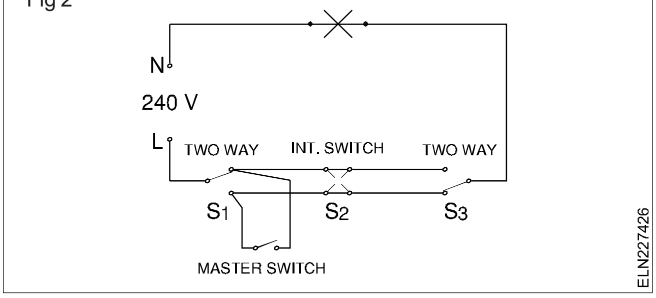
The schematic diagram (Fig 1) is for controlling one lamp from five locations using two two-way switches and three intermediate switches is given below.

Fig 1



In the schematic diagram (Fig 2) is for controlling one lamp from 3 positions with a master control as a security control switch. The lamp is controlled independently from three places by switches S_1, S_2 and S_3. When the master switch 'M' is 'ON' the lamp is permanently 'ON'and cannot be controlled by switches S_1, S_2 and S_3.

Fig 2



As intermediate switches are costly two numbers of two-way switches can be linked through a common bar and can be used as an intermediate switch. This circuit controls one lamp from 3 places.

Main board with MCB DB Switch and fuse box

Objectives: At the end of this lesson you will be able to
- **state the I E regulations/ B I S recommendations/ NE Code of practice with regard to the main board and distribution fuse box.**

Reception and distribution of main supply

There shall be a circuit breaker or a linked switch with fuse in each live conductor of the supply mains at the point of entry.

The neutral wire should not have any break in the form of switch or fuse unit. In the main switch, the neutral conductor should be marked clearly.

The main switchgear shall be located in a place where it is accessible and should be near to the terminating point of the service line.

Main switches and switchboards

Reference BIS 732-1963 and NE code.

All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply.

Location

Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms or laundries, or in bathrooms, lavatories, toilets, or kitchens.

In the case of switchboards unavoidably fixed in places likely to be exposed to atmospheric weather, the outer casing shall be weatherproof and shall be provided with glands or bushings or adapted to receive screwed conduit, according to the manner in which the cables are run.

Metal-clad switchgears shall preferably be mounted on any of the following types of boards.

Hinged type metal boards

These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back.

The joints shall be welded. The board shall be securely fixed to the wall by means of rag bolts, plugs, or wooden gutties and shall be provided with a locking arrangement and an earthing stud. All wires passing through the metal board shall be bushed. Alternatively, hinged type metal boards shall be made of sheet covering mounted on channel or angle iron frames.

Such types of boards are particularly suitable for small switchboards for mounting metal-clad switchgears connected to supply at low voltages.

Fixed type metal boards

These shall consist of an angle or channel iron frame fixed on the wall or on the floor and supported on the wall at the top, if necessary. There shall be a clear distance of one metre in front of the switchboard.

Such types of boards are particularly suitable for large switchboards for mounting large number of switchgears or higher capacity metal-clad switchgear or both.

Teak wood boards

For small installations connected to a single phase 240 volts supply, teak wood boards may be used as main boards or sub-boards. These shall be of seasoned teak or other durable wood with solid back impregnated with varnish of approved quality with all joints dovetailed.

Thoroughly protected both inside and outside with good insulating varnish conforming to IS:347-1952 and of not less than 6.5 mm thickness, shall be provided at the back for attachment of incoming and outgoing cables. There shall be a clear distance of not less than 2.5 cm between the teak wood board and the cover,

Recessing of boards

Where so specified, the switchboards shall be recessed in the wall. The front shall be fitted with a hinged panel of teak wood or other suitable materials, such as Bakelite, or with unbreakable glass doors in teak wood frames with locking arrangement, the other surface of the doors being flush with the walls. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

Arrangement of apparatus

Equipment which is on the front of a switchboard shall be so arranged that inadvertent personal contact with live parts is unlikely during the manipulation of switches, changing of fuses or like operation.

No apparatus shall project beyond any edge of the panel. No fuse body shall be mounted into 2.5 cm of any edge of the panel and no hole other than the holes by means of which the panel is fixed shall be drilled closer than 1.3 cm from any edge of the panel.

In every case in which switches and fuses are fitted on the same pole, these fuses shall be so arranged that the fuses are not live when their respective switches are in the 'off' position.

No fuses other than the fuses in the instrument circuit shall be fixed on the back of or behind a switchboard panel or frame.

Marking of apparatus

Where a board is connected to a voltage higher than 250 volts, all the apparatus mounted on it shall be marked in the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected.

Alternating current

Three phases – red, yellow and blue.

Neutral – black.

Where three-phase, 4-wire wiring is done, the neutral shall be in one colour and the other three wires in another colour.

Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

Main and branch distribution boards

The main and branch distribution boards shall be of any type mentioned here.

The main distribution board shall be provided with a switch or circuit-breaker on each pole of each circuit, a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

Branch distribution boards shall be provided with a fuse on the live conductor of each circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. One spare circuit of the same capacity shall be provided on each branch distribution board. Lights and fans may be wired on a common circuit. Such sub-circuit shall not have more than a total of ten points of lights, fans and socket outlets. The load of such circuit shall be restricted to **800 watts**. If a separate fan circuit is adopted, the number of fans in the circuit shall not exceed ten.

Power sub-circuits

The outlet shall be provided according to the load design for these circuits but in no case shall there be more than two outlets on each circuit. The load on each power sub-circuit should be restricted to **3000 watts.**

Installation of distribution boards

- The distribution fuse-boards shall be located as near as possible to the centre of the load they are intended to control.
- Distribution boards shall be fixed at a height not more than 2 metres from the floor level.
- These shall be fixed on suitable stanchion or wall and shall be accessible for replacement of fuses.
- These shall be of either metal-clad type or all-insulated type. But, if exposed to weather or damp situations, they shall be of weatherproof type and, if installed where exposed to explosive dust, vapour or gas, they shall be of flame proof type.
- Where there are two or more distribution fuse-boards in feeding low voltage circuits and fed from a supply at medium voltage, these distribution boards shall be:
  - fixed not less than 2 m apart; or
  - arranged so that it is not possible to open two at a time, namely, they are interlocked and the metal case is marked 'Danger 415 Volts'; or
  - installed in a room or enclosure accessible to only authorized persons.
- All distribution boards shall be marked 'Lighting' or 'Power' as the case may be and also marked with the voltage and number of phases of the supply. Each shall be provided with a circuit list giving details of each circuit with controls, the current rating and its size of fuse-element.

Wiring of distribution boards

In wiring branch distribution board, the total load of the consuming devices shall be divided, as far as possible evenly between branch circuits.

Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve or lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without cutting away cable strands.

Fuses

a A fuse carrier shall not be fitted with a fuse element of higher rating than that for which the carrier is designed.

b The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.

c Every fuse shall have in its own case or cover, or in an adjacent conspicuous position, an indelible indication of its appropriate current rating for the protection of the circuit which it controls.

Selection of size of conductor

The size of conductors of circuits shall be so selected that the drop in voltage from the consumer's terminals in a public supply (or from the bus-bars of the main switchboard controlling the various circuits in a private generation plant) to any point on the installation does not exceed 3 per cent of the voltage at the consumer's terminals.

In each circuit or sub-circuit the fuse shall be selected to match the cable rating to ensure the desired production.

All conductors shall be of copper or aluminium. The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area of not less than 1.00 mm^2 copper and 1.50 mm^2 aluminium. The cross-sectional areas of conductors for power wiring shall be not less than 2.5 mm^2 copper, 4.00 mm^2 aluminium. The minimum cross-sectional area of conductors of flexible cords shall be 0.50 mm^2 copper.

Branch switches

Where the supply is derived from a three-wire or four-wire source and distribution is done on the two wire system, all the branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or fuse shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit.

Passing through walls and floors

Where conductors pass through walls the conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit or in a porcelain tube of such a size which permits easy drawing in. The end of the conduit shall be neatly bushed with porcelain, wood or other suitable material.This steel conduit shall be earthed andsecurely bushed.

Where a wall tube passes outside a building so as to be exposed to the weather, the outer end shall be bell mouthed and turned downwards and properly bushed on the open end.

Fixing to walls and ceilings

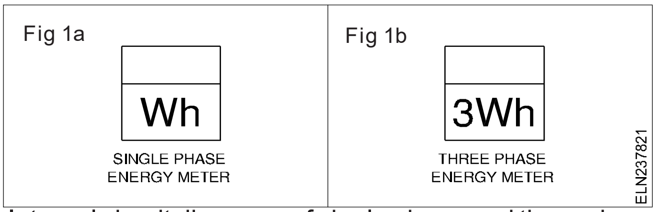
Plugs for ordinary walls or ceilings shall be of well seasoned teak or other suitable hardwood not less than 5 cm long and 2.5 cm square on the inner end and 2 cm square on the outer end. They shall be cemented into walls to within 6.5 cm of the surface, the remainder being finished according to the nature of the surface with plaster.

In the case of new buildings, wherever possible, teak wood plugs shall be fixed in the walls before they are plastered. To achieve neatness, plugging of walls or ceilings may be done by a suitable type of asbestos, metallic or fibre fixing plug.

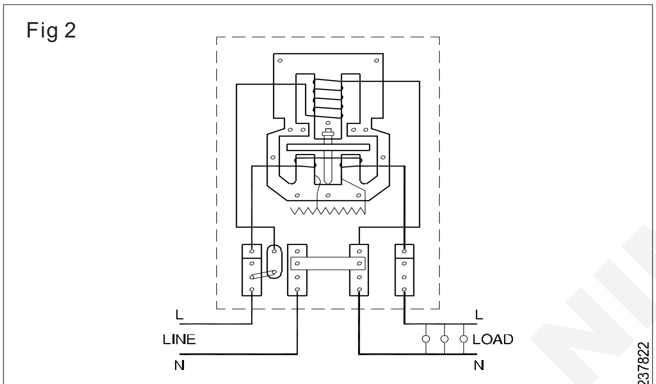
NE code of practice and IE Rules for mounting energy meter board

Objectives: At the end of the lesson you shall be able to
- **state the BIS recommendations pertaining to the mounting of the energy meters.**

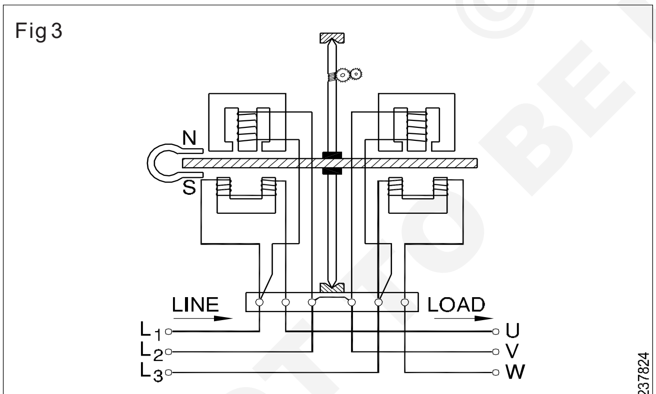
The BIS symbols for energy meters are given in Figs 1a and 1b



Internal circuit diagrams of single phase and three phase meters are Fig 2 and 3 respectively.



INTERNAL CONNECTION OF SINGLE PHASE ENERGY METER



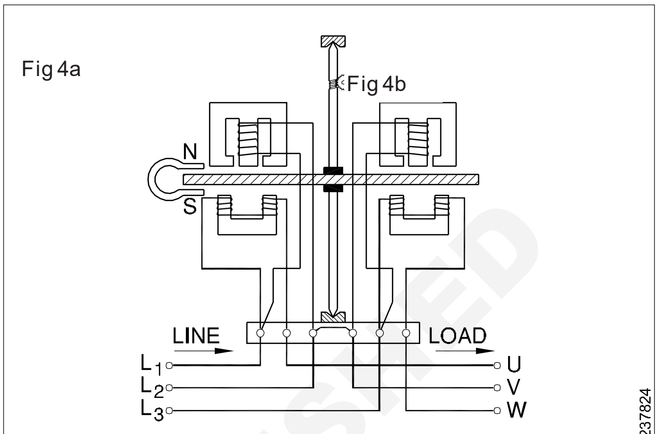
INTERNAL CONNECTIONS OF THREE PHASE ENERGY METER

In earlier domestic installations the service mains were brought inside the consumer premises and first connected to the IC cutouts, then to the energy meter and to the consumer main switch (Fig 4a and 4b)

However, to avoid pilferage of electricity, certain electricity boards insist that the service connections should first be connected to the energy meter, then to the I C cutout and then to the consumer main switch. In all the cases the neutral should be directly connected from the outgoing terminals of the energy meter to the consumer main switch. (Fig 4b)

Precautions while installing energy meters

- Energy meters which are tested and approved by the local electricity board authorities only should be used.



INTERNAL CONNECTIONS OF THREE PHASE ENERGY METER

- Energy meters should be used in vertical position only.
- Connections for incoming and outgoing supply should be made according to the manufacturer's instructions/ connection diagram which will be available on the inner side of the terminal plate of the energy meters.

NE code of practice and IE rules for energy meter installation

Energy meters shall be installed at such a place which is readily accessible to both the owner of the building and the authorised representatives of the supply authority.

It should be installed at a height where it is convenient to note the meter reading; it should preferably be not installed below 1 m from the ground. The energy meters should either be provided with a protective covering, enclosing them completely, except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking it.

Any meter placed upon the consumer's premises shall be of appropriate capacity and shall be deemed to be correct if its limits of error do not exceed 3% above or below absolute accuracy at all loads in excess of one tenth of full loads and up to full load.

No meter shall register at no load.

General instructions : The body of the energy meter should be earthed to the general mass of earth using a proper size of earth continuity conductor depending upon the current capacity of the installation.

For multi-storeyed buildings which consist of a number of offices or commercial centres or flats occupying various areas, the electrical load for each of them is metered separately. In such cases, all the energy meters are located in a meter room which is normally situated on the ground floor.

Estimation of load, cable size, bill of material and cost for a wiring installation

Objectives: At the end of this lesson, you will be able to
- **calculate the load(s) and select the number of sub(branch) circuits**
- **estimate the load in a circuit**
- **select proper cable size for branch main circuits and the supply system**
- **estimate and list out the accessories for given wiring installation.**

A minimum of two lighting sub-circuits shall be provided in each house so that in case of fault in one sub-circuit, the whole house is not plunged in total darkness.

The load on power circuits should be restricted to 3000 watts having not more than two socket outlets.

Estimation of load requirements

Electrical installation in domestic dwellings is basically designed to cater to light and fan loads and for electrical appliances and gadgets. In estimating the current to be carried by any branch circuit, unless the actual values are known, these shall be calculated based on the following recommended ratings.

Item	Recommended rating (in watts)
Incandescent lamps	60
Ceiling fans	60
Table fans	60
6 A, 3-pin socket-outlet points	100
Fluorescent tube	40
Power socket outlets (16 A)	1000

Example

Estimate the cost of material for wiring PVC channel for an office room having 2 lamps 1 fan one 6A socket outlet.

To estimate the cost of material the electrician has to follow these steps:

Type of wiring to be decided- PVC channel (casing and capping - given).

Position of the electrical points/Loads has to be decided as per the requirment.

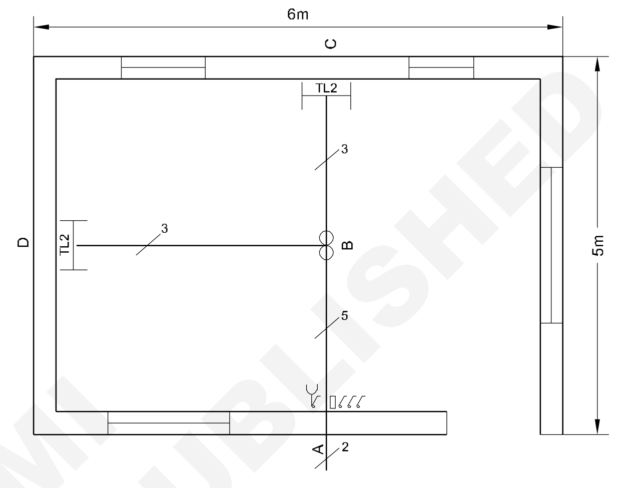
Layout of the office has to be prepared (Fig 1).

Total load to be calculated, In the given example

i	Tube 2nos x 40 W	= 80 W
ii	Fan1no x 60 W	= 60 W
iii	6A socket 1 no	= 100 W
		240 W

circuit/connection diagram for the room has to be developed.

Fig 1



LAYOUT DIAGRAM OF AN OFFICE ROOM

Based on the layout and circuit diagram calculate the length of PVC channel required.

1) Length of PVC channel in Roof = 5 +3 = 8m

2) Vertical drops = 0.5 +0.5 +2.0 = 3.0m

Total = 8+ 3.0 = 11.0 m

3) Add 10% tolerance = 1.1 m

12.1 m

Calculate the length of wire and size of wire based on layout, circuit diagram and load. In the given example,the total load is 240W the current taken by the total load are

$$I = \frac{P}{V \times \cos\theta} = \frac{240}{240 \times 0.8} = 1.25A$$

Hence PVC copper flexible 1sqmm wire is enough to this circuit/room. However since this wiring come in the catagory of commercial wiring, for safe-side, we can choose 1.5sq mm PVC insulated copper flexible wire.

Assume vertical drop is 0.5 m for tube lights and 2m for switch board then the length of wire required is

From A to B and vertical drop = (2.5 +2)m x 5 = 22.5 m

From B to C and vertical drop = (2.5 +0.5) m x 3 = 9m

From B to D

vertical drop	= (3 +0.5)m x 3	=10.5m
total length	= 22.5 + 9 +10.5	= 42m
add 10% telerance	= 42 + 4.2	= 46 m

The maximum number of wire runs in a PVC channel is 5 hence 19 mm x 10mm PVC channel may be used.

List of electrical accessories required with complete specification has to be prepared. Also calculate the cost of materials as per the present market rate.

SI No	Accessories	Length	unit price	price
1	PVC channel 19 mm x10mm	12m		
2	1.5 sq mm PVC insulated copper flexible 650V	46 m		
3	Flush type SPT switch 6 A 250 V	4 No		
4	Flush type socket 6 A 250V	1No		
5	Wooden switch board 250mm x 150mm	1No		
6	Tube light fitting complete set 250V 4 feet 40W	2No		
7	Ceiling fan 250V, 1200 mm sweep	1 No		
8	electrcial fan regulator 250V , 60W	1No		
9	Wood screws 15 x 4mm, 25 x 5mm, 30 x6mm	25 Nos each		
10	PVC insulation tape 19mm width 9m length	1No		
11	Ceiling rose 3 plate 250 V , 6 A	3No		
Total	Cost of the material required			

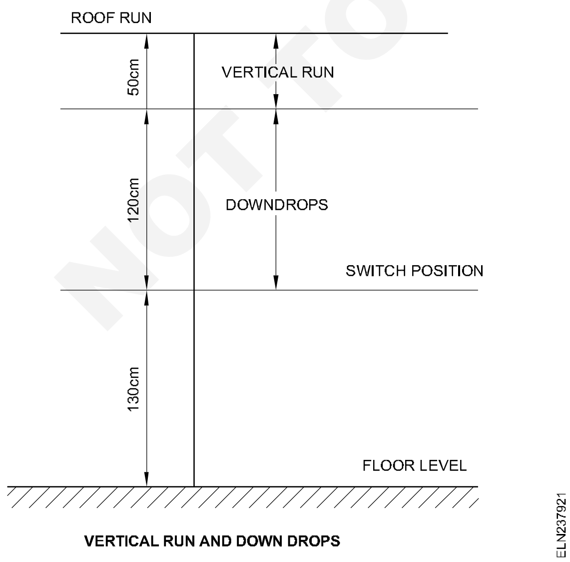
Estimation for 3 phase domestic and commercial wiring

Objectives: At the end of this lesson you shall be able to
- **state specific rules related to 3-phase wiring installations**
- **estimate the wiring by load calculation, load distribution, layout diagram, wiring diagram, selection of cables, selection of conduit, calculation of conduit length, cable length, accessories required and the cost of wiring.**

Estimation of wiring

Fig 1 shows the vertical and down drops and switch position measurement from the ground level.

Fig 1



Study the consumer's requirement of light, fan and power points in each room (Fig 2).

Required conduit length has to be calculated as per given method.

NE code recommends the horizontal run of cables should be at a height of 2.5m (250cm) and the height of switches from floor level should be 130cm. The example taken here for the roof height is 3m (300cm) from floor level. In all cases the dimension of the rooms should be available for estimating.

Vertical run : As such all vertical runs can be calculated as under (Refer Fig 4) for L_2 phase.

Length of selected conduit =

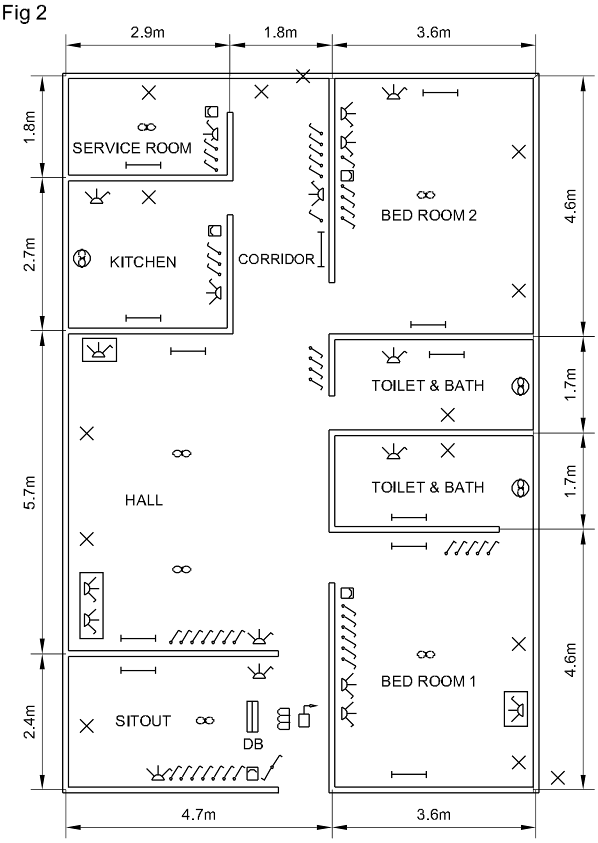
Roof height - (down drop + switch height) x No. of vertical runs

= 3m - (1.20m + 1.30m) x No. of vertical heights
= (3m- 2.5m) x No. of vertical heights
= 0.5m x No. of vertical heights (Eqn. 1)

The value 0.5m will change if there is difference in roof height and height of horizontal run of conduit changes.

= (2.5m - 1.3m) x No. of down drops for switches
= 1.2m x No. of down drops to switches

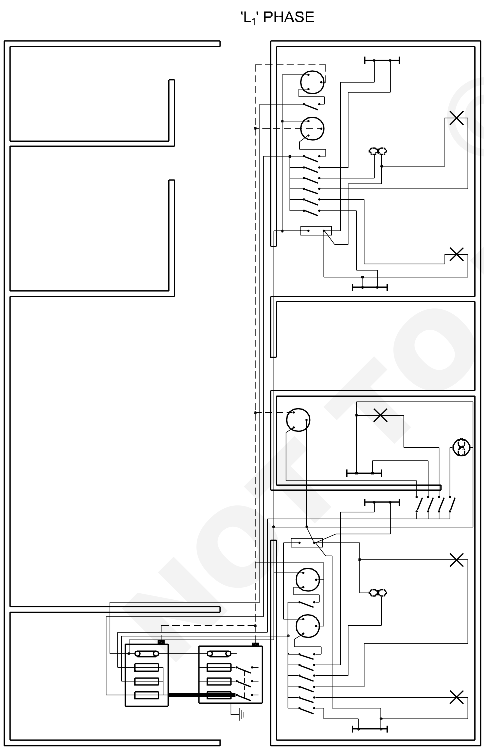
Fig 2



ACCESSORIES POSITION DIAGRAM

ELN237922

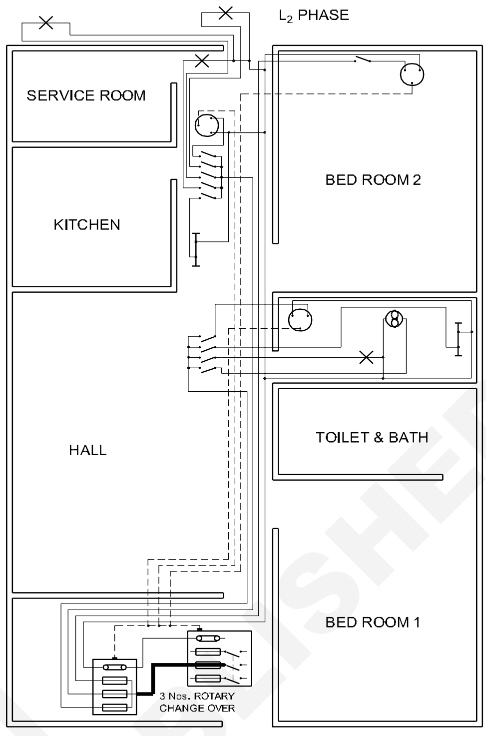
Fig 3



LAYOUT DIAGRAM OF PHASE L_1

ELN237923

Fig 4



LAYOUT DIAGRAM OF PHASE L_2

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Length of conduit required for down drops

This could be calculated as under:

Length of selected conduit = Height of conduit in horizontal run - Switch position height x No. of down drops for switches

Length of conduit required for roof runs

This could be calculated as under

Length of selected conduit = Sum of the actual length of roof run taken in each case.

For each size the total requirement is to be calculated.

Length of conduit required for horizontal run

Length of selected conduit = sum of the actual length of horizontal run taken in each case.

Length of conduit required for the distance between main switch and DB is to be calculated. In most of the cases wall is thickness has to be taken into account.

Example : (Refer the layout and wiring diagram with respect to phase L_1) In all cases except for main switch and DB the cable used is 1/1.12 copper cable and maximum number of cable it can accommodate in 19mm conduit is 7 cables. Hence PVC conduit of 19mm is chosen.

1 Length of conduit required for vertical run

Length for vertical run = 0.5m x No. of vertical height

A careful study of layout indicates there are 8 vertical height runs

= 0.5m x 8 = 4m of 19mm PVC conduit

2 Length of conduit required for down drops

Length of down drops = 1.2m x No. of down drops

A careful study of layout indicates there are 9 down drops = 1.2m x 9 = 10.8m

3 Length of conduit required for roof runs

Length of conduit = 2.35m + 2.35m + 2.35m + 2.35m + 1.45m + 0.9m = 9.75m

4 Length of conduit required for horizontal runs

Length of conduit = 4.7m + 3.6m + 1m + 1m + 1.2m + 4.7m + 2.4m + 1.35m + 1.2m + 2m + 2.35m + 5.7m + 2.9m + 2.9m + 1.35m + 2.7m + 2.5m + 1.45m + 1.8m + 1.45m = 48.25m

5 Length of conduit required for main switch and DB

If individual phase line is to be drawn through 19mm PVC conduit will be sufficient on the other hand if all three phase cables to be drawn through single pipe, the requirement to be calculated separately.

Assuming individual phases will be drawn through individual conduits the 19mm PVC conduit will be sufficient to draw two cables of sizes upto 1/2.8 or 7/1.06 aluminium and copper cables respectively.

Length of conduit required for the distance between main switch and DB : Length of conduit = wall thickness + allowance for connection = 0.36m + 0.5m + 0.5m = 1.36m

Total length of PVC conduit 19mm for wiring phase L_1 as per layout and wiring diagram

= Vertical run + down drops + roof runs + horizontal runs + switch DB
= 4m + 10.8m + 9.75m + 48.25m + 1.36m = 74.16 m

Assuming 10% wastage, the total required length of 19mm PVC conduit will be 73.81m + 7.3m = 81.11m or say 80m

Calculation of length of cable required for wiring phase L_1: For calculating the length of cable accurately the layout and wiring diagrams should be referred. Selected cable in this case is 1 sq.mm copper cable.

Cable required = For outside runs (($L_1 + L_2 + L_3 + L_4$) down drop + Horizontal run + switch board to outside wall (thickness of wall)
+ DB to switch board (DD + HR + DD)
+ Switch board to L_5 + (DD + HR)
+ L_5 to F_1 (VR + RR)
+ L_5 to L_6 L_7 (HR + HR)
+ DB to SB_2 (DD + HR + DD)
+ SB_2 to L_9 (DD + HR)
+ L_9 to F_2 (VR + RR)
+ SB_2 to S_3, S_4 (DD + HR + DD)
+ L_9 to L_{10} (HR)
+ L_{10} junction to F_3 (VR + RR)
+ L_{10} junction to L_{11} (HR)
+ S_3, S_4 to S_5 (DD + HR + DD)
+ From DB to S_6 (DD + HR +DD)
+ From S_6 to L_{12} (DD + HR)
+ L_{12} to F_5 (HR)
+ S_6 to F_4 (DD + HR + DD)
+ S_6 to L_{13} (DD + HR)
+ S_6 to S_8 (DD + HR + DD)
+ S_6 to S_7 (DD + HR + DD)
+ S_8 to F_6 (DD + RR)
+ F_6 to L_{15}
+ F_6 to L_{14}

= + (3.6m + 1m)2 + (4.7m + 1m)3	26.3m
+ (0.36M+ 0.5m) x 5 + (1.2m + 3m + 1.2m)2	15.1m
+ (1.2m + 3m + 1.2m)2	10.8m
+ (1.2m + 4m + 1.2m)5	32.0m
+ (0.5m + 2.35m)2	5.7m
+ (1.2m + 2.35m)3 + 2.35m x 2	15.35m
+ (1.2m + m2 + 1.2m)2	8.8m
+ (1.2m + 4m + 2m)6	43.2m
+ (0.5m + 2.35m)2	5.7m
+ (1.2m + 1.5m)2	5.4m
+ (1.2m + 4m + 2m + 1.2m)2	14.8m
+ 2m x 4	8.0m
+ (0.5m + 2.35m)2	5.7m
+ (2m + 2.5m)2	9.0m
+ (1.2m + 5m + 1.2m)2	14.8m
+ (1.2m + 4m + 5.7m + 2.9m + 2m + 1.2m)2	34.0m
+ (1.2m + 1.4m + 1.5m)3	12.3m
+ (1.5m + 1.35m)2	5.7m
+ (1.35m x 3m) + (1.35m x 2m)	6.75m
+ (1.35m + 1.45m + 1.2m)2	8.00m
+ (1.2m + 1.4m + 0.9m + 1.2m)2	9.4m
+ (1.2m + 1.45m + 1.2m)2	7.7m
+ (1.2m + 1.45m)3	7.95m
+ 0.9m x 2m	1.8m
+ 0.9m x 2m	1.8m
	325.95m
Add 10%	32.59m
Say 360m of 1 sq.mm copper	358.54m

The length of the cable required for power circuit in phase L_1. The cable chosen is 4 sq.mm copper cable which can carry 24 amps

Total length of cable = (1.2m + 0.36m + 2.4m + 3.6m + 2.4m + 1.2m)2
= 11.16m x 2
= 22.32m

Add 10% for wastage = 2.2m

24.52m

Say 25m of 4 sq.mm copper cable is required.

In the same way for the circuits in L_2 and L_3 phases should be calculated. After the list of accessories for entire wiring is prepared the cost of the accessories could be obtained from any local electrical dealer.

Instructor is requested to discuss with the trainees about the mandays required to complete the job alongwith the cost of labour.

Total cost of wiring comprisis of following components.

Total cost of wiring = cost of the accessories
+ cost of cable
+ cost of conduit
+ cost of hardware items
+ labour cost

Estimation of cost for workshop wiring

Objectives: At the end of this lesson you shall be able to
- **calculate the full load current and size of cables**
- **estimate the cost for workshop wiring**
- **tabulate the material required.**

The trainees can be instructed to estimate the cost of materials for the workshop wiring. Some of the guidance are given below for the trainees and instructor referance.

A sample requirement is given below for trainee's reference

1 One 5HP, 415V 3 phase motor

2 One 3HP, 415V 3 phase motor

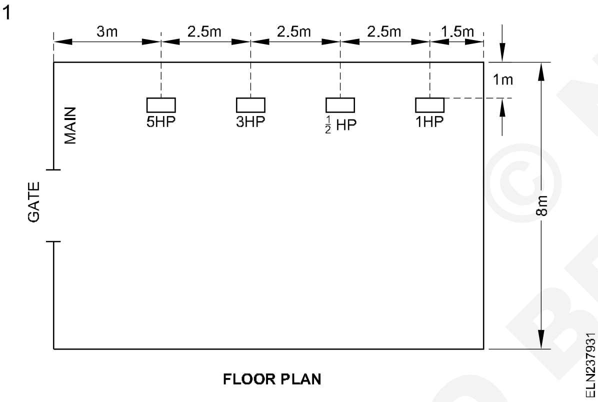
3 One ½ HP, 240V 1 phase motor

4 One 1HP, 415V 3 phase motor

The motors are to be arranged in row (Fig 1).

The main switch, motor switch and starters are to be mounted at a height of not more than 1.5m from the ground level and the height of horizontal run from ground level will be 2.5 m.

Fig 1



Calculation for the size of cable:

Assuming the motor efficiency to be 85% and the power factor to be 0.8 for all the motors and the supply voltage is 400V.

$$\text{FL current of 5HP motor} = \frac{5 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 7.8A$$

$$\text{FL current of 3HP motor} = \frac{3 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 4.68A$$

$$\text{FL current of ½ HP motor} = \frac{0.5 \times 735.5}{240 \times 0.85 \times 0.8} = 2.25\ A$$

$$\text{FL current of 1HP motor} = \frac{1 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 1.56\ A$$

The main switch and the cable from meter to main switch should be capable of handling starting current of one motor of high rating plus full load current of the all other motors.

i.e, 15.6+4.68+2.35+1.56 = 24.19A

Assuming the starting current of each motor will be two times of their full load current Table 1 gives cable size of each motors to be installed for guidance.

Table - 1

Sl. No.	Motor	FL current I_L in Amp	Starting current $I_S = 2I_L$ in Amp	Recommended cable size
1	5HP motor	7.5	15.6	2.0mm² coppere conductor cable (17A) or 2.5mm² aluminium conductor cable (16A)
2	3HP motor	4.68	9.36	2.0mm² copper conductor cable (17A)
3	1/2 HP motor	2.25	4.5	1.0mm² copper conductor cable (11A) minimum recommended cable
4	1HP motor	1.56	3.12	1.0mm² copper conductor cable (11A) minimum recommended cable

The type and gauge of cable shall be selected by referring the table - 1

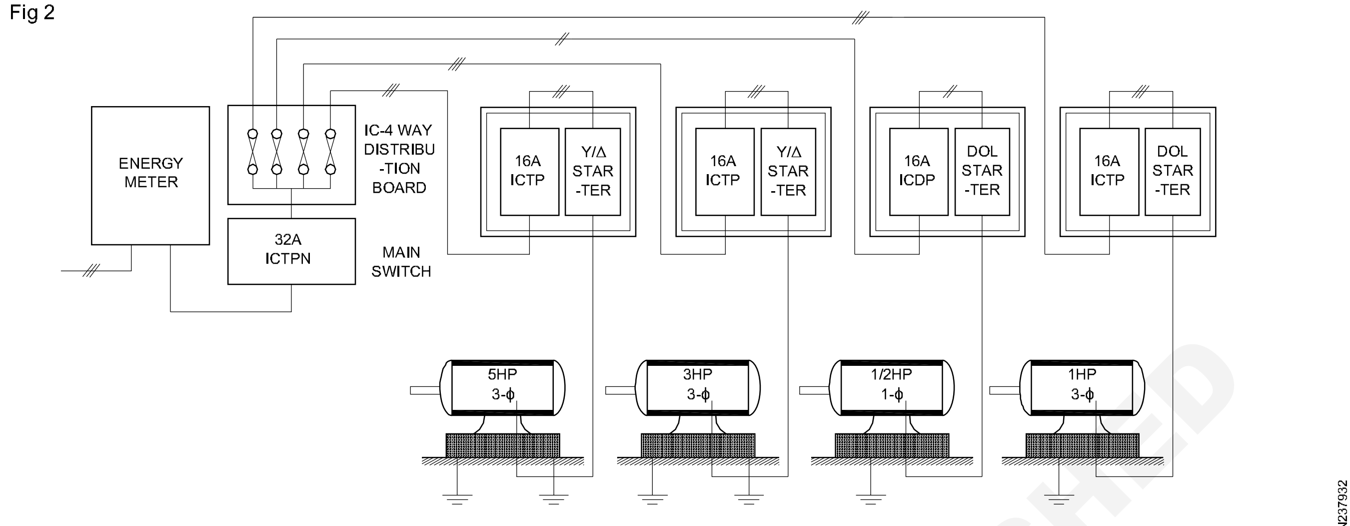
Some guidance are given bleow to select the suitableswitches and distribution board for trainees reference.

- A 32A, 415V ICTP switch with fuses can be used as main switch.
- 16A, 415V, ICTP switches with fuses can be used for 5HP, 3HP, & 1HP motors.

- 16A, 240V, ICDP switch with fuses can be used for ½ HP motor.
- 415V, 4 way, 16A per way IC distribution board with neutral link can be used for power distribution.

The single typical line diagram of power wirings (Fig.2)

Fig 2



SINGLE LINE DIAGRAM OF POWER WIRING IN WORKSHOP

Calculation for the sizes and length of conduit:

19mm heavy gauge conduit should be used for 3 cable runs and 24.4 mm heavy gauge conduits should be used for 6 cable runs.

- 19 mm heavy gauge conduit

Length from main board to 5HP motor starter = 1+1+3+1 = 6.0m

Length from main board to 3HP motor starter = 1+1+5.5+1 = 8.5m

Length from main board to ½ HP motor base = 1+1+8+1+1.5+1.5 = 14.0m

Length from main board to 1HP motor base = 1+1+10.5+1+1.5+1.5 = 16.5m

Total = 45.0 m

10% wastages = 4.5m

Total length = 49.5m, say 50.0m

- 25.4 mm heavy gauge conduit.

Length from meter to main switch = 0.75 m

Length from 5HP motor starter to 5HP motor base (1.5 +1.5) 3.0 m

Length from 3HP motor starter to motor base = 3.0 m

Total = 6.75 m

10% wastage = 0.67 m

Total = 7.42m, Say 8.0m

- 25.4 mm flexible conduit for 5HP & 3 HP motor (0.75+0.75) = 1.5, Say 2.0m
- 19mm flexible conduit for 1/2 HP & 1 HP motor (0.75+0.7) = 1.5, Say 2.0m

Calculation for the length of cables:

2.0mm^2 copper conductor from main board to 5HP motor terminals = 3(1+1+3+1) + 6(1.5+1.5+0.75) = 40.5m

15% wastages & end connections = 7.2 m

Total = 47.7m , Say = 48.0m

1.0mm^2 copper conductor from main board to 1/2 HP motor terminals = 2(1+1+8+1+1.5+1.5+0.75) = 29.5 m

15% wastages & end connections = 7.76m

Total = 37.26m, Say 38m

Trainees may be instructed to tabulate the list of materials.

Testing a domestic wiring installation - location of faults - Remedies

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **state the type of test to be carried out in wiring installations and explain the procedure of conducting them**
- **determine the condition of installation and the method of improving the condition.**

General requirement of inspection and tests (Ref: B.I.S.732-(Part III) 1982.)

Before a completed installation or an addition to the existing installation is put into service, inspection and testing shall be carried out in accordance with the Indian Electricity Rules, 1956. In the event of defects being found, these shall be rectified as soon as practicable, and the installation re-tested.

Items to be inspected in a lighting circuit

Lighting circuits: The lighting circuits shall be checked for ensuring the following.

- Neutral links are provided in double pole switch-fuses which are used for lighting control, and no fuse is provided in the neutral.
- The plug points in the lighting circuit are all of 3-pin type, the third pin being suitably earthed.
- A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment.
- Proper connectors and junction boxes are used wherever joints are to be made in conductors or when cross-over of conductors takes place.
- Clear and permanent identification marks are painted in distribution boards.
- The polarity having been checked, all fuses and single pole switches are connected on the phase conductor only and wiring is correctly connected to the socket-outlets.
- The ends of the conduits enclosing the wiring leads are provided with ebonite or other suitable bushes.
- Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals.
- The number of wires in a conduit conforms to the provisions of Part II of BIS 732.

Testing of installation: After inspection, the following tests shall be carried out, before an installation or an addition to the existing installation is put into service.

1 Continuity or open circuit test
2 Polarity test
3 Earth and ground test
4 Insulation and leakage test:
   - between conductors
   - between conductors and earth.

Continuity or open circuit test: This test is carried out to check the continuity of cables in the individual sub-circuits.

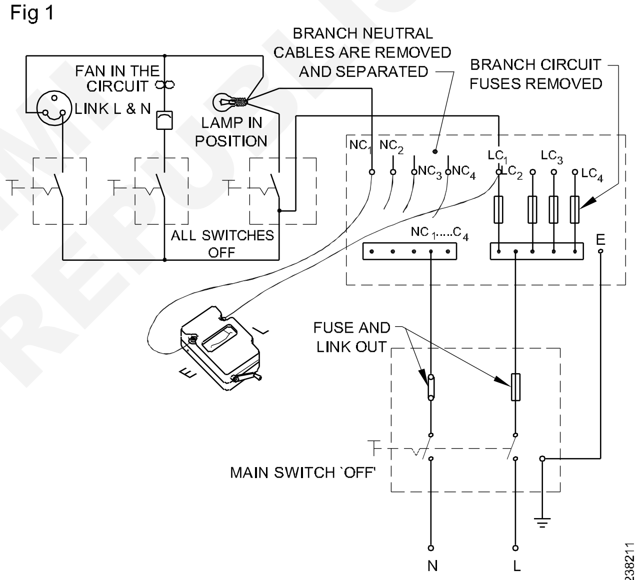
Before conducting this test, the main and all the distribution circuit fuses should be removed.

The phase and the neutral of the individual circuits should be identified from the distribution board and segregated.

Place all bulbs in position, connect fans to respective ceiling roses, regulators and switches, short all socket outlets by linking the phase and neutral.

Connect the Megger terminals E and L to the individual circuit phase and neutral (Fig 1) and rotate the Megger.

Fig 1



CONTINUITY OR OPEN CIRCUIT TEST

By switching the switches ON and OFF one by one, the Megger should show zero reading and infinity alternatively. The two-way switches may have to be operated alternatively to ensure the correct test results.

If the Megger shows no continuity in the `ON' condition of the switch, then the particular circuit is deemed to be open. On the other hand, if the Megger shows continuity in both the `ON' and `OFF' positions of the switch, this indicates short in the particular circuit.

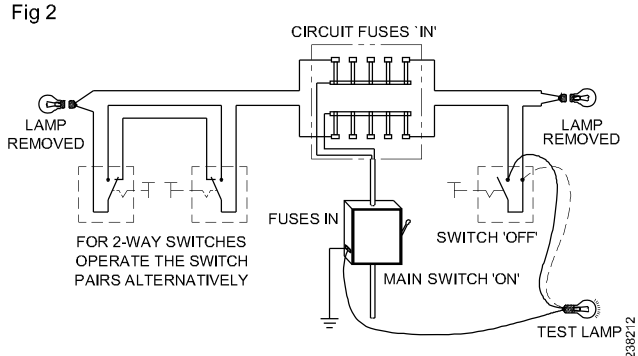
Remember to remove all the shorting links at socket points and to connect the phase to the fuse, and neutral to the link, before switching `ON' the supply.

Polarity test: This test is conducted to check whether switches are connected in phase/live cable or not.

For conducting this test, the lamps are removed from the lamp-holders, the fan regulators are kept in the `OFF' position and the fuses inserted in the main and distribution boards.

Remove the switch covers and switch `ON' the supply. Connect one end of the test lamp to the earth continuity conductor and the other end of the test lamp to the switch terminals alternatively (Fig 2).

Fig 2



POLARITY TEST

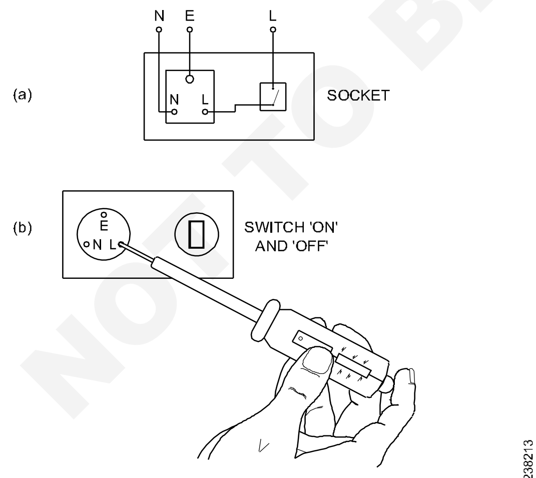
Lighting of the test lamp indicates that the phase or live cable is controlled by the switch.

A further polarity test should be done on the sockets to verify whether

- The phase wire is connected to the right side hole of the socket (Fig 3a).
- The switch controls the phase wire.

  For this test, a neon tester could be inserted in the right side hole of the socket as shown in Fig 3b and the control switch is switched `ON'. Lighting of the neon tester when the switch is `ON' and no light when the switch is `OFF' indicate correct polarity. This test is a must, in all old or new wiring installations as a safety measure.

Fig 3



POLARITY TEST ON SOCKETS

Insulation tests in wiring installation (BIS 732 (Part II) - 1982.)

The following tests shall be done:

Insulation resistance between conductors and earth: For this test, put `OFF' the main switch and remove the main fuse-carrier. All distribution fuses should be `IN'; the lamps should be in their holders and all switches for fans and lights should be in the `IN' position. Unplug all the appliances from the sockets, and short the phase and neutral of the sockets with a jumper wire.

Connect the phase and neutral cables at the outgoing terminals of the main switch together, and connect the lead of the Megger terminal to the shorted cables. (Fig 4) Connect the other lead of the Megger to the earth connection and rotate the Megger at its rated speed.

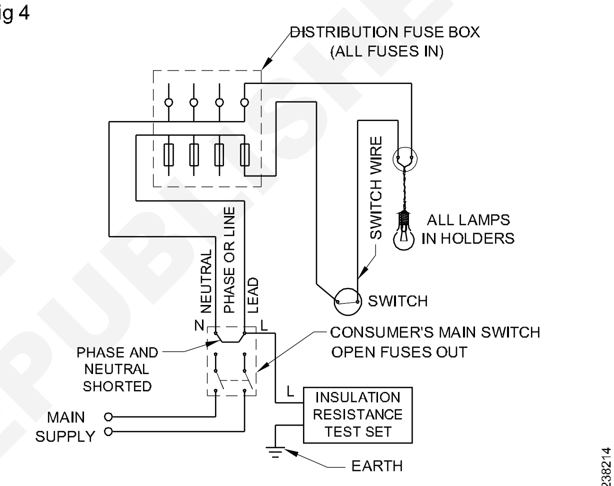
The reading thus obtained should not be lower than the lowest of the values obtained in these three methods.

Method 1 - **Standard value as per B.I.S.**

Standard value of insulation resistance

$$= \frac{50}{\text{No.of points in the circuit}} \text{Mega ohms}$$

Fig 4



INSULATION RESISTANCE TEST BETWEEN CONDUCTORS AND EARTH

where the switch, the lamp-holder and the socket are taken as individual points.

In case, the wiring is done in PVC insulated cables, 50 should be replaced by 12.5.

Method 2 - **I.E. rules state that the leakage current in an installation should not exceed 1/5000th part of the full load current of the installation.**

Applying this, the value of insulation resistance

$$= \frac{\text{Supply voltage in volts}}{\text{Leakage current}} \text{ohms}$$

$$= \frac{\text{Supply voltage in volts x 5000}}{\text{Full load current of the insatallation}}$$

Where leakage current

$$= \text{Full load current of the installation x } \frac{1}{5000}$$

Hence the insulation resistance

$$= \frac{\text{Supply voltage in volts x 5000 x } 10^{-6}}{\text{Full load current of the installation}} \text{Megaohms}$$

Method 3 - **Thumb rule**

The measured insulation resistance of an installation should not be less than one megohm.

Insulation resistance between conductors: For this test, switch off the mains and remove the fuse-carriers.

Remove all lamps from their holders, disconnect all appliances and keep all switches in the ON position.

Keep all the distribution fuses in position.

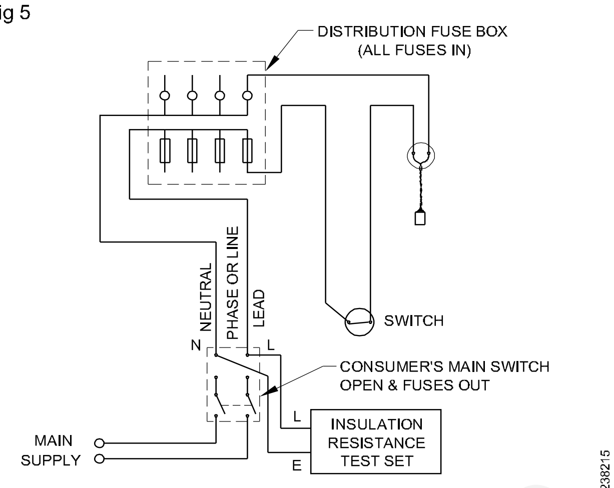
Connect one test prod of the Megger to the phase cable and the other to the neutral (Fig 5).

Rotate the Megger and measure the insulation resistance in megohms.

The reading in megohms should not be less than the lowest of the readings obtained in any one of the three methods, stated under `Insulation resistance between conductors and earth.

Inspection, testing and improving the condition of wiring installations

Fig 5



INSULATION RESISTANCE TEST BETWEEN CONDUCTORS

The table given below shows the test results, and the methods to improve the conditions of the wiring installations.

Test Results and Methods for Improving the conditions

S. No.	Test Conducted	Test results	Method of Improvement
1	Continuity or open circuit test	a) Zero reading	a) Ok.
		b) Higher reading in terms of kiloohms or megohms	b) Operate each individual switch in the circuit.Where the reading jumps to a higher value, there will be an open circuit, either by fused bulbs or loose connections at the terminals or break in the wire. After identifying the subcircuit, check the continuity of cables in the smaller zones till the defect is detected and rectified. Where 2-way switches are encountered,operate the switches one by one to detect the fault.
2	Polarity test	a) Polarity was found wrong throughout the installation.	a) Switch off the mains. Remove the fuse-carrier.Interchange the output terminals at ICDP switch or at DB.
		b) Polarity found wrong in one or two sockets.	b) See that the phase is connected to the right side terminal of the socket.
4	Insulation test between conductors and earth (or) between the phase and neutral	a) 1 megohm or above	a) Ok. Check the value of the insulation resistance by the formula $\text{Megohms} = \frac{50}{\text{No.of outlets}}$ For PVC wired installation replace 50 by 12.5. In case the measured value of insulation resistance is equal to or more than the calculated value, the insulation is OK.
		b) Less than 1 megohm	b) Otherwise locate the fault by sectionalising the zone and replacing the defective cable with a good one. If, however, the values obtained are not sufficiently high, withdraw all the fuses of the distribution fuse-board and test again. This test will include only that portion of the installation between the main switch and the distribution fuse-board. If the fault does not lie in this section,proceed to the distribution fuse-board, and test each branch circuit in turn till the faulty circuit or circuits are discovered.

Earthing - Types - Terms - Megger - Earth resistance Tester

Objectives: At the end of this lesson you shall be able to
- **explain the reasons for system and equipment earthing**
- **define the terminology related to earthing**
- **state and explain the methods of preparing pipe earthing and plate earthing, according to B.I.S. recommendations**
- **explain the procedure for reducing the resistance of earth electrodes to an acceptable value.**

Earthing

Connecting the non-condutive metal body/parts of an electrical equipment and system to the earth through a low resistance condutor is called as **earthing**.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and substations.

The purpose of system earthing is to:

- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

Terminology

> **Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.**

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

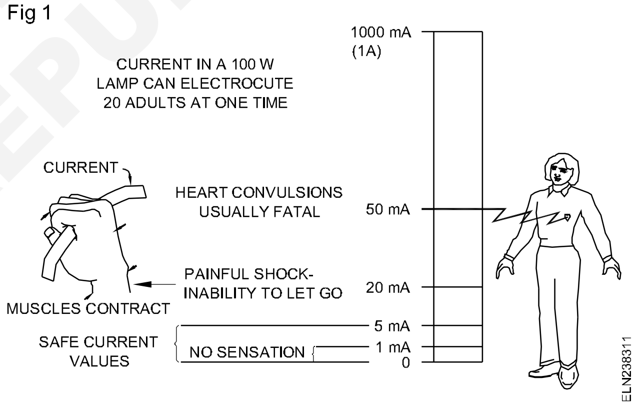
Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Fig 1 shows the magnitude of current and its effect

Fig 1



Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part

Table 1 shows the body resistance at specified areas of contact.

Table 1

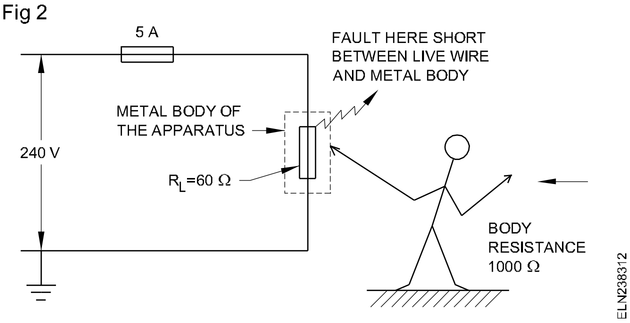
Skin conditon or area	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1: **Metal body of apparatus when it is not earthed**

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

Fig 2



The value of current through the body = $\frac{V}{R_{Body}}$

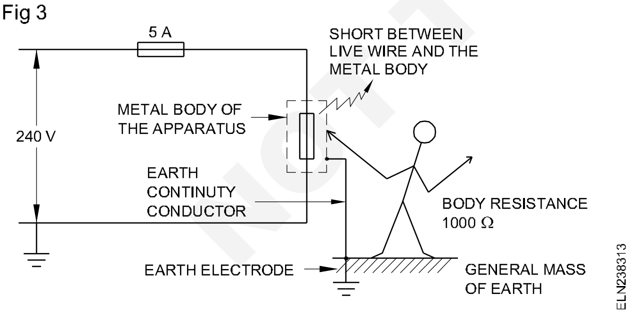
$$= \frac{240}{1000} = 0.24 \text{ amps or 240 milliamps.}$$

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

CASE 2: **Metal body of apparatus when earthed.**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Fig 3



Assuming that the sum of the resistace of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

$$\text{the leakage current} = \frac{V}{R_{Total}} = 240/10 = 24 \text{ amps.}$$

This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

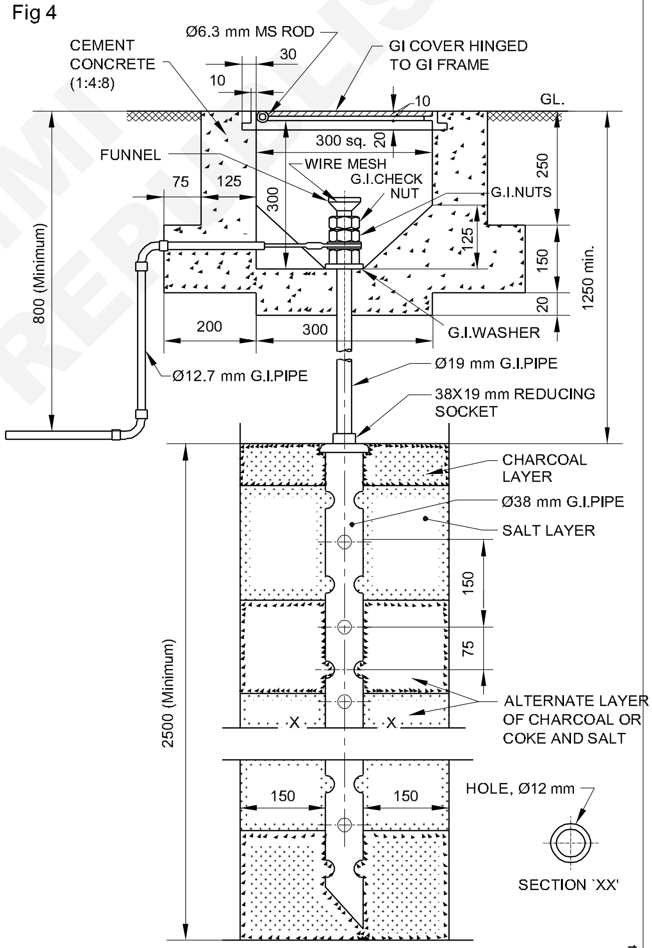
By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

Types of earth electrodes

Rod and pipe electrodes (Fig 4): These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.

Fig 4



NOTE: DIMENSIONS ARE IN mm UNLESS OTHERWISE SPECIFIED.

PIPE EARTHING

Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. The length of the electrodes shall be atleast 2.5 m, and the inclination not more than 30^0 from the vertical.

Plate electrodes (Fig 5): Plate electrodes,when made of galvanised iron or steel,shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

Fig 5

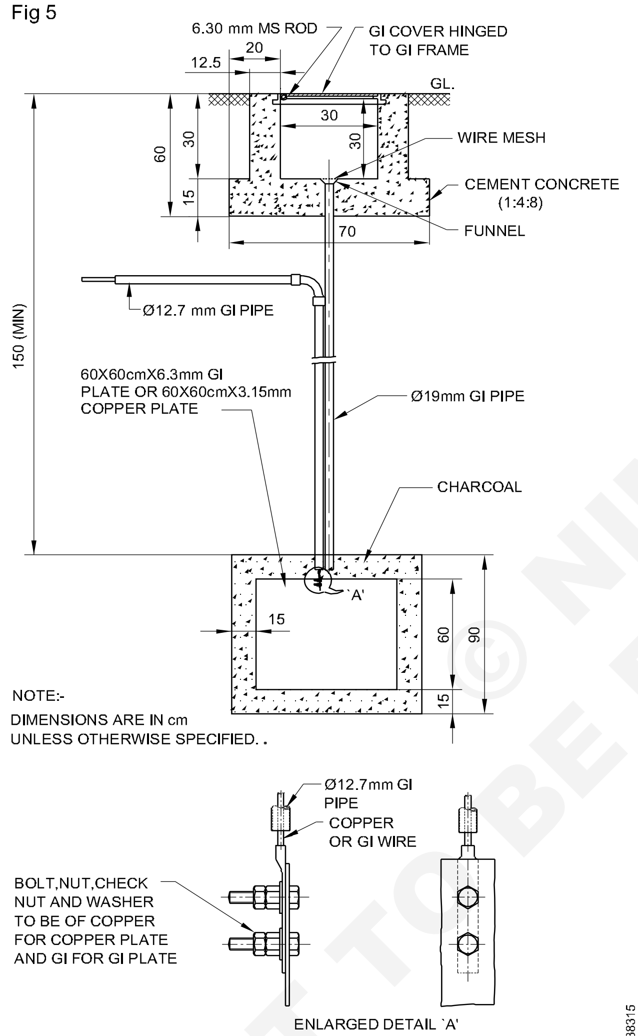


PLATE EARTHING

Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Plate electrodes is recommended in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atleast 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be atleast 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

The earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance.

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

Insulation resistance tester (Megger)

Objectives: At the end of this lesson you shall be able to
- **state the working principle of an insulation tester (Megger)**
- **explain the construction and working of megger**
- **state the uses of an insulation tester like insulation test, continuity test etc.**
- **state the safety precautions to be observed while using an insulation tester.**

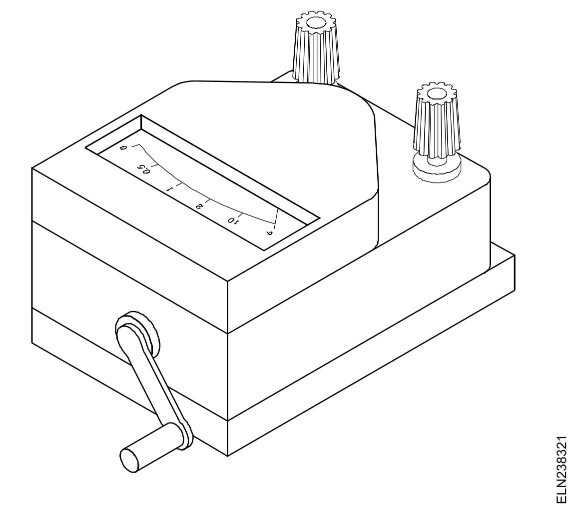
Megger

It is an electrical measuring instrument generally used to measure the insulation resistance of an installation/ equipment etc in terms of Megaohms.

Necessity of megohmmeter

Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 1) A megohmmeter is commonly known as MEGGER.

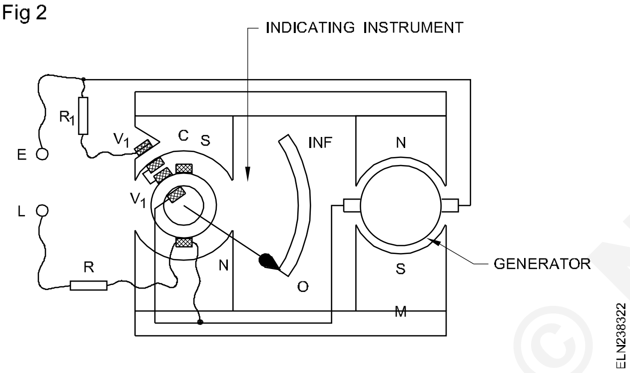
Fig 1



Construction

The megohmmeter consists of (1) a small DC generator, (2) a meter calibrated to measure high resistance, and (3) a cranking system. (Fig 2)

Fig 2



A generator commonly called a magneto is often designed to produce various voltages. The output may be as low as 500 volts or as high as 1 megavolt. The current supplied by the megohmmeter is in the order of 5 to 10 milliamperes. The meter scale is calibrated: kilo-ohms (K Ω) and megohms(MΩ).

Working principle

The permanent magnets supply the flux for both the generator and the metering device. The voltage coils are connected in series across the generator terminals. The current coil is arranged so that it will be in series with the resistance to be measured. The unknown resistance is connected between the terminals L and E.

When the armature of the magnet is rotated, an emf is produced. This causes the current to flow through the current coil and the resistance being measured. The amount of current is determined by the value of the resistance and the output voltage of the generator.

The torque exerted on the meter movement is proportional to the value of current flowing through the current coil.

The current through the current coil, which is under the influence of the permanent magnet, develops a clockwise torque. The flux produced by the voltage coils reacts with the main field flux, and the voltage coils develop a counter-clockwise torque.

For a given armature speed, the current through the voltage coils is constant, and the strength of the current coil varies inversely with the value of resistance being measured. As the voltage coils rotate counter-clockwise, they move away from the iron core and produce less torque.

A point is reached for each value of resistance at which the torques of the current and voltage coils balance, providing an accurate measurement of the resistance. Since the instrument does not have a controlling torque to bring the pointer to zero, when the meter is not in use, the position of the pointer may be anywhere on the scale.

The speed at which the armature rotates does not affect the accuracy of the meter, because the current through both the circuits changes to the same extent for a given change in voltage. However, it is recommended to rotate the handle at the slip speed to obtain steady voltage.

Because megohmmeters are designed to measure very high values of resistance, they are frequently used for insulation tests.

Connection for measurement

When conducting insulation resistance test between line and earth, the terminal 'E' of the insulation tester should be connected to the earth conductor.

Precautions

- A megohmmeter should not be used on a live system.
- The handle of the megohmmeter should be rotated only in a clockwise direction or as specified..
- Rotate the handle at slip speed.

Uses of a megohmmeter

- Checking the insulation resistance
- Checking the continuity.

Specification of Megger :

Nowadays electronically operated, Meggers are available, called as push button type for general application and for industrial application motorised megger are also available. Hence a megger is basically specified based on the voltage generated by it .

Example: 250 V, 500V, 1KV, 2.5KV, 5KV.

Earth resistance tester

Objectives: At the end of this lesson you shall be able to
- **state the precautions to be followed while selecting a site for the earth electrode**
- **define earth resistance tester**
- **explain the principle constructon and working of an earth resistance tester**
- **explain the method of measuring the earth resistance**
- **state the IE rules pertaining to earthing.**

Precautions to be followed while selecting the site for earth electrode: However, even the earth electrode, either rod or plate type, implanted properly in the earth according to the specified recommendations is found to have high resistance resulting in failure of safety. The earth electrode resistance could be kept at a reasonable level.

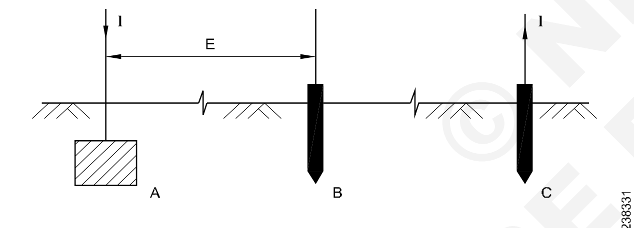
Necessity of measuring of earth electrode resistance: The only way to ensure the acceptable value of earth electrode resistance is to measure the resistance with the use of an earth resistance tester.

Earth resistance tester: It is an electrical measuring instrument used to measure the resistance between any two points of the earth. It is also called as earth tester.

Principle: The earth tester works on the principle of the fall of potential method.

In this method the two auxiliary electrodes B and C are placed at a straight line (Fig 1).

Fig 1



FALL OF POTENTIAL METHOD

An alternating current of I_{amps} magnitude is passed through the electrode A to the electrode C via the earth and the potential across electrodes A and B is measured.

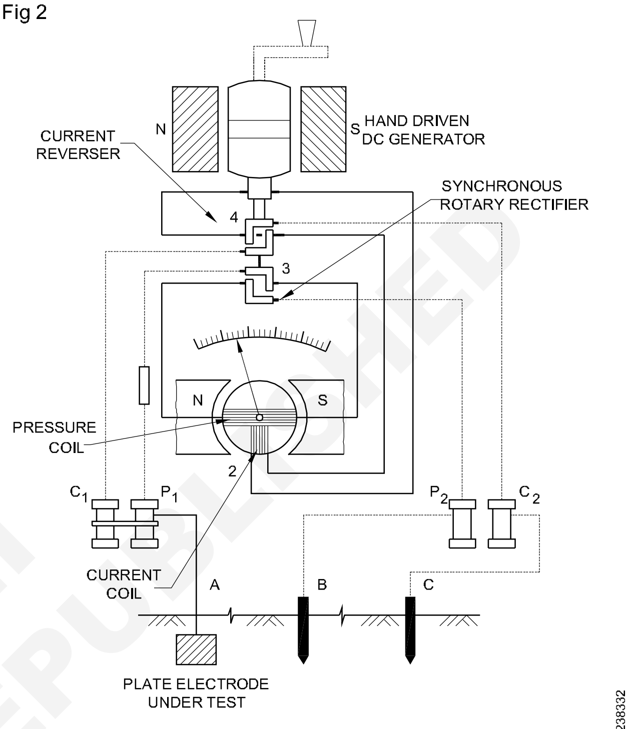
The resistance of electrodes B and C does not influence the measurement result.

This is achieved by placing the electrode C at a sufficient distance from A so that the resistance areas of A and C are quite independent. A distance of above 15 metres between electrode A and C is regarded as sufficient distance.

Construction and working of earth tester : The earth tester essentially consists of a hand drive generator which supplies the testing current and a direct reading ohmmeter (Fig 2).

The ohmmeter section of this instrument consists of two coils (potential and current coils) kept at 90° to each other and mounted on the same spindle. The pointer is attached to the spindle. The current coil carries a current proportional to the current in the test circuit whereas the potential coil carries a current proportional to the potential across the resistance under test.

Fig 2



EARTH TESTER

Thus the current coil of the instrument acts as an ammeter in the fall of potential method and the pressure coil acts as the voltmeter. Since the deflection of the ohmmeter needle is proportional to the ratio of the current in the two coils, the meter gives resistance readings directly.

When DC is used in electrode resistance measurement the effect of electrolytic emf interferes with the measurement and the reading may go wrong. To avoid this, the supply to the electrodes should be AC.

To facilitate this the DC produced by the the hand generator is changed to AC through a current reverser. After the alternating current passes through the electrodes, the measurement should be done by an ohmmeter which requires DC supply.

To change the alternating voltage drop outside the instrument to direct voltage drop inside, a synchronous rotary rectifier is used (Fig 2)

Sometimes the meter needle vibrates during measurement due to the fact that strong alternating currents of the same frequency as the generated frequency enters the measuring circuit.

In such cases the handle rotating speed of the instrument may be either increased or decreased. In general these instruments are designed such that the readings are not affected by strong currents or by electrolytic emfs.

Method of earth resistance measurement: To measure the earth electrode resistance, the earth electrode is preferably disconnected from the installation. Then two spikes (the current and pressure spikes) are to be driven into the ground at a straight line at a distance of 25 metres and 12.5 metres respectively from the main electrode under test. The pressure and current spikes and the main electrode need to be connected to the instrument (Fig 1)

The earth tester has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrode.

I.E. Rules pertaining to earthing

Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules 1956, as amended from time to time, and the relevant regulations of the electricity supply authority concerned. The following Indian Electricity Rules are particularly applicable to both system and equipment earthing: 32,51,61,62,67,69,88(2) and 90.

Extracts from Indian Electricity Rules, 1956

Rule no. 32: **Identification of earthed and earthed neutral conductors and position of switches and cut-outs therein.**

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be compiled with.

1 An indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such a conductor to be distinguished from any live conductor. Such indication shall be provided:

   a where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply

   b where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made.

2 No cut-out, link or switch other than a linked-switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:

   a a link for testing purposes or

   b a switch for use in controlling a generator or trans former.

Rule no.51: **Provisions applicable to medium, high or extra high voltage installations**

All metal work enclosing, supporting or associated with the installation, other than that designed to serve as ta conductor, shall, if considered necessary by the Inspector, be connected with earth.

Rule no.61: **Connection with earth**

1 The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage.

   a The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

   b In the case of a system comprising electric sypply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

   c The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

   d In the case of an alternating current system, there shall not be inserted in the connection with earth any impedance (other than that required solely for the operation of switchgear or instrumets), cut-out or circuit-breaker, and the result of a test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

   e No person shall make connection with earth by the aid of, nor shall keep it in contact with, any water main not belonging to him except with the consent of the owner thereof and of the inspector.

   f Alternating current systems which are connected with earth as aforesaid may be electrically interconnected. Provided that each connection with earth is bonded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

2 The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulation or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3 All metal casings or metallic coverings contained or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction-boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electroliers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated, all plug sockets shall be of the three-pin type and the third pin shall be permanently and efficiently earthed.

4 All earthing systems shall, before electric supply lines or apparatus are energised, be tested for electrical resistance to ensure efficient earthing.

5 All earthing systems belonging to the supplier shall, in addition, be tested for resistance on a dry day during the dry season not less than once every two years.

6 A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector when required.

Rule no.62: **Systems at medium voltage**

Where a medium voltage supply system is employed, the voltage between earth and any conductor forming part of the same system shall not, under normal conditions, exceed low voltage.

Rule no.67: **Connection with earth**

1 The following provisions shall apply to the connection with earth of three-phase systems for use at high or extra-high voltages:-

In the case of star-connected with earthed neutrals or delta-connected systems with earthed artificial neutral point

a The neutral point shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station and at the sub-station and may be earthed at any other point, provided that no interference of any description is caused by such earthing;

b In the event of an appreciable harmonic current flowing in the neutral connections so as to cause interference with communication circuits, the generator or transformer neutral shall be earthed through a suitable impedance.

2 In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be the one to be connected with earth.

3 Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.

Rule no.69: **Pole type substations**

1 Where platform type construction is used for a pole type substation and sufficient space for a person to stand on the platform is provided, a substantial hand rail shall be built around the said platform, and if the hand rail is of metal, it shall be connected with earth:

Provided that in the case of pole type substation on wooden support and wooden platform the metal hand-rail shall not be connected with earth.

Rule no.88: **Guarding**

1 Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken.

Rule no.90: **Earthing**

1 All metal support of overhead line and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected ordinarily at four points in every mile or 1.601 km, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fitting attached thereto shall be efficiently earthed.

2 Each stay-wire shall be similarly earthed unless an insulator has been placed in at a height not less than 10 ft. from the ground.

The details of ELCB and relay are already discussed in the lession 1.7.62

Illumination terms - Laws

Objectives: At the end of this lesson you shall be able to
- **state and explain different terms used in illumination**
- **state properties and advantages of good illumination**
- **state and explain laws of illumination.**

Definitions

A few principle terms in connection with illumination are defined below.

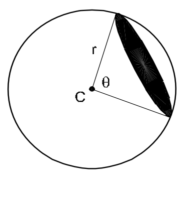
Luminous flux (F or F)**:** The flux of light emitted from a luminous body is the energy radiated per second in the form of light waves. The unit of luminous flux is `lumen'(lm).

Luminous intensity(I): The luminous intensity of a light source in a given direction is the luminous flux given out by the light source per unit solid angle. The angle subtended by an area r^2 on the surface of sphere of radius r, at the centre of sphere is unit solid angle. In SI, the unit of luminous intensity is the candela.

Candela: This is the amount of light emitted in a given direction by a source of one candle power. SI base unit is candela (cd). 1 candela = 0.982 international candles.

Lumen (lm)**:** It is the unit of luminous flux. This is defined as the amount of light contained in one steradian from a source of one candela at its focus. (Fig 1)

Fig 1



If the shaded area = r^2 and a source of one candela is at the centre C, the light contained within the solid angle is one lumen.

The light output of electric lamp is measured in lumens and their luminous efficiency is expressed in lumens per watt (lm/w).

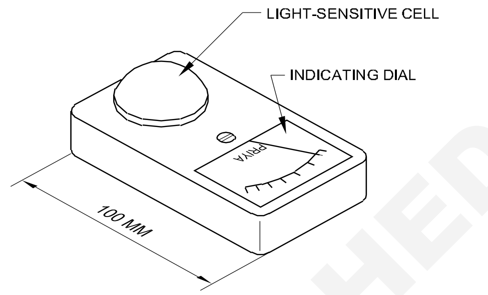
Illuminance or Illumination (E): Illuminance of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The metric unit is the lumen / m^2 or lux (lx).

Lux: This is the total output of light. Lumen per square meter (1m/m^2) or lux is the intensity of illumination produced in the inner surface of a hollow sphere of radius one meter by a standard candle at the centre. Sometimes this is also known as metre-candle.

Lighting engineers use a pocket-size instrument called a `lightmeter' to measure illuminance; and the reading in lux is read off the scale (Fig 2).

Factors to be viewed for correct illumination: The following are the important factors which should be considered while planning correct and a good illumination:

Fig 2



TYPICAL POCKET-SIZE LIGHT-METER FOR MEASURING ILLUMINANCE.

Nature of work : Considering the nature of work , sufficient and suitable lighting sould be maintained. For example, a delicate work like radio and TV assembling, etc. requires good illumination to increase the production of work where as for rough work like storage, garages, etc needs very small illumination.

Design of Apartment : The design of apartment must be kept in view while planning scheme for illumination. It means that the light emitted by the illumination source should not strike the eyes of the occupants or workers.

Cost : It is an important factor which should be considered while designing an illumination scheme for particular purpose.

Maintenance Factor : While planning illumination, it should also be kept in view the amount of reduction of light due to accumulation of dust or smoke on the source of light and after how much period cleanliness is required. Where there is a possibility of heavy loss of light due to the adherence of smoke, arrangement for the extra light is to be made from the very beginning.

Properties of good illumination

An illumination source should, have the following properties.

i It should have sufficient light.

ii It should not strike the eyes.

iii It should not produce glareness in the eyes.

iv It should be installed at such a place that it gives uniform light.

v It should be of correct type as needed.

vi It should have suitable shades and refelectors.

Advantages of good illumination

i It increases production in the workshop.

ii It reduces the chances of accidents.

iii It does not strain the eyes.

iv It reduces the wastage or loss of material.

v It increases the interior decoration of the building.

vi It gives smoothing effect to mind.

Laws of illumination

Inverse square law: If the internal radius of a sphere is increased from 1 metre to r metres, the surface area of it is increased from 4π to $4\pi r^2$ square metres. With a uniform point source of light of one candela at the centre, the number of lumen per square metre on the sphere of radius r metres.

$$= \frac{4\pi}{4\pi r^2} = \frac{1}{r^2}$$

Hence the illumination of a surface is inversely proportional to the square of its distance from the source. This is called the **Inverse Square Law of Illumination.**

Types of lamps

Objectives : At the end of this lesson you shall be able to
- **list out the types of lamps**
- **explain the different types of lamps**
- **explain the construction and working of tungsten filament lamp.**

Types of lamps

There are many types of electric lamps now available. They differ in construction and in the principle of operation.

They give light as a result of heating the filament to a very high temperature. The lamps can be grouped as follows.

Electric lamps
- Filament lamps
  - Carbon
  - Metal
- Arc lamps
- Discharge lamps
  - Cold cathode
  - Hot cathode

Filament lamp: A lamp in which a metal, carbon or other filament is rendered incandescent by the passage of electric current.

Vacuum lamp: A filament lamp in which the filament operates in a vacuum.

Gas-filled lamp: A filament lamp in which the filament operates in an inert gas.

Halogen lamp: A tungsten filament lamp in which the tungsten filament operates in a relatively small space filled with an inert gas and halogen of iodine or bromine.

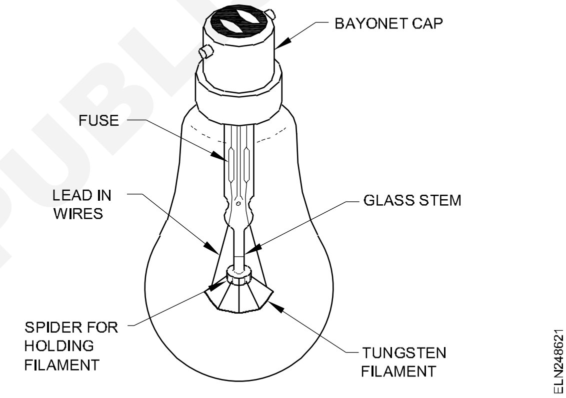
Arc lamp: An electric lamp in which the light is emitted by an arc.

Discharge lamp: An electric lamp in which the light is obtained by a discharge of electricity between two electrodes in gas or vapour.

Tungsten filament lamp: This lamp consists essentially of a fine wire of the metal, tungsten (the filament) supported in a glass envelope and the air evacuated from the glass bulb - hence called a **vacuum lamp**.

Fig 1 shows the parts of tungsten filament lamp

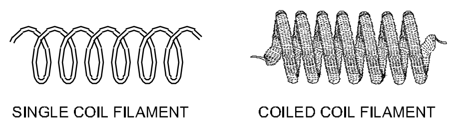
Fig 1



The two types of filaments (Fig 2) are

- single coil filament
- coiled coil filament.

Fig 2



The main advantage of a coiled coil lamp is the higher light output.

Direct and indirect lighting

Objectives: At the end of this lesson you shall be able to
- **explain direct and indirect lighting.**

Direct lighting type has largest efficiency from energy utilization point of view but glare is always present. Such systems are used for flood and Industrial lighting.

Indirect lighting type designed to avoid glare and recommended for specific purposes.

Semi direct type designed to avoid glare and recommended for offices and other specific purposes.

Semi indirect type designed to avoid glare and recommended for specific purposes.

Low voltage lamps - different wattage lamps in series

Objectives: At the end of this lesson you shall be able to
- **state the purpose of differtent voltage lamps**
- **calculate and compare the hot resistance of the same voltage but of different wattage/current lamps**
- **describe the method of measuring and calculating the 'hot resistance'**
- **state the effects of different wattage lamps in series.**

Purpose: In quite a few places we use low voltage supply i.e. 6V, 12V or 24V, such as in automobile vehicles. Automobile vehicles are equipped with many lights to provide an efficient lighting system for both day and night driving conditions. The various lights require the use of different wattage and types of light lamps to provide the amount of illumination desired.

Glow conditions of low wattage lamps with current flow through it: An electric lamp changes electrical energy into heat and light, when current flows through its filament and causes it to become incandescent. The filament is made of tungsten wire. The low voltage lamps are generally of low wattage because at a low voltage, the current taken by the filament for a given wattage is much more as compared to the domestic light.

Different wattage lamps in series: If the two lamps of different wattage in parallel across in A.C. circuit, it should be same voltage for proper operation. But, if they are connected in series they should have the same current ratings.

All the bulbs in house are probably connected in parallel and they will draw the current it requires, and all the lamps will glow bright.

If two lamps with unequal wattages and same voltage ratings are connected in series they will divide up the available voltage between them.

Low wattage lamp will glow bright, due to high resistance and high voltage drop. High wattage lamp will glow dim, due to low resistance and low voltage drop.

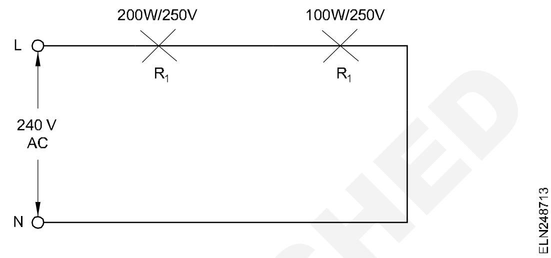
Example

In a circuit the two lamps rated as 200W/ 250V, and 100W/ 250V are connected in series across 240 volt A.C. supply. (Fig 1)

200W (higher wattage) lamp will glow dim and

100W (low wattage) lamp will glow bright.

Fig 1



because,

The resistance of 200W/ 250V lamp,

$$R_1 = \frac{V^2}{W_1} = \frac{250 \times 250}{200} = 312.5\ \Omega$$

The resistance of 100W/250V lamp,

$$R_2 = \frac{V^2}{W_2} = \frac{250 \times 250}{100} = 625\ \Omega$$

Total resistance $R_T = 312.5 + 625 = 937.5\ \Omega$

$$\text{current } I = \frac{V}{R_T} = \frac{240}{937.5} = 0.256\text{A}$$

voltage drop in 200W lamp, $= IR_1 = 0.256 \times 312.5 = 80\text{V}$

Voltage drop in 100W lamp, $= IR_2 = 0.256 \times 625 = 160\text{V}$

Power V X I = 240 X 0.256 = 61.4 W

Hence,

The 100W lamp having high voltage drop due to high resistance it will glow bright than high wattge lamp 200W which is having low voltage drop and low resistance.

Construction details of various lamps

Objectives: At the end of this lesson you shall be able to
- **explain the construction and working of neon sign tubes**
- **explain the colour mechanism of neon signs.**

Neon sign lamp

Gas discharge lamp

A gas discharge lamp is one in which some inert gas is filled in a glass tube having two electrodes sealed into each end, which on heating allows the flow of electron through it. To obtain a continuous flow of electron, gas is first charged but as the supply is disconnected from the bulb, the gas is discharged. Such a lamp is known as electric Gas Discharge Lamp. Electric gas discharge lamps are of two main types:

(i) Cold cathode lamp

(ii) Hot cathode lamp

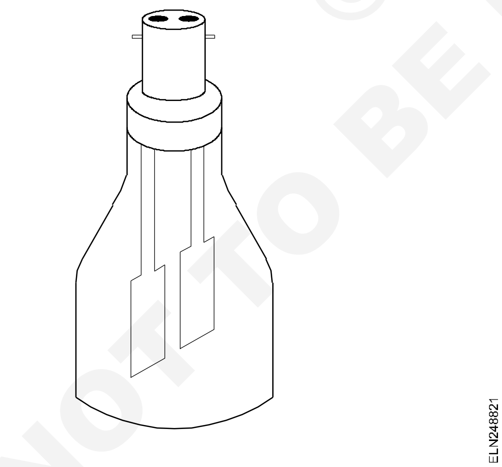
Cold Cathode Lamps (i) Neon lamp, (ii) neon sign tubes, (iii) sodium vapour lamp.

Hot Cathode Lamps (i) mercury vapour lamp (medium pressure), and (ii) fluroscent tube (low pressure mercury vapour lamp)

Types of gas discharge lamps

Neon Lamp This is a cold cathode lamp as shown in Fig 1 Neon gas at low pressure is used in it.

Fig 1



Construction

In this lamp, two flat or spiral electrodes are kept close together in a glass bulb so that the lamp can be operated at low voltage such as 150 V dc or 110 V ac. On giving supply to the electrodes, the gas becomes ionised and emits light which is reddish in colour. In usual practice a 2000W resistance is also connected in series with the electrodes which is placed in the cap of the lamp. This minimizes the fluctuation of current due to large variation of potential difference.

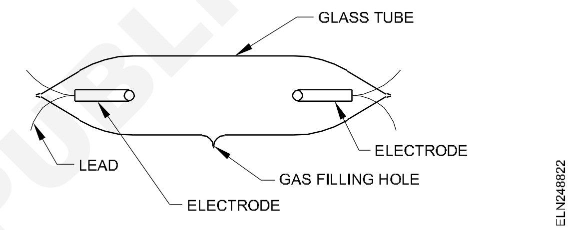
Uses

A neon lamp is generally used as an indicator lamp to indicate the presence of supply. It gives a small quantity of light and can also be used as a night lamp. A neon lamp of this type is also used in the testing pencil which is of 0.5 W.

Neon sign tube

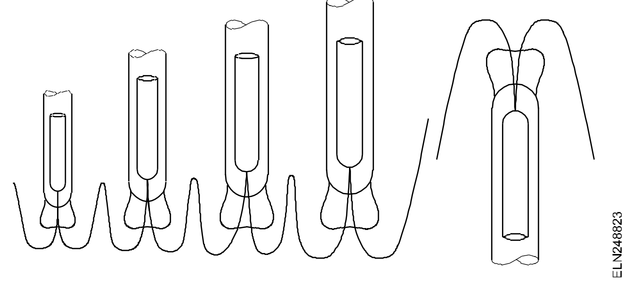
Construction of neon sign tube: Neon sign tube lamps are used mostly for advertising purposes. Fig 2 shows the construction details of a neon sign tube. A neon sign tube is made of glass.

Fig 2



The length of the tube varies from 1 metre to 5 metres, and the diameter varies from 10 mm to 20 mm. The tubes are joined with electrodes which are operated at high voltage. The electrodes are connected with nickel wires for more length or to different letters. (Fig 3)

Fig 3



The shape of the electrode is cylindrical. The electrodes are made of nickel, iron or copper. The electrode consists of:

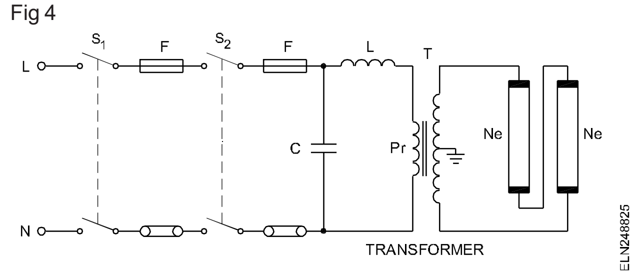
- a glass shell
- a lead in wires
- a glass jacket seal
- a ceramic collar. (heat resisting material)

The electrodes are fitted at the end of the tubes and fused. A vacuum is created in the tube before filling it up with an inert gas, such as neon or helium. After that it will be sealed. The neon sign tube will operate at 2000V to 15000V depend upon the length of the tube.

Working of neon sign tube: The neon sign tube requires a high voltage to operate. (Fig 4) This is obtained by a leakage field transformer (T) which simuntanously limits the current. The colour and the temperature of a neon tube depend on the gas inside, and we can also get various colours by using different fluorescent materials.

When high voltage is applied between the electrodes, the positive ions and the electrons drift towards the cathode and anode respectively. The movement of electrons increases with the potential and attain a very high velocity. The movement of electrons results in collision with the netural atoms, and may detach electrons from them. The high velocity of electrons is responsible for luminous discharge (light). The striking voltage of a neon sign lamp is about 1.5 times higher than the operating voltage, which is controlled by the R.F. choke)'L'.(Fig 4)

Fig 4



Circuit description and operation

Step-up transformer: The step up transformer is used to obtain a high voltage. The centre tap is earthed. The secondary output voltage is connected to the neon lamp.

R.F. choke L is connected in series with the primary of the leakage transformer to limit the surge current of the neon lamp. (Fig 4)

The capacitor C It is connected across the primary of the transformer to improve the power factor.

The fireman switch S2 It is connected alongwith the main switch and is used as an emergency switch. (Fig 4)

Main switches normally 15A 250V ICDP are used to control the circuits.

H.T. cables are used to connect the secondary of the transformer to the neon sign lamp as per IE rule No 71.

Colour mechanism of neon sign lamp: When electric current is conducted by a gas or vapour it produces luminous light. The elements most commonly used in this process of producing light by gaseous discharge are neon or mercury. The neon discharge yields orange-red light which is very popular in making advertising signs. The pressure of neon in the tubes is usually from 3 to 20 mm of the Hg. (millimeter of mercury)

The ultimate colour produced by using fluorescent powders depends not only on the chemical composition of the powders but also on the gas, the pressure at which the gas was filled, the diameter of the tubing and the operating current.

Colour Mechanism - Table

	Basic powder	Colour
1	Calcium tungstate	Blue
2	Magnesium tungstate	Blue-white
3	Calcium silicate	Pink
4	Zinc silicate	Green
5	Zinc beryllium silicate, depending upon the activating agent	Yellow, white, pink
6	Cadmium silicate	Yellow, pink
7	Cadmium borate	Pink

Installation: All equipment to be housed in an earthed metal or substantial containers suitable for high voltage. A notice `Danger-High Voltage' in the type of lettering as stated in 1.E regulation No.71, to be permanently fixed near to the equipment.

Sodium vapour lamp

Objectives: At the end of this lesson you shall be able to
- **state the sodium vapour lamp and its types**
- **describe the construction of low and high pressure sodium vapour lamp**
- **state the functions of the parts in the circuit.**

Sodium vapour lamp and its types: Sodium vapour lamp is a cold cathode gas discharge lamp, which gives a yellow colour light. Sodium lamps are particularly suitable in fog as their yellow light can penetrate fog better.

The average life of a sodium vapour lamp is well over 6000 hours. There are two types of Sodium Vapour lamps as given below:

- low pressure SV lamp
- high pressure SV lamp.

Construction

Low pressure sodium vapour lamp: In the sodium vapour lamps efficiency decreases rapidly as the current density is increased above a certain value. Consequently the lamp has to be operated at a low current density and this necessitates a large surface area of the tube.

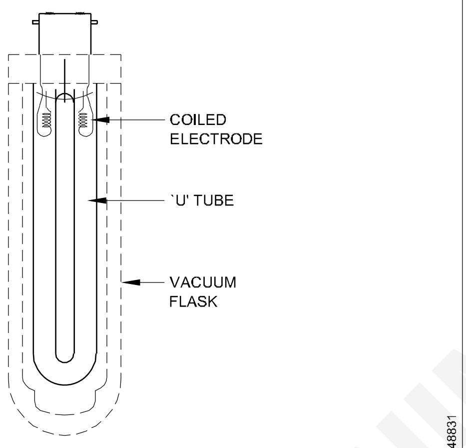
This lamp possesses a brightness of 7.5 candle per sq.cm. Because of these points the length of this tube has to be very long.

As stated above low pressure Sodium Vapour lamps require a long tube, but as there is limit to the practicable size of such a jacket of the vacuum flask type, the long lamp tube is bent to a `U' shape to suit the jacket.

The low pressure Sodium Vapour lamp possesses a `U' shaped glass tube internally coated with fluorescent powder, consisting of Sodium together with Neon and one percent of Argon, the function of the Argon being used to reduce the initializing voltage.

In a cold lamp the Sodium is in the form of solidified drops on the inner walls. The tube contains two Barium and Strontium coated, coiled Tungsten electrodes at both ends. The two ends of the electrodes are fixed to the bayonet cap. (Fig 1) Connection diagram is Fig 3.

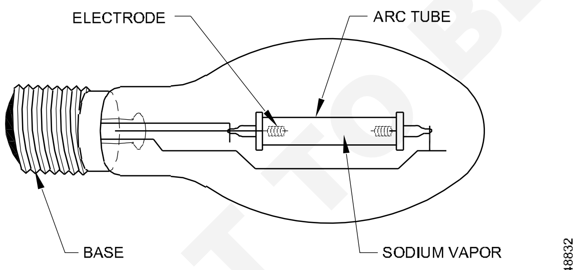
Fig 1



SODIUM DISCHARGE LAMP

High pressure sodium vapour lamp: A high pressure Sodium vapour lamp (Fig 2) operates at a much higher current which flows through a much shorter arc tube (discharge tube).

Fig 2

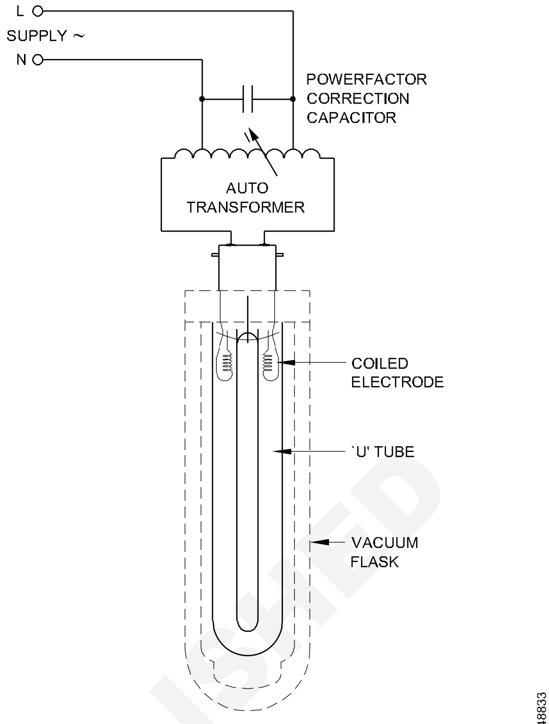


HPSV LAMP

This discharge tube is made of sintered aluminium ceramic discharge arc tube which is resistant to the hot ionised Sodium Vapour up to a temperature of about 1600^0C which transmits over 90% of visible radiation.

The discharge tube operates at a pressure of about half an atmosphere, and is enclosed in an evacuated hard glass envelope of elliptical shape to maintain the tube at the correct temperature. The lamp gives a rich Golden light which enables colours to be easily distinguished. This discharge tube contains Sodium and Mercury, with Argon or xenon added at a low pressure for starting purposes at low pressure.

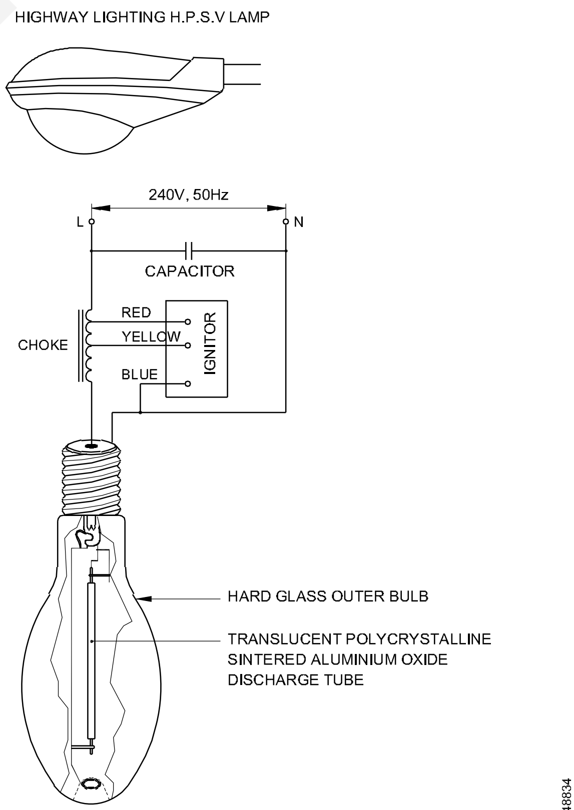
Fig 3



SODIUM DISCHARGE LAMP

A voltage pulse of about 2.5 KV is required to initiate the discharge (Fig 4) in higher pressure Sodium Vapour lamp. This high voltage pulse is generated by high external ignitor or by built in thermal starter.

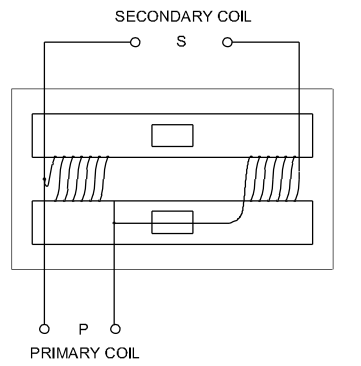
Fig 4



HIGH PRESSURE SODIUM VAPOUR LAMP

Leak transformer: The ignition voltage of sodium lamps varies from 400 to 600V. A `leak transformer' performs the dual role of providing the ignition voltage initially, and acting as a choke for limiting the current subsequently when the lamp starts conducting. The diagram of a leak transformer is shown in Fig 5.

Fig 5



LEAK TRANSFORMER

The primary and the secondary windings are connected in series and placed around the centre limb of a 3-core yoke. Between the coils, a loose iron core is clamped in the yoke on either side, which acts as a shunt for the magnetic field.

Under no-load conditions, the resistance of the shunt is large due to air gaps, with the result the magnetic field moves through the limbs of the yoke, and the device acts as an auto-transformer. But when the lamp ignites and consumes current, a part of the magnetic field leaks away through the shunt due to the counter-acting field of the secondary.

The device now acts as a choke coil reducing the voltage across the lamp electrodes to the required value.

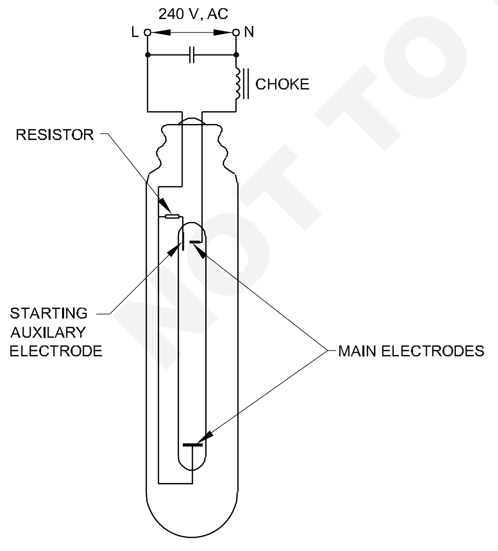
High pressure mercury vapour lamp (H.P.M.V)

Objectives: At the end of this lesson you shall be able to
- **state the principle of discharge lamps**
- **describe the working of a `high pressure' mercury vapour lamp**
- **explain the different types of mercury vapour lamps.**

All modern discharge lamps operate in a translucent enclosure. The initial discharge is usually struck in argon or neon.

The discharge occurs in an inner tube enclosed in an outer evacuated tube. (Fig 1) The inner tube of glass or quartz contains mercury and a small amount of argon to assist in the starting of the discharge. The electrodes are rich in electron-emittting materials in order to permit ease in the release of electrons.

Fig 1



MA TYPE HPMV LAMP CIRCUIT

HPMV lamps

The lamp operates at high pressure. To start the discharge, an auxiliary electrode is positioned quite close to the main electrode. The auxiliary electrode is connected to the lamp terminal through a high resistor.

The high resistor limits the current. When switched on, the normal mains voltage is not sufficient to start the discharge between the main electrodes but it can start over the very short distance between the main and auxiliary electrodes.

At the beginning, the discharge current passing through the high resistance causes a potential difference to develop between the starting electrode and one of the main electrode through the argon gas. The discharge now spreads rapidly until it takes place between the main electrodes.

The argon discharge then warms up the tube and vaporises the mercury. Soon the gas content is mainly mercury vapour and the argon has less and less effect. The discharge then takes place in the mercury vapour.

Types of HPMV lamps

Three different types of high pressure mercury vapour lamps are:

- MA type (MV lamp with auxiliary electrode)
- MAT type (MV lamp with tungsten filament)
- MB type. (MV lamp with auxiliary electrode and Bayonet cap)

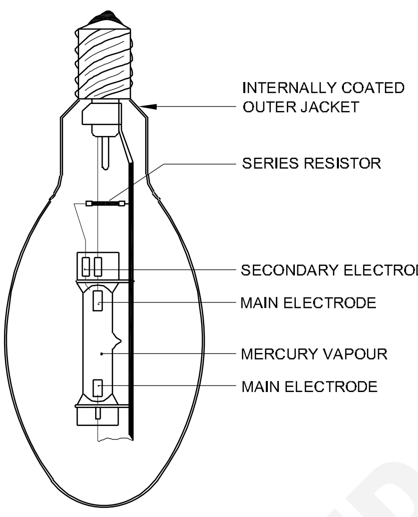
Among the 3 types only MA type is explained below:

MA type HPMV lamp: The discharge tube is made of borosilicate which is quite hard. The tube consisting of the main and auxiliary electrodes is sealed with an inside pressure of one and a half atmospheres. The lamp has a screw cap and is connected to the mains through the choke. (Fig 2) The lamp takes about 5 minutes to start giving full output.

This lamp, once switched off, will not restart again until the pressure developed inside the tube falls back. It takes about 7 minutes to start again. There is no harm in keeping the switch on. The lamp should always be hung vertically, otherwise the inner tube will be damaged.

The efficiency is 45 lm/watt for 400 watts lamp

Fig 2



MA TYPE HPMV LAMP

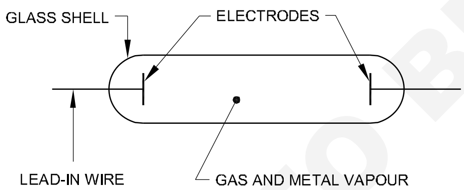
ELN248842

Fluorescent lamp

Objectives : At the end of this lesson you shall be able to
- **state the principle of discharge lamps**
- **describe the construction of single tube fluorescent lamp with its components**
- **state the function of each component in the circuit.**

Principle of a discharge lamp : The basic principle of a gas-discharge lamp is explained in Fig 1. Gases are normally poor conductors, especially at atmospheric and higher pressures, but application of suitable voltage (known as ignition voltage) between two electrodes in a sealed envelope containing gas at low pressure ionises the gas, and current passes from one electrode to the other through the gas medium.

Fig 1



GAS-DISCHARGE LAMP

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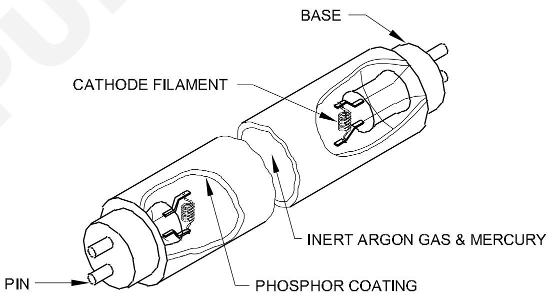
A glass shell with two electrodes apart is connected through lead in wires to the voltage source. The space within the shell is filled with low pressure vapour. When the voltage applied to the electrodes is increased to a certain value, the gas inside gets ionised and starts conducting.

Construction of fluorescent tubes: A fluorescent light bulb is basically a glass tube capped by two bases. (Fig 2) These bases are fitted with pins to carry current to internal components called cathodes. Contained inside the tube are minute droplets of mercury and an inert gas.

The inner surface of the tube is coated with a fluorescent powder or phoshphor. This phosphor emits light when exposed to ultra-violet rays. Cathodes or electrodes are made up of coiled tungsten filaments coated with a mixture of barium and strontium oxides.

Fig 2



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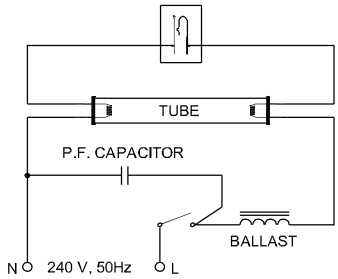
Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is as in (Fig 3)

Fig 3



CIRCUIT DIAGRAM

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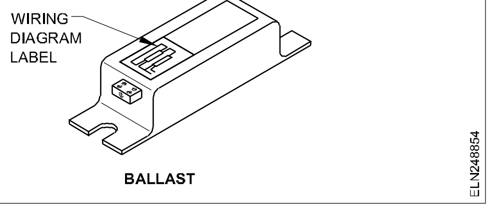
Function of the various parts in a fluorescent light circuit

Ballast (Choke)**:** The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of heavy current to the tube cathodes to keep them from burning out.

Fig 4



Starters: A starter in the fluorescent tube circuit performs two functions.

- It completes the circuit at first for preheating the electrodes.
- It opens the circuit to provide voltage kick for ignition.

There are two types of starters.

- Glow-type
- Thermal type

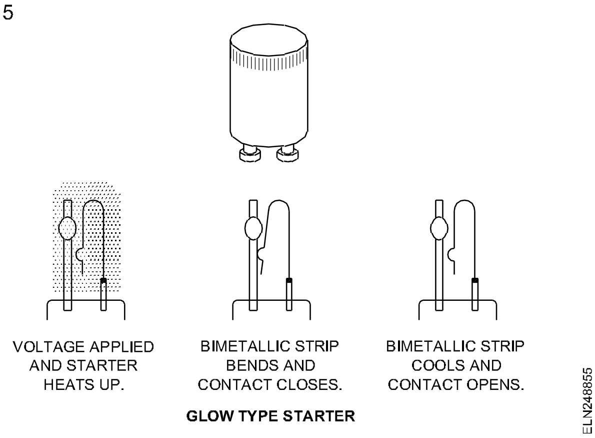
Glow type starters: A glow-type starter switch (Fig 5) is the one most widely used. It consists of a gas-filled glass tube containing two electrodes, one of which is a bimetallic strip. When voltage is applied to the starter, a glow discharge occurs between the two contacts. The heat thus developed causes the bimetallic strip to deflect and close the circuit.

Current for preheating the electrodes starts flowing. At the same time the glow discharge ceases resulting in the cooling of the bimetallic strip. The contacts reopen and the voltage induced in the choke coil provides the ignition voltage.

Thermal type starter: The starter has a bimetalic strip close to the resistance R which produces heat.

Thermal type starters are generally enclosed in a hydrogen - filled glass bulb G. The two switch electrodes E_1 and E_2 are normally closed when the lamp is not in operation. When normal supply is switched on, the lamp filament electrodes A and B are connected together through the thermal switch and a large current passes through them.

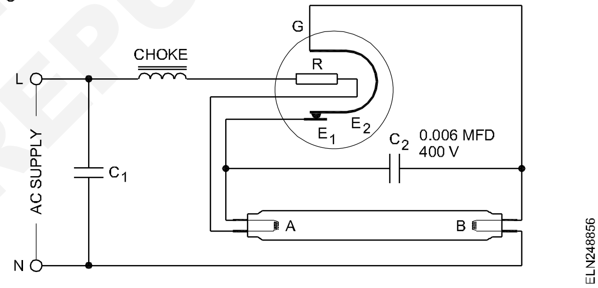
Fig 5



Consequently, they are heated to incandescence. Meanwhile the heat produced in resistance R causes the bimetallic strip E_2 to break contact. The inductive surge of about 1000V produced by the choke is sufficient to start discharge through mercury vapours as explained. The heat produced in R keeps the swtich contacts E_1 and E_2 open during the time as shown in Fig 6.

A 0.006 MFD capacitor (C_2) is connected across the electrodes of the starter contacts (bimetals) in the case of both thermal and glow type starters, to eliminate any radio interference effects that may be caused by the opening and closing of the bimetallic contacts.

Fig 6



Halogen lamp

Objectives: At the end of this lesson you shall be able to
- **explain Halogen lamp construction**
- **describe the principle of tangsten halogen regenerative cycle process**

Construction: Halogen lamps are the most advanced and multi-purpose incandescent lamps. Although they belong to the incandescent family of lamps, they are designed to provide a superior quality of crisp white light, long life, high efficiency and constant lumen maintenance. Due to their reduced size, the halogen lamps allow for the most compact and stylish fixture designs. Halogen lamps operate on the tungsten halogen regenerative principle which eliminates filament evaporation and bulb blackening. As a result, the initial lumens and color temperature are maintained throughout the lamp life. The use of bromine, which is a transparent gas, increases efficiency by 28 -33 lumens/watt as compared with iodine because there is less absorption of light by the filled gas (Fig 1).

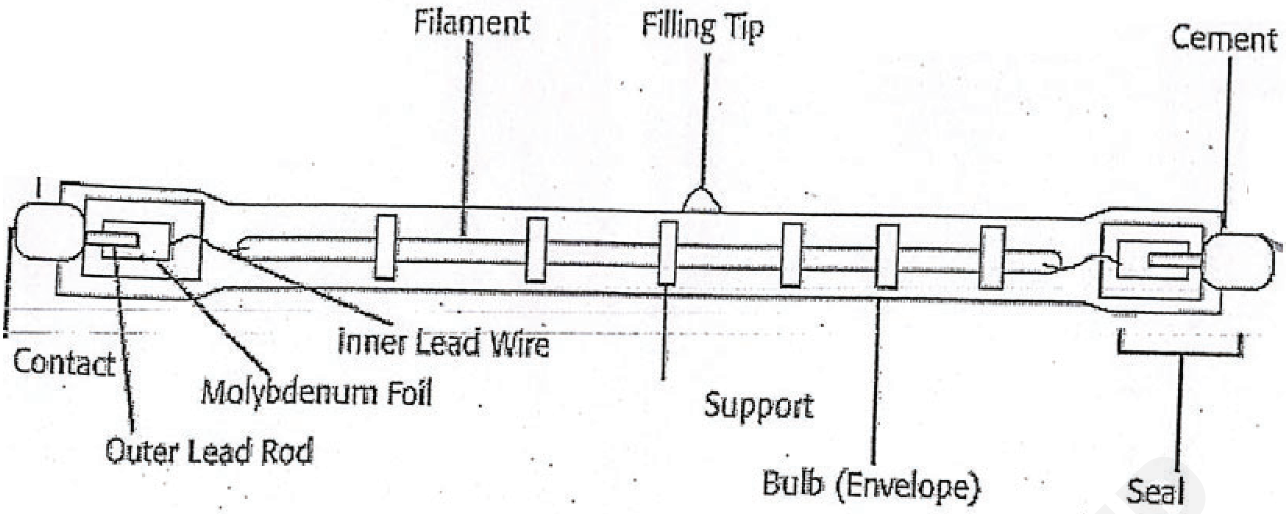
Principle of tungsten halogen regenerative cycle process

1 If the lamp is turned on, tungsten particles evaporate from filament and attach on to bulb wall. At the same time, halogen is decomposed and becomes atomic halogen.

2 Atomic halogen is diffused on the bulb wall and combines with free tungsten particle to become transparent and volatile tungsten halide.

3 Due to the high temperature (over 500°F) on the bulb wall, tungsten halide is volatilized and circulated back to filament.

Fig 1



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4 After tungsten halide is decomposed around the filament at a high temperature, halogen gas is released, ready to combine again, and tungsten is re-deposited on the filament, whereby the process is ready to begin again.

The halogen lamp's envelope is made of quartz glass because of the high operating temperature and pressure required to permit the halogen regenerative cycle process. Quartz also renders the lamp extremely resistant to heat impact. The small dimensions of halogen lamps allow accurate control over the light beam for a better focused and precise light.

Tungsten Halogen Lamp

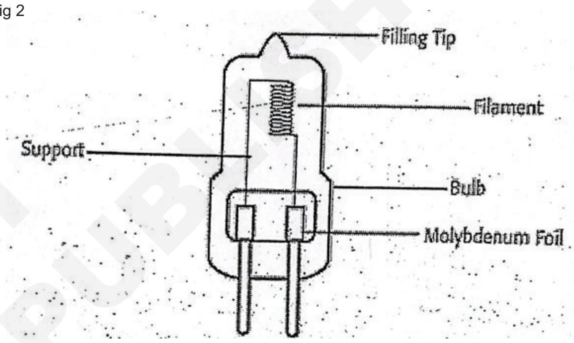
Halogen is the name given to group of gaseous elements like flourine, chlorine, bromine and Iodine.In incandescent lamp the life of filament is affected by evaporation of tungsten.

To prevent this a small amount of halogen gas (say iodine) is added to the argon gas filling of the lamp. Evaporated tungsten iodine is very volatile and suffers thermal diffusion in direction of filament and gets decomposed into tungsten and halogen.

Tungsten so relesed is deposited back on filament restoring its strength. Thus addition of halogen results in formation of a regenerative cycle and evaporation of tungsten is prevented. This also results in increased efficiency as tungsten filament can now be heated to much more temperature (Fig 2).

To maintain this regenerative cycle, it is necessary that the wall temperature is maintained high to 2500^0C. The lamp envelope is therefore made of quartz due to which it is possible to miniaturise, as filling gas can now be filled at high gas pressure.

Fig 2



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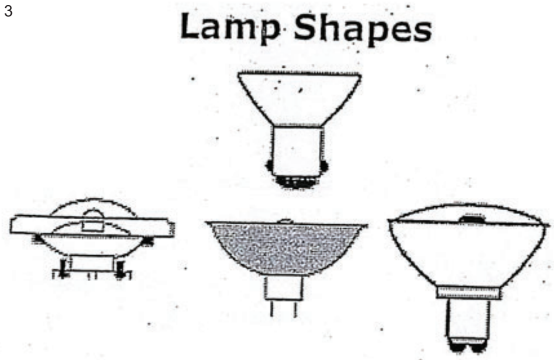
The efficacy of this lamp is 50% more as compared to GLS for equal watage and life is just double. These lamps have better colour rendition. These are available in sizes of 500 W to 5kW. Halogen lamp with much better efficiency and lesser sizes but having very less life are manufactured for TV photography and film camera purpose.

The Fig 3 shows the different shapes of halogen lamps.

Fig 3



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Compact Fluorescent Lamp (CFL)

Objectives: At the end of this lesson you shall be able to
- **explain the construction of CFL**
- **describe the working principle of CFL**
- **state the types of CFL's and tubes.**

CFL Lamp

Construction: A compact fluorescent lamp (CFL), also called compact fluorescent light, energy-saving light, and compact fluorescent tube, is a fluorescent lamp designed to replace an incandescent lamp; some types fit into light fixtures formerly used for incandescent lamps. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and a compact electronic ballast in the base of the lamp (Fig 1)

Fig 1

Fig 2.3.12.01

A CFL has a higher purchase price than an incandescent lamp, but can save over five times its purchase price in electricity costs over the lamp's lifetime.

Working principle : The principle of operation in a CFL bulb remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating on the bulb (as well as into heat when absorbed by other materials such as glass).

CFLs radiate a spectral power distribution that is different from that of incandescent lamps. Improved phosphor formulations have improved the perceived color of the light emitted by CFLs, such that some sources rate the best "soft white" CFLs as subjectively similar in color to standard incandescent lamps.

Types of CFL

There are two types of CFLs:

1 Integrated lamps

2 Non-integrated lamps.

Integrated lamps: Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs. Integrated CFLs work well in many standard incandescent light fixtures, reducing the cost of converting to fluorescent.

Non-integrated lamps: Non-integrated CFLs have the ballast permanently installed in the luminaire, and only the lamp bulb is usually changed at its end of life. Since the ballasts are placed in the light fixture, they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the bulb reaches its end-of-life. Non-integrated CFL housings can be both more expensive and sophisticated.

Light Emitting Diodes (LEDs)

Objectives: At the end of this lesson you shall be able to
- **state the advantages of LEDs over-conventional bulbs**
- **explain the principle of working of LED**
- **state the popular types of LED.**

Light emitting diodes (LED)

One of the most common and popular of new devices in the optical electronics is the **Light Emitting Diode** abbreviated as **LED**. These LEDs are now used as indicators in almost all electrical and electronic circuits and equipments.

The advantages of LEDs over incandescent bulbs are listed below:

1 LEDs have no filaments to heat and so require less current to glow.

2 LEDs require lower voltage level (typically 1.2 to 2.5 V) than the conventional bulbs.

3 LEDs last much longer - upto several years.

4 Because there is no filament to heat up, LEDs are always cool.

5 LEDs can be switched ON and OFF at a much faster rate compared with conventional lamps.

Principle of working of LEDs

Although LED is also a type of diode, it cannot and should not be used for the purpose of rectifying AC to DC.A LED is a semi conductor device which emits visible ligt when it is property connected with the electric supply.

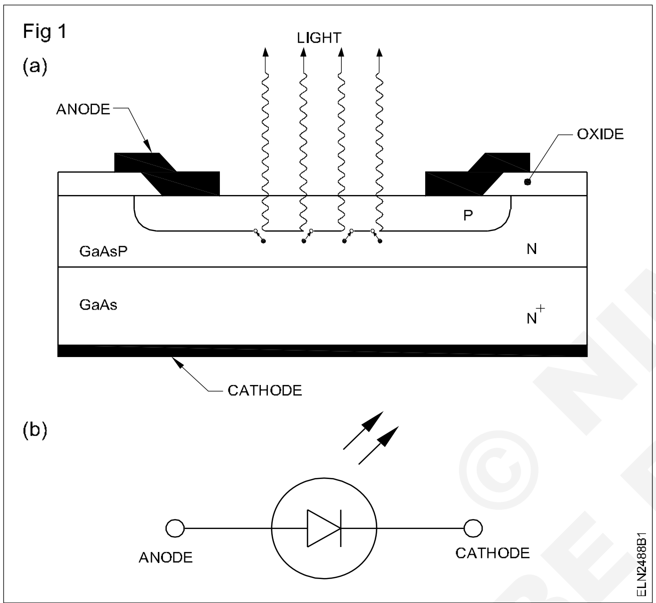
Recall that a general purpose diode or a rectifier diode conducts when energy is supplied to the electrons (Si=0.7V, Ge=0.3V) to cross the barrier junction. Each electron, after acquiring the supplied extra energy, crosses the junction and falls into the hole on the P side of the junction while the electron recombines with a hole, the electron gives up the extra energy by it. This extra energy is dissipated in the form of heat and light.

In general purpose diodes because the silicon material is not transparent(opaque), the light produced by the electrons does not escape to the outer environment. Hence, it is not visible. But LEDs are made using semi-transparent materials instead of silicon.

Because the material used in making LEDs is semi-transparent, some of the light produced by the electrons escapes to the surface of the diode, and, hence, is visible. (Fig 1a)

LEDs are typically doped with gallium arsenic, gallium phosphate or gallium arseno-phosphate. Different dopes cause the LED to emit light of different colours (wave-lengths) such as red, yellow, green, amber, or even invisible infrared light.

The schematic symbol of LED Non-integrated lamps is as shown in (Fig 1b). The arrows are used to indicate that light is radiated from the device.



Types of LEDs

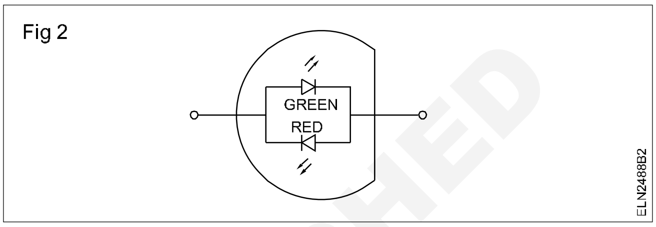
Single colour LEDs: Most of the commercially available and commonly used LEDs are single colour LEDs. These LEDs radiate one of the colours such as red, green, yellow or orange. Different coloured LEDs will have different forward voltages as given in the table below:

Colour of LED	Red	Orange	Yellow	Green
Typical Forward voltage drop	1.8V	2V	2.1V	2.2V

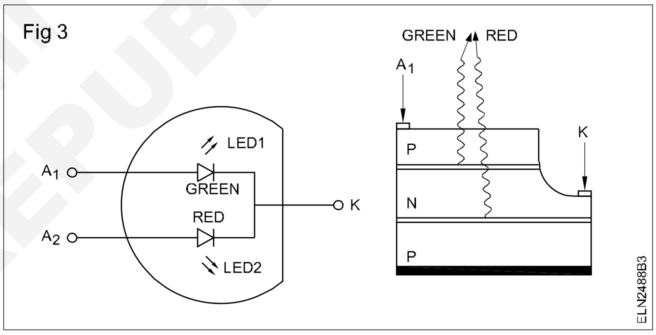
These typical forward voltage drops are at a typical LED forward current I_f = 20 mA.

Two colour LEDs: These LEDs can give two colours. Actually, these are two LEDs put in a single package and connected . (Fig 2)

In a two-colour LED, two LEDs are connected in inverse parallel, so that one of the colour is emitted when the LED is biased in one direction and the other colour is emitted when the LED is biased in the other direction. These LEDs are more expensive than the single colour LEDs. These LEDs are useful to indicate +ve, –ve polarities, GO-NOGO indication, null detection etc.



Multicolour LEDs: These are special types of LEDs which can emit more than two colours. These LEDs comprises of a green and a red LED mounted in a three-pin common cathode package. (Fig 3)



Output colour	Red	Orange	Yellow	Green
LED-1 current	0	5mA	10mA	15mA
LED-2 current	15mA	3mA	2mA	0

This LED will emit green or red colour by turning ON only one LED at a time. This LED will emit orange or yellow by turning on the two LEDs with different current ratios as shown in the table given above.

High pressure metal halide lamps

Objectives: At the end of this lesson you shall be able to
- **describe the working principle of metal halide lamp (M.H.L)**
- **explain the starting of M.H lamp**
- **state the parts of MH lamp and its starting methods.**

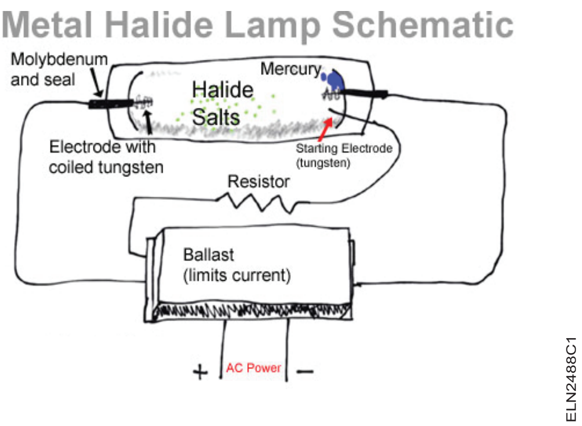
Metal halide lamps

This type of lamp is also known as an `MH' lamp. It is an HID lamp (High intensity Discharge), which means it provides most of its light from the electric arc within a small discharge tube. It is becoming increasingly popular due to its good quality white light and good efficiency. The most prominent use of the MH lamp is in stadiums and sports fields. It is also used widely for parking lots and street lighting in urban areas.

Working Principle

Fig 1 shows the schematic connection diagram of a metal Halogen lamp in to the AC supply. A resistor is connected to limit the current so as to increase the life of ballast.

Fig 1



When the lamp is cold the halides and mercury are condensed on the fused quartz tube. When the lamp is turned on current passed through the starting electrode and jumps the short distance to the main electrode (Fig 1), this is aided by argon gas. The argon strikes an arc at low temperatures.

After the initial small arc the tube heats up and the mercury is vaporized. Electric arcs fight to works through the distance of a gas, but over time more molecules of the gas become ionized. This makes it even easier for more electric current to pass through, so the arc gets wider and hotter.

In the lamp as the first arc heats up, it begins to turn the solid mercury into a vapor, soon the arc is able to travel through the mercury vapor to reach the other main electrode on the opposite side of the discharge tube. There is less resistance on this path now and current stops flowing through the starting electrode, just as a river changes course to a path of least resistance, drying out the previous channel.

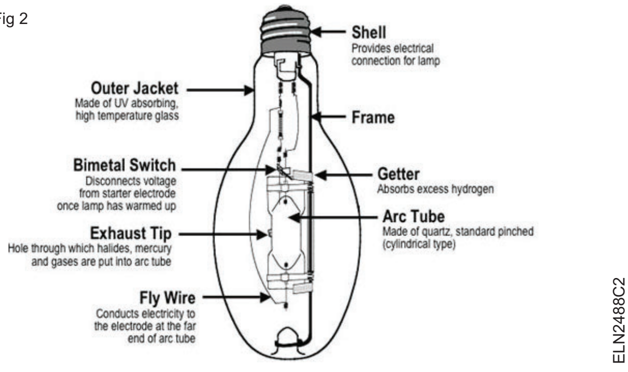
Parts of Metal Halide lamps.

Fig.2 shows the inner parts and its various function of a metal halide lamp. The inner tube contains the electrodes and various metal halides, along with mercury and inert gases that make up the mix. The typical halides used are some combination of Sodium, Thallium, and Scandium and Dysprosium Iodides. These iodides control the lamp's spectral power distribution and provide color balance by combining the spectra of the various iodides used.

Light is generated by creating an arc between the two electrodes located inside the inner arc tube. The inner arc tube is typically made of quartz, and this is a very harsh environment, with high temperatures approaching 1000°C and pressure of 3 or 4 atmospheres.

To start a metal halide lamp, a high starting voltage is applied to the lamp's electrodes to ionize the gas before

Fig 2



current can flow and start the lamp. The outer jacket is usually made of Borosilicate glass to reduce the amount of UV radiation emitted from the lamp.

Starting Metal Halide Lamps

A metal halide lamp's starting requirements are important because they impact the type of ballast that the lamp requires. Two methods are used to start MH lamps: probe start (standard start) and pulse start.

Probe start refers to the method used to ignite the arc in the tube. A traditional or probe start metal halide lamp has three electrodes - two for maintaining the arc and a third internal starting electrode, or probe.

A high open circuit voltage from the ballast initiates an arc between the starting electrode and the operating electrode at one end of the arc tube. Once the lamp reaches full output, a bi-metallic switch closes to short out the probe, thereby discontinuing the starting arc.

Pulse-start MH lamps do not have a starting probe electrode. An igniter in the pulse start system delivers a high voltage pulse (typically 3 to 5 kilovolts) directly across the lamp's operating electrodes to start the lamp, eliminating the probe and bi-metallic switch needed in probe start lamps.

Without the probe electrode, the amount of pinch (or seal) area at the end of the arc tube is reduced, which allows for increased full pressure and reduced heat loss. Furthermore, using an ignitor with a lamp reduces tungsten sputtering by heating up the electrodes faster during starting, reducing the lamp's warm-up time.

Advantages of MH Lamps

- Excellent Color Rendering
- Compact Size
- Versatility
- High Efficiency
- Positive Environmental Impact
- Long Life
- Better Light Quality
- Designable Color

Lighting for decoration - Serial set design - Flasher

Objectives: At the end of this lesson you shall be able to
- **state the methods used for decoration**
- **state the names of flasher and their function.**

Use of decoration lights

Electric light decoration for special occasions like wedding parties, festivals and fairs is a common feature nowadays. Special electric light sign circuits add much colour, fun and pleasure on the occasion. Electric signs, particularly neon signs, are extensively used in advertisements which have tremendous eye catching effects. Decoration with electric signs improves the appearance of a building and makes the place more attractive.

Two methods are mainly used for decoration.

- Signs employing miniature low voltage incandescent lights which can be switched on and off in sequence to produce the desired effect.
- Neon signs employing tubes shaped to produce designs in various colours, the colour being determined by the type of gas used in the tube.

Miniature incandescent lamps: Miniature incandescent lamps are normally available with 6V, 9V, 12V & 16V ratings with different colours which may be grouped in series or series parallel combinations for operation in available 240V supply.

For getting different messages and decoration effects the following types of flasher signs are used.

Speller type flashers are used for spelling out signs letter by letter or word by word for building up or down, plain on-off flashing, with changing colour.

Speed type flashers are used for operating spectacular signs such as lighting waving-flags, - flame, revolving wheels etc.

Script type flashers as the name implies are used when the effect of handwriting in script letters is desired.

An example of a speed type flasher for revolving is shown in Fig 1. The speed of running light/ rotating light can be adjusted. In this three-point running light (the sign flasher) there are three groups of lamps, each group switched on and off, in sequence, for running effect (Fig 2) with the help of a small induction motor which is running on eddy current principle and is connected to 240V/115V 50 Hz. Cans or drums are mounted on a shaft which is rotated by the motor.

Fig 1

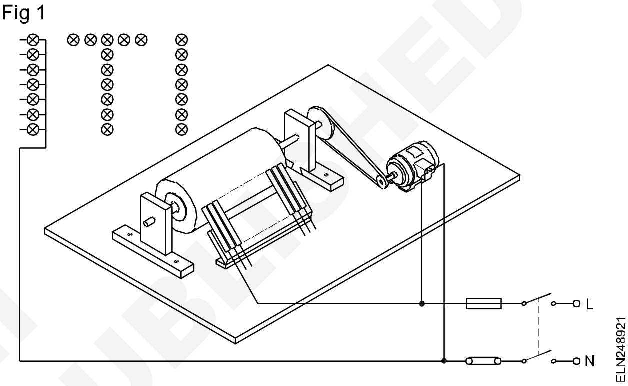
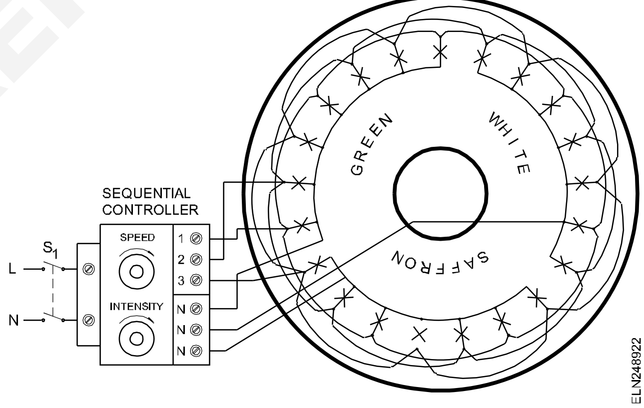


Fig 2



The circumference of the cans or the drums are so cut that the brushes will make contact only during the fixed portion of the revolution, thus completing the circuit. We can make three independent circuits by the 3-point sign flashers which are switched 'ON' and 'OFF' successively.

Designing a decorative serial lamp for a given supply voltage

Objectives: At the end of this lesson you shall be able to
- **calculate the number of bulbs to be connected in series for a given supply voltage.**

Serial set design

We have to design a row of 6 or 9 volts lamps. If these lamps are connected directly to the 240V supply, the lamps will get fused immediately. Therefore the lamps are to be connected in series. The calculation as shown will be -

1 For 6 volts lamps

$$\text{Total No. of lamps required} = \frac{240}{6} = 40 \text{ lamps.}$$

Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 40 + (5% of 40)

= 40 + 2 = 42 lamps.

2 For 9 volts lamps

Total No. of lamps required= $\frac{240}{9} = 26.6 \text{ or } 27 \text{ lamps}$

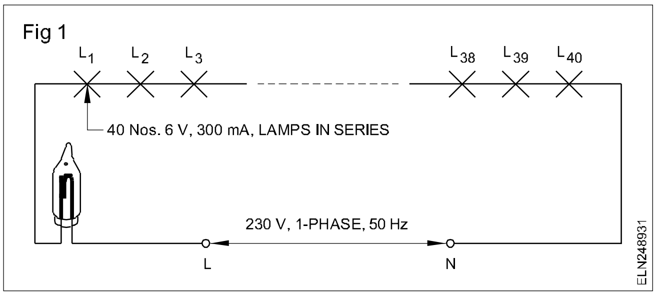
Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 27 + (5% of 27)

= 27 + 2 = 29 lamps.

The circuit for a series lamp connection of 6V lamp and supply voltage 240V. (Fig 1)

Fig 1



Precautions

- Never connect the low volt lamps directly to the mains.
- Never touch the exposed wires.

In the above case we discussed for 6V and 9V lamps. In the market we get for 6 volts different current ratings viz. 100mA, 150mA, 300mA, 500mA. The shape of the lamp for the above current ratings however remains the same.

For the series lamps to work satisfactorily the current rating of all the lamps should be the same.

We can prepare serial lamps with different voltages but of the same current rating.

Example

You have 25 lamps of 6V, 300mA rating and 20 numbers of 9V,300mA lamps. How will you design a 'serial lamp' circuit for 240V supply mains

a using all the available 6V lamps and for the rest of 9V lamps.

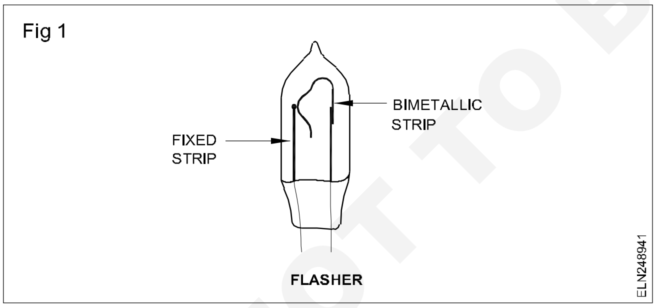
b using all the available 9V lamps and for the remaining 6V lamps.

Flasher

Objectives: At the end of this lesson you shall be able to
- **state the purpose of the flasher in the series lamp circuit.**

Flasher: In the row of lamps of low voltage, a small lamp (flasher) of filament type is connected in series with the other lamps. This lamp (flasher) does not give light but acts as a switch for the other lamps. This lamp contains a bimetal strip, which is in contact with a fixed strip (Fig 1).

Fig 1

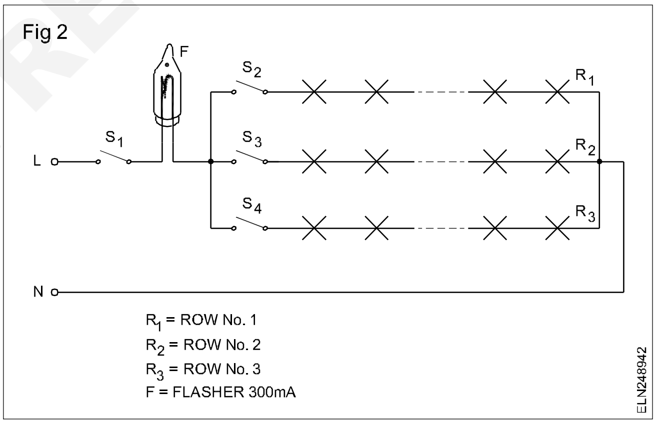


When the row of lamps is connected across the supply and switched ON, the bimetal strip gets heated up, this breaks the contacts and disconnects supply to the other lamps, making the lamps OFF.

After a few seconds, the bimetal strip cools down and makes contact. The supply to the other lamps is ON and the lamps light up. This is a twinkling type row of lamps used for decoration (Fig 2).

The rating of the flasher in each row of (small) low voltage lamps must be the same as that of the other lamps in that series circuit. If the lamps are of different ratings, then the flasher should be of the lowest current capacity in that circuit.

Fig 2



Though the flasher can be connected anywhere in the series circuit, it should be connected at the supply (phase) considering it as a switch.

The operating condition of the flasher can be decided by observation. If the bimetal strip is found welded to a fixed strip, then the flasher is not useful and if it is in an unserviceable condition. It can also be found out by connecting in circuit and tested for its condition, i.e. whether it is operating or not.

When a number of series lamp rows are connected in parallel the flasher should be connected at the input of supply as shown in Fig 2.

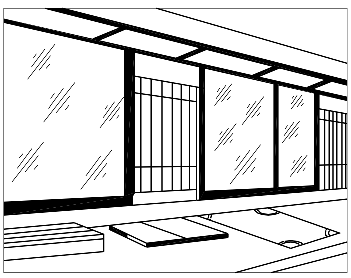
Show case lights and fittings - calculation of lumens efficiency

Objectives: At the end of this lesson you shall be able to
- **state the types of bulbs for illumination**
- **explain direct and indirect lighting and showcase lighting**
- **explain the luminuous efficiency calculation.**

Show case lighting: A number of commercial establishments use visual representation to their products, using a lighting system called show case lights. Some of them are discussed below.

Counters and dealing shelves: In bank cages and ticket offices supplementary trough lighting equipment is usually located at the top of the cages to produce a band of light lengthwise on the counter. Troughs may be covered with diffusing glass or fitted with longitudinal louvers to shield the lamps. Sixty watt lamps on 15 to 18 inch centres will generally be adequate. (Fig 1)

Fig 1



Small metal bracket type reflectors luminary or regular 25 or 40 watt tubular lamps effectively illuminate small vertical display racks, stands and cabinets. (Fig 2)

Fig 2

Small compact lens posts available in both 250 and 400 watt size, mounted on columns or ceiling brackets, give sales emphasis to small counter or table displays. Adjustable in spot size for 12 to 48 inches diameter spot at 10 ft. a 250 watt unit at 10 ft. will deliver 200 to 250 feet candles, with a 12 to 15 inches spot size: the 400 watt unit will give 350 to 400 foot candles. (Fig 3)

For extended vertical surface displays - rungs, tapestries, draperies, paintings - a series of 150 or 200 watt lens plate units at the ceiling is suitable for fixed display locations. Bracket type parabolic, polished metal troughs produce equivalent results and have some advantage in greater mobility. (Fig 4)

Fig 3

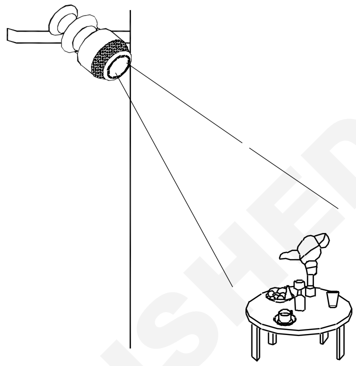
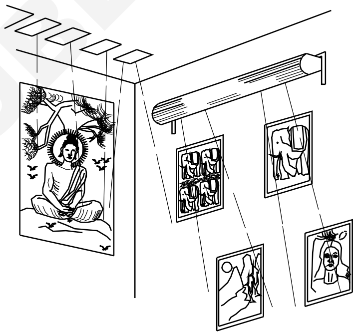


Fig 4



For necessity and impulse items such as groceries, where attention rather than critical seeing is the requirement, less engineering refinement is needed in shelf lighting equipment. Concentrating trough reflectors which incorporate luminous panels for changeable advertising copy are satisfactory. Sockets 30 cms apart may be fitted with 40 to 100 watt lamps, as conditions dictate. (Fig 5)

Fig 5

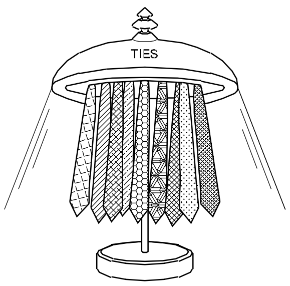
For lighting displays on columns or built-in shelving a metal nosing along the front edge of each shelf effectively conceals small 25 watt tubular lamps as shown in the sketch. Lamps should be spaced not more than 30 cms apart. Lumiline lamps are, of course, equally suitable in many cases.

Displays of glassware and bottled goods are highly attractive and colourful if lighted by transmitted light as shown in Fig 5. An opal glass panel, illuminated uniformly from behind the lamps spaced not more than 1½ times their distance at the back of the glass will provide a suitable luminous background.

Circline tubes used for window show case: For circline tubes the ballasts are specially designed and are easily adaptable to assembly on the stem of portable lamps and in shallow wall and ceiling fixtures, and in some designs they can be mounted within the circle of the tube.

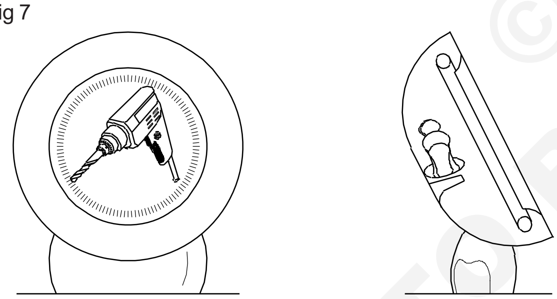
Ballast equipments designed for use with the 8¼ inch 22 watt, 12-inch 32 watts. circle line include two single lamp ballasts, one with uncorrected power factor. The other with high power factor. Many of the portable lighting equipments - dressing table, desk lamp, vanity mirror, tie rack, display unit and boudoir lamps such as Fig 6 and 7 - in which the 8¼ inch circline will be used which have small thin bases and slender stems.

Fig 6



TIE RACK

Fig 7



DISPLAY UNIT

There are varieties of goods which are being displayed in showcases of different colours, size, shape, fineness etc. Hence Different shades and colour layers will be used to get the proper colour of goods or fineness of detail or both by proper illumination.

Precaution should be taken while putting the merchandise in showcases so that wiring will not be damaged. Also the wiring and merchandise should not get damaged due to the excessive heat of lamps.

Luminous Efficiency Calculation

Luminous Efficiency: Luminous efficiency is a measure of how will a light source produces a visible light. It is a quantity of measurement for light source and it is defined as the ratio of luminous flux to power of the lamp in watts. It's unit is **lumen/watt** in SI unit.

$$\text{Luminous efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

This is important, it describes how much light is being given compare to the amount of electricity is used.

Purpose of calculating luminous efficiency

Typical house hold spends 30% of the electricity bill in lighting. Money can be saved by bringing the most cost efficient lighting option in home needs.

For example : A 60w light bulb usually produces 860 lumens. Calculate the luminous efficiency.

$$\text{So, efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

$$= \frac{860}{60} = 14.3 \text{ lumen/watt}$$

Instruments - Scales - Classfication - Forces - MC and MI meter

Objectives: At the end of this lesson you shall be able to
- **state the instrument, position, types**
- **state the terminal markings in instrument**
- **state the instrument scales type.**

Electrical Measuring Instrument

Electrical measuring instruments (meters) is an apparatus, used for measuring the electrical quantities like current, voltage, resistance power and energy etc.

Identification of instrument

The instrument should be identified for the quantity to be measured, the range, suitability for a particular type of supply etc. by carefully going through the data available on the dial.

Types of current: The types of supply on which the instrument is suitable for measurement is indicated by symbols as follows.

—	Direct current
~	Alternating current
⎓ ~	Direct and alternating current

Testing potential (voltage): The star mark on the dial indicates the voltage to which the instrument is subjected for test.

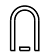
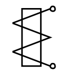
☆	Testing potential 500V
☆ 2	Testing potential over 500V eg, 2000V(2KV)

Using position: Instruments must be used as per the specified position mentioned on the dial.

⊥	Vertical using position.
⊓	Horizontal using position.
∠60°	Angle of usage eg. 60^0 tilt angle.

Instruments used in any position other than the one specified may cause error in reading.

Measuring instrument types

	Moving coil instrument
	Moving iron instrument
	Electrodynamic quotient instrument
	Moving coil instrument with rectifier

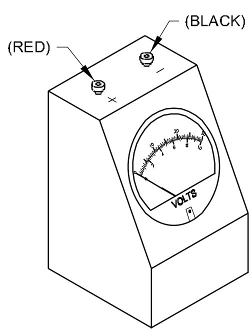
Indication error: Instruments are manufactured to read within certain accuracy. This is indicated on the dial by a number close to the other symbols.

1	Indication error ± 1%
2.5	Indication error ± 2.5%
3.5	Indication error ± 3.5%

Terminal markings: In a moving coil type of instrument, the terminals are marked with + and – . The positive (+) terminal is red in colour and the negative(–) terminal is black in colour (Fig 1). This type of instrument must be connected in the circuit with correct polarity. i.e. the +ve of supply to the +ve of instrument and the –ve of supply to the –ve of the instrument.

In the moving iron type there is no polarity marking on the terminals. Both the terminals are of the same colour. The instrument can be connected in the circuit without identifying the line and neutral of the supply.

Fig 1



Classification of electrical instruments - Essential forces, MC and MI meter

Objectives: At the end of this lesson you shall be able to
- **classify electrical instruments with respect to standard, function and operation by the effect of electric current**
- **explain the type of forces required for the proper functioning of an electrical indicating instrument.**

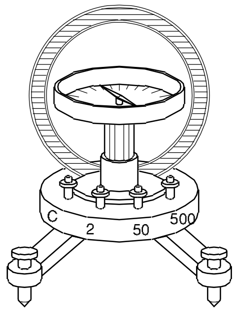
Electrical instruments may be classified based on the following.

- Manufacturing standards
- Function
- Effects of electric current on the instruments.

Manufacturing standards: The electrical instruments may, in a broad sense, be classified according to the manufacturing standards into absolute instruments and secondary instruments.

Absolute instruments: These instruments give the value of quantity to be measured in terms of deflection and instrument constants. A good example of an absolute instrument is the tangent galvanometer (Fig 1).

Fig 1



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These instruments are used only in standard laboratories.

Secondary instruments: In these instruments the value of electrical quantity (voltage, current, power, etc.) to be measured can be determined from the deflection of the instruments on the calibrated dial. These instruments should be calibrated in comparision with either an absolute instrument or with one which has already been caliberated. All the instruments used commercially are secondary instruments.

Functions

Secondary instruments are further classified according to their functions, that is, whether the instrument indicates, or records the quantity to be measured. Accordingly, we have indicating, integrating and recording instruments.

Indicating instruments: These instruments (Figs 2) indicate the value of voltage, current power etc., directly on a graduated dial. Ammeters, voltmeters and wattmeters belong to this class.

Integrating instruments: These instruments measure the total amount, either the quantity of electricity or the electrical energy, supplied to a circuit over a period of time. Ampere hour meters and energy meters belong to this class. Fig 3 shows the Kilowatt hour/energy meter.

Fig 2

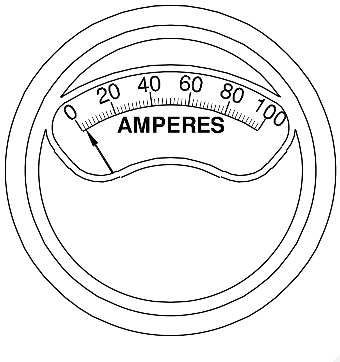

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Fig 3

Energy meter

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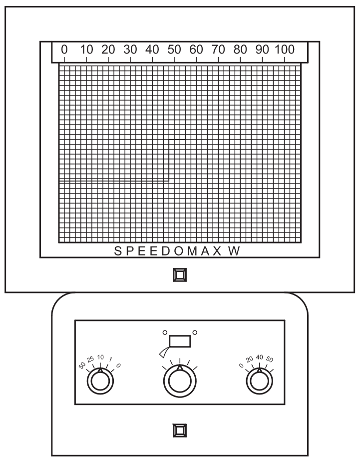
Recording instruments: These instruments register the quantity to be measured in a given time, and are provided with a pen which moves over a graph paper. With this instrument, the quantity can be checked for any particular date and time. Recording voltmeters, ammeters and power factor meters belong to this class. Fig 4 shows such a recording instrument.

Fig 4



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Effects of electric current used on electrical instruments: Secondary instruments may also be classified according to the various effects of electricity upon which their operation depends. The effects utilised are as follows.

- Magnetic effect
- Heating effect
- Chemical effect
- Electrostatic effect
- Electromagnetic induction effect

Essential forces required for an indicating instrument: The following three forces are essential requirements of an indicating instrument for its satisfactory operation. They are

- deflecting force
- controlling force
- damping force.

Deflecting force or operating force: This causes the moving system of the instrument to move from its `zero' position, when the instrument is connected to the supply. To obtain this force in an instrument, different effects of electric current, such as magnetic effect, heating effect, chemical effect etc. are employed.

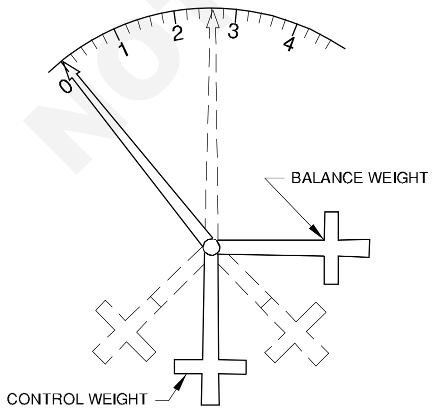
Controlling force: This force is essential to control the movement of the moving system and to ensure that the magnitude of the deflction of the pointer is always the same for a given value of the quantity to be measured. As such, the controlling force always acts opposite to the deflecting force, and also brings the pointer to zero position when the instrument is disconnected from the supply.

The controlling force could be produced by any one of the following ways.

- Gravity control
- Spring control

Gravity control: In this method, small adjustable weights are attached to the opposite extension of the pointer (Fig 5). These weights are attracted by the earth's gravitational pull, and thereby, produce the required controlling force(torque). The instruments with gravity control are to be used in the vertical position only.

Fig 5

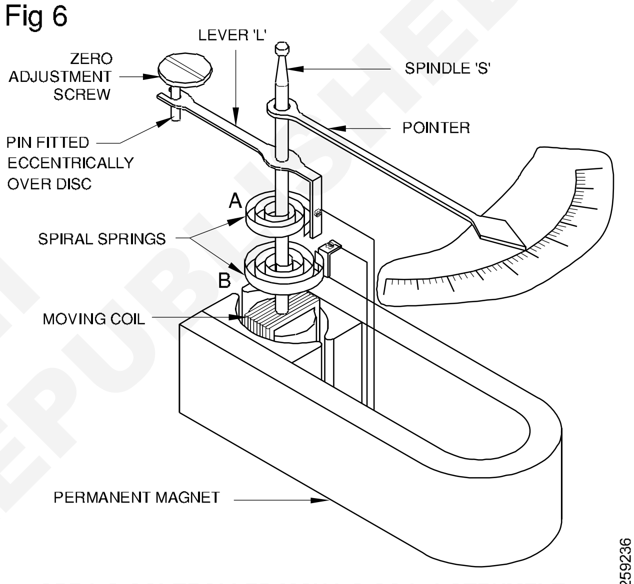


GRAVITY CONTROL

When the instrument is not connected to the supply, the control weight and the balance weight attached to the opposite end of the pointer make the pointer to be at zero position (Fig 5). When the instrument is connected to the supply, the pointer moves in a clockwise direction, thereby displacing the weights (Fig 5). Due to the gravitational pull, the weights will try to come to their original vertical position, thereby exerting a controlling force on the movement of the moving system.

Spring control: The most common arrangement of spring control utilises two phosphor-bronze or beryllium-copper spiral hair-springs A and B, the inner ends of which are attached to the spindle S (Fig 6). The outer end of the spring B is fixed, whereas that of A is attached to the end of a lever `L' pivoted at P, thereby enabling the zero adjustment to be easily effected when needed.

Fig 6



SPRING CONTROLLED MOVING COIL INSTRUMENT

The two springs A and B are wound in opposite directions so that when the moving system is deflected, one spring winds up while the other unwinds, and the controlling force is due to the combined torsions of the springs.

These springs are made from such alloys that they have:

- non-magnetic properties (should not get affected by external magnetism)
- low temperature cofficient (do not elongate due to temperature)
- low specific resistance (can be used for leading current `in' and `out' of the moving system).

Spring controlled instruments have the following advantages over the gravity controlled instruments.

They are:

- the instruments can be used in any position
- the control springs help in leading in and out the current to the moving coil of the instruments.

Damping force: This force is necessary to bring the moving system to rest in its final deflected position quickly.Without such damping, the combination of the inertia of the moving system and the controlling force makes the pointer (moving system) to oscillate about its final deflected position for some time before coming to rest, resulting in a waste of time in taking the reading.

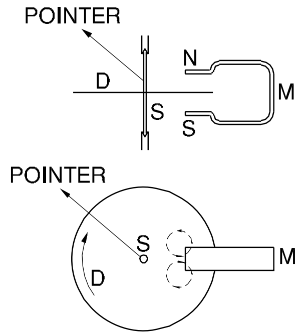
The two methods of damping, commonly employed are:

- eddy current damping
- air friction damping.

Eddy current damping: Fig 7 shows one form of eddy current damping. A copper or aluminium disc D,is attached tothe spindle 'S'. When the pointer moves, the disc also moves.

The disc is made to move in the air gap between the poles of a permanent magnet M. The moving disc cuts the flux, thereby inducing eddy currents in the disc. According to Lenz's law, the flux produced by the eddy current opposes the movement of the disc, thereby effecting the damping force.

Fig 7



EDDY CURRENT DAMPING

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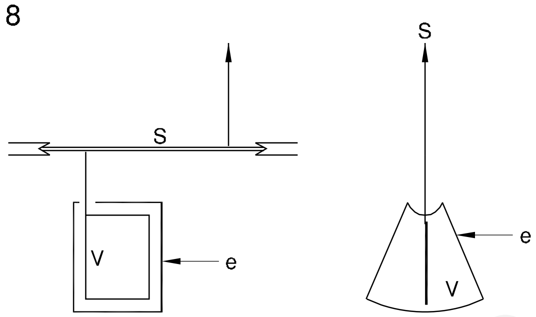
In the case of moving coil instruments, the moving coil is wound on a thin aluminium former. The eddy currents induced in the former produces the damping force.

Air friction damping: Fig 8 shows the method of obtaining air friction damping. Accordingly a thin metal vane V is attached to the spindle S, and the vane is made to move inside a sector shaped box 'e' while the pointer moves on the graduated scale.

Fig 8



AIR FRICTION DAMPING

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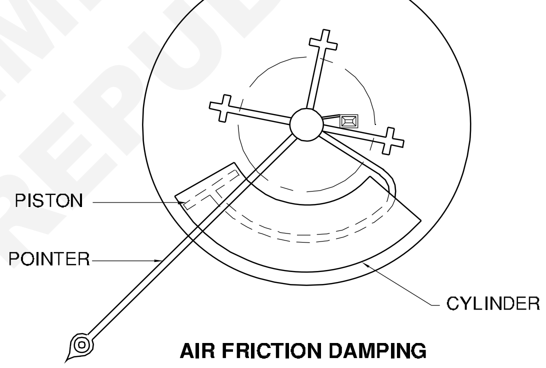
Alternatively, the vane in the form of a piston could be arranged to move inside an air chamber (cylinder) as shown in Fig 9. In the above two cases, the air inside the air chamber opposes the movement of the vane/piston, and, thereby, the damping force is created.

Fig 9



AIR FRICTION DAMPING

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Permanent magnet moving coil (PMMC) instruments

Objectives: At the end of this lesson you shall be able to
- **state the principle of a permanent magnet moving coil (P.M.M.C) instrument**
- **describe the construction and operation of a P.M.M.C instrument**
- **state the uses, advantages and disadvantages of a P.M.M.C instrument.**

Moving Coil and Moving Iron Instruments :

Instruments are classified based on their moving system They are :

(i) Moving Coil Instruments (MC)

Permanent Magnet Moving Coil Instrument (PMMC)

Dynamo meter type instruments

(ii) Moving Iron Instruments (MI)

Attraction type

Repulsion type

The most commonly used instrument to measure DC quantities like voltage and current, is the permanent magnet moving coil (PMMC) instrument.

Permanent magnet moving coil (PMMC) instruments

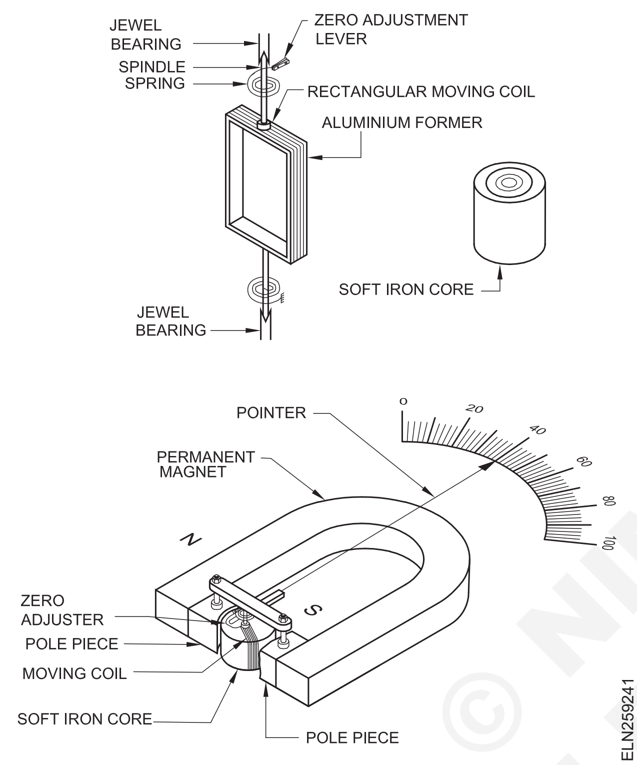
The most commonly used instrument to measure DC quantities like voltage and current, is the permanent magnet moving coil (PMMC) instrument.

Principle: The working of the PMMC instrument is based on the principle that when a current-carrying conductor is placed in a magnetic field, it is acted upon by a force which tends to move the conductor. The DC motor also works on this principle.

Construction: The PMMC instrument consists of a permanent magnet and a rectangular coil wound with a very fine gauge insulated copper wire on a thin light aluminium former.

The aluminium former not only supports the coil, but also produces eddy current for damping. The coil and the former are attached with spindles on either side, and supported by jewelled bearings so as to make the assembly move freely in the air gap (Fig 1).

Fig 1



The two ends of the coil are connected to two phosphor-bronze springs, fixed one on each spindle to lead in and lead out the current. The springs are spiralled in the opposite direction in order to neutralize the effect of temperature changes.

The horseshoe shaped permanent magnet is made of an alloy called 'Alnico' and it has soft iron pole pieces which are shaped to distribute uniform flux in the air gap.

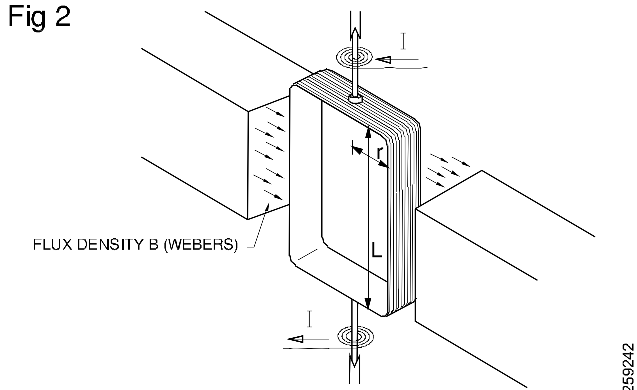
A soft iron core is fixed in such a way that the moving coil can move within the gap, between the soft iron core and the pole pieces. The function of the soft iron core is (i) to decrease the reluctance of the magnetic path between the poles and thereby increase the magnetic flux and (ii) to make the flux uniformly distributed in the air gap.

The pointer is attached to one of the spindles, and it moves on a graduated scale when the coil is deflected by the quantity to be measured.

Operation: When the current is passed through the coil, the coil experiences a force due to the interaction of the magnetic fluxes, produced by the permanent magnet and the current in the moving coil.

We have the force 'F' in the coil equal to BLIN Newtons Fig 2

Fig 2



PRINCIPLE OF THE MOVING COIL INSTRUMENT

where

- B - The flux density in the air gap in Webers/square metre,
- L - The active length of one conductor in the air gap in metres
- I - The current in amperes passing through the coil and N is the number of turns.

Torque produced in the coil

= force X perpendicular distance between the centre of the conductor to the centre of the spindle in metres.

Let us assume the distance as 'r'metres.

Hence we have

T = Fr Newton metres

T = BLINr Newton metres.

(F = BLIN Newton)

But B,L,N and r are constants for a particular instrument and can be denoted by a letter 'K'. As such

Torque = KI

Torque proportional to I

From the above equation we can infer that the deflecting torque of a PMMC instrument is directly proportional to the current, and, therefore, the scale of the PMMC instrument is uniform that is the scale in which the space between numbers are equal.

Hence, while connecting the instrument in DC the polarity should be correctly observed. Further the instrument will not deflect when connected to an AC supply.

The PMMC instrument could be directly used to measure milli or micro amperes as the moving coil can carry a low current only. With proper shunts, this instrument could be used to measure large currents, and with proper series resistors, called multipliers, it could be converted into a voltmeter.

Advantages: The PMMC instrument

- consumes less power
- has uniform scale and can cover an arc up to 270^o
- has high torque/weight ratio

- can be modified as voltmeter or ammeter with suitable resistors
- has efficient damping
- is not affected by stray magnetic fields, and
- has no loss due to hysteresis.

Disadvantages: The PMMC instrument

- can be used only in DC
- is very delicate
- is costly when compared to a moving iron instrument
- may show errors due to loss of magnetism of the permanent magnet.

Uses: It can be used as volt meter and Ammeter

Moving-iron instruments

Objectives: At the end of this lesson you shall be able to
- **state the principle of moving-iron instruments - attraction and repulsion type**
- **describe the construction and working of a moving-iron Instrument**
- **state the use, advantages and disadvantages of moving-iron instruments.**

Moving-iron instruments: This instrument derives its name from the fact that a piece of soft iron which is attached to the spindle and needle moves in a magnetic field, produced by the current or by a current proportional to the quantity of electricity being measured.

There are two types of this instrument which are used either as voltmeter or ammeter.

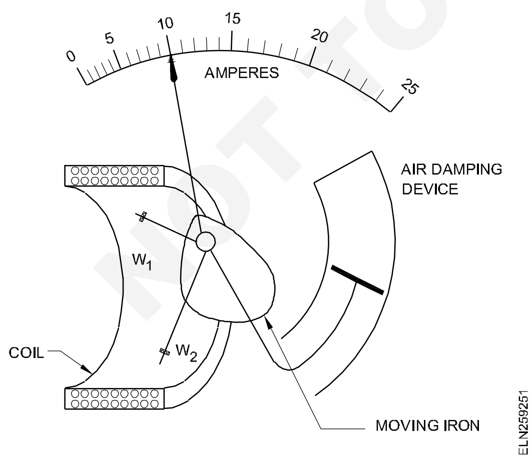
They are:

- attraction type
- repulsion type.

Principle of operation: The attraction type instrument works on the principle of magnetic attraction, and the repulsion type instrument works on the principle of magnetic repulsion between two adjacent pieces of soft iron, magnetised by the same magnetic field.

Construction and working of attraction type moving-iron instrument: This instrument consists of an electromagnetic coil having an air core (Fig 1). Just in front of the air core, an oval shaped soft iron piece is eccentrically pivoted in a spindle (Fig 1).

Fig 1



The spindle is free to move with the help of the jewelled bearings, and the pointer, which is attached to the spindle, could thus move over the graduated scale. When the electromagnetic coil is not connected to the circuit, the soft iron piece hangs vertically down, due to gravitational force and the pointer shows zero reading.

When the electromagnetic coil is connected to the supply, the magnetic field created in the coil attracts the soft iron piece (Fig 1). Due to the eccentricity of pivoting of the iron piece, the enlarged portion of the iron piece is pulled towards the coil. This in turn moves the spindle and makes the pointer to deflect.

The amount of deflection of the pointer will be greater when the current producing the magnetic field is greater. Further the attraction of the soft iron piece is independent on the current direction in the coil. This characteristic enables the instrument to be used both in DC and AC.

Construction and working of repulsion type moving-iron instrument: This instrument consists of a coil wound on a brass bobbin B, inside which two strips of soft iron M and F are set axially (Fig 2a). Strip F is fixed whereas the iron strip M is attached to the spindle S, which also carries the pointer P.

Spring control is used, and the instrument is designed such that when no current is flowing through W, the pointer is at zero position and the soft iron strips M and F are almost touching. (Fig 2a & 2b)

When the instrument is connected to the supply, the coil W carries current which in turn produces a magnetic field. This field makes the fixed and moving-iron F and M respectively to produce similar poles in the ends. Therefore, the two strips repel each other.

The torque set up produces a deflection of the moving system end. Therefore it brings into play a controling torque due to torsion of the control springs or weights. The moving system comes to rest in such a position that the deflecting and controlling torques are equal.

In this type of instrument, air damping is used commonly which is provided by the movement of a piston P_N in a cylindrical air chamber C (Fig 2a).

Deflecting torque and graduation of scale: However, in the moving-iron instruments, the deflecting torque is proportional to the square of the current passing through the coil. As such the scale of this instrument will be uneven. It is cramped at the beginning and open at the end (Fig 3).

Fig 2a

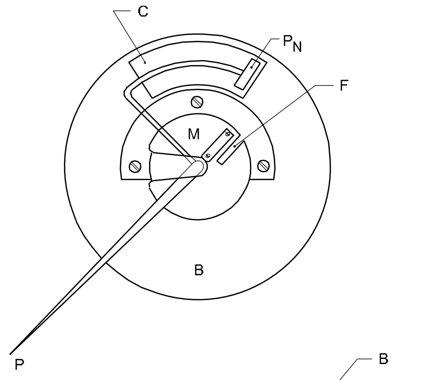


Fig 2b

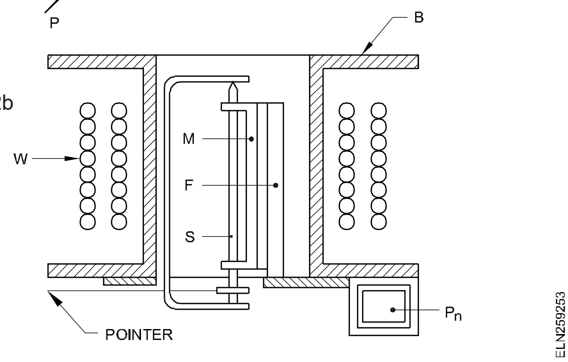
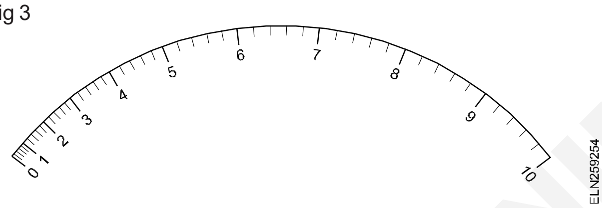


Fig 3



In order to achieve uniformity of scale, some manufacturers have designed tongue shaped strip as fixed soft iron (Fig 4a).

The fixed iron consists of a tongue-shaped soft iron sheet bent into a cylindrical form, while the moving iron is made of another soft iron sheet, and is so mounted as to move parallel to the fixed iron and towards its narrower end (Fig 4b).

The torque, which is proportional to the square of the current, is proportionally reduced by the narrow portion of the fixed iron, resulting in more or less even torque and thereby uniform scale.

These instruments are either gravity or spring controlled, and the damping is achieved by the air friction method

Uses, advantages and disadvantages of Moving-iron instruments

Uses: They are used as voltmeters and ammeters.

> **The coil W is wound with thick conductor of less number of turns for ammeters and is wound with thin conductors of large number of turns for voltmeter.**

Fig 4a

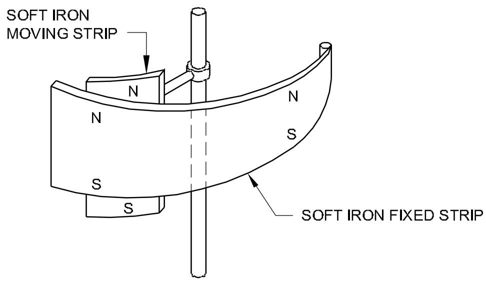
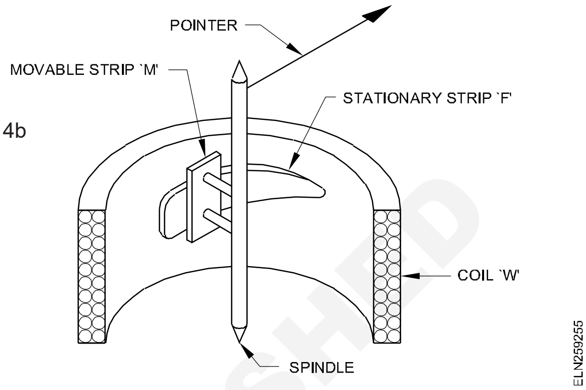


Fig 4b



Advantages

- They can be used for both AC and DC, and are hence called unpolorized instruments.
- They have a small value of friction errors as the torque/ weight ratio is high.
- They are less costly when compared to the moving coil instruments.
- They are robust owing to their simple construction.
- They have satisfactory accuracy levels within the limits of both precision and industrial grades.
- They have scales covering 240°.

Disadvantages

- They have errors due to hysteresis, frequency changes, wave-form and stray magnetic fields.
- They have non-uniform scales commonly. However, special manufacturing designs are utilized to get more or less uniform scales.

Dynamometer type instrument

Objectives: At the end of this lesson you shall be able to
- **state the principle of dynamometer type instrument**
- **describe the construction, and working of the dynamometer type instruments**
- **explain the internal connections of a dynamometer instrument when used as a voltmeter, ammeter and wattmeter**
- **state the advantages and disadvantages of using the dynamometer instruments.**

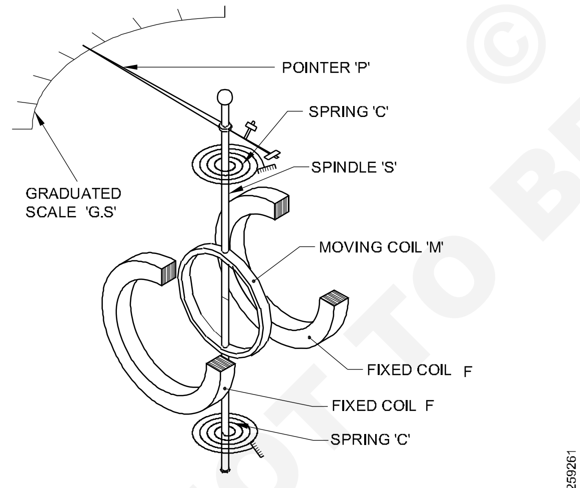
Electro-dynamic or Dynamo-meter type Instruments

Working principle: This Instrument works on the principle of DC motor. That is, whenever a current-carrying conductor is kept in a magnetic field, a force is created and it tends to move the conductor away from the magnetic field. In a dynamo- meter instrument, the magnetic field is produced by an electromagnet named as fixed coils.

The moving coil, either connected in series or parallel with the fixed coil, carries a proportionate current. Operation of this instrument in both AC and DC is possible due to the fact that when ever the current reverses in AC, the direction of flux in the fixed coils as well as the direction of flux produced by moving coil, reverses at the same time resulting in the same direction of torque.

Construction: A general arrangement of the instrument is shown in Fig 1. The main magnetic field is produced by the fixed/stationary coil. This coil is divided into two sections to give a uniform field in the centre and also to allow the moving coil mechanism to be placed in between them.

Fig 1

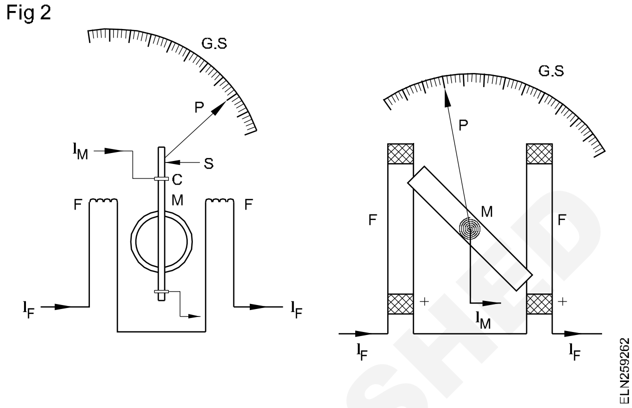


DYNAMOMETER INSTRUMENT

The fixed coils F and F are placed close together and parallel to each other (Fig 2). The air core section removes hysteresis effects when used in AC circuits. The moving coil `M' is mounted on a spindle `S' and the spindle is free to move in the air gap with the help of jewelled bearings.

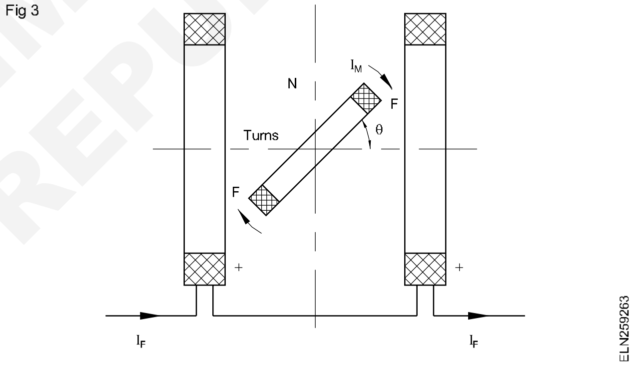
The pointer `P' is attached to one end of the spindle and the spindle end made to move on a graduated scale `G S'. The controlling torque is provided by two phosphor-bronze springs `C' attached to the spindle. Further the springs are used to allow the current `in' and `out' from the moving coil.

Fig 2



Working: As shown in Fig 3,let the current passing through the fixed coils be I_F, and the current passing through the moving coil be I_M. The field strength will be proportional to the current I_F.

Fig 3



The deflecting torque is produced due to the interactions of the magnetic fields produced by the fixed and moving coils and will be proportional to the current carried by them.

The deflecting torque T_d is proportional to I_F and I_M where I_F is the current in the fixed coil and I_M is the current in the moving coil.

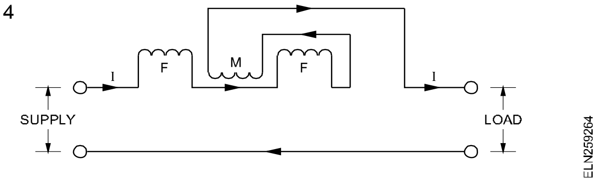
From the above torque equation, it is clear that the instrument when used as voltmeter or ammeter will have ununiform scale due to the square law response.

However, when used as a wattmeter, the instrument will have uniform scale.

Connection of this instrument requires modification depending up on the usage viz, ammeter, voltmeter or wattmeter as explained below.

Dynamometer instrument as an ammeter: This instrument could be used as milli or micro ammeter by connecting the fixed and moving coils in series (Fig 4).

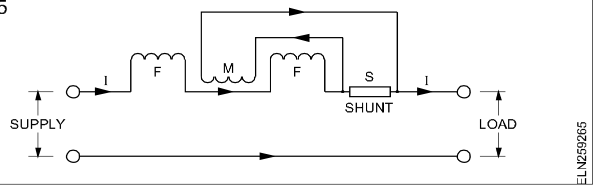
Fig 4



As the moving coil is made by winding small gauge (thin) wire, the above connection is unsuitable for measuring heavy currents.

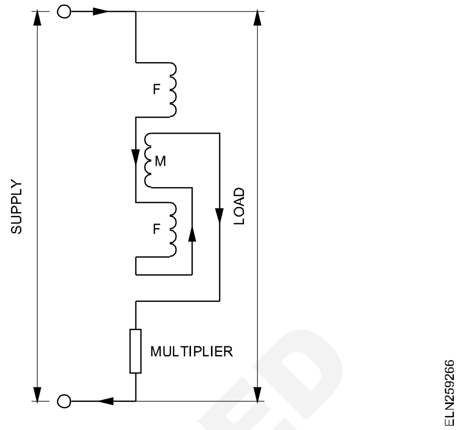
When the instrument is to be converted as an ammeter to measure large currents, the moving coil is connected across a shunt (Fig 5). Both AC and DC, measurements are possible.

Fig 5



Dynamometer instrument as a voltmeter: When this instrument is used as voltmeter, the fixed and moving coils are joined in series along with a high resistance (multiplier) (Fig 6). This voltmeter could be used both in AC and DC.

Fig 6



Advantage : This instrument can be used both AC and DC

Digital Ammeter

Objectives: At the end of this lesson you shall be able to
- **state the features of digital ammeter**
- **state the movements, special operation and standard.**

Digital Ammeter

Digital Ammeters are instruments that measure the current in ampere and display it in digital. These instruments provide information about current drawn and current continuty to help users troubleshoot electric loads.

They have both positive and negative leads and low internal resistance. Digital ammeters are connected in series with a circuit so that current flow passes through the meter.

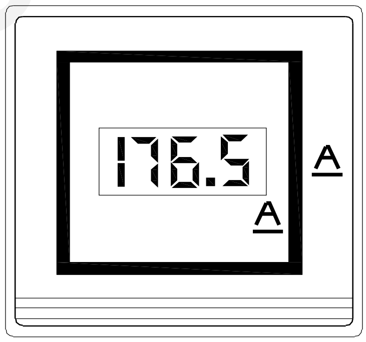
It can be used to measure the A.C and D.C. Many digital ammeters include a current sensor built in the meter.

Features:

Different types of digital ammeters can measure different ranges of A.C current and D.C current and also A.C frequency.

Batteries are provided in it to operate without plug-in-power and suitable for cutdoor use Fig 1 shows a typical digital ammeter.

Fig 1



TYPICAL DIGITAL AMMETER

Standards :

Digital ammeters must have a certain standards and specifications to ensure proper design and functionality refer IEC 600 51 - 2.

Digital Volt Meter (DVM)

Objectives: At the end of this lesson you shall be able to
- **distinguish between analogue and digital voltmeter**
- **list out the advantage of DVM**
- **explain the working principle of DVM.**

Digital Volt Meter (DVM) :

The Digital Volt Meter(DVM) is an electrical measureing instrument which is used to measure line potential difference (P.D) between two points. The voltage to be measured may be AC or DC.

Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

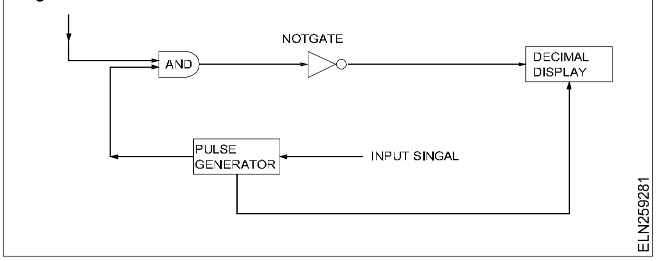
Advantages of Digital Voltmeters:

- Read out of DVMs is easy as it eliminates observational errors in measurement
- Parallax error is eliminated
- Reading can be taken very fast
- Output can be fed to memory devices for storage and future computations
- More versatile and accurate
- Compact portable and cheap
- Requires low power

Working Principle of Digital Voltmeter:

The block diagram of a simple digital voltmeter is shown in the Fig 1 It consists the following blocks

Fig 1



1 Input signal

2 Pulse generator

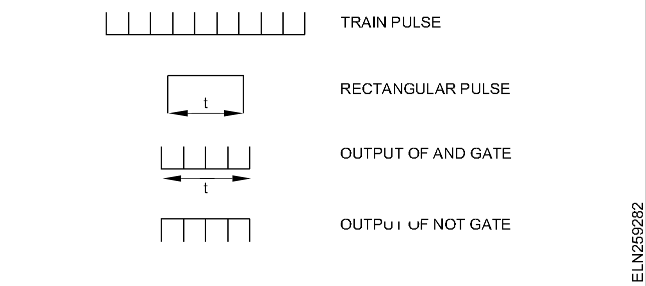
3 AND gate:

4 Decimal Display

Working (Fig 2)

- Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
- Output of pulse generator is fed to one leg of the AND gate.

Fig 2

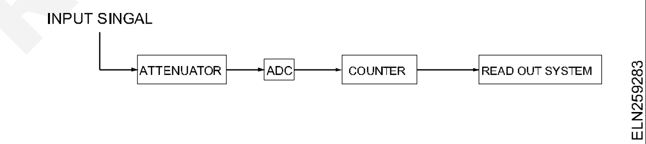


- The input signal to the other leg of the AND gate is a train of pulses.
- Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.
- This postitive triggered train is fed to the inverter which converts it into a negative triggered train.
- Output of the inverter is fed to a counter which counts the number of triggers in the duration which is proportional to the input signal i.e. voltage under measurement

This counter can be calibrated to indicate voltage in volts converts an analog signal into a train of pulses, the number is proportional to the input signal. So a digital voltmeter can be made by using any one of the A/D conversion methods (Fig 3)

Now-a- days digital voltmeters are also replaced by digital multi meters due to its multitasking feature.

Fig 3



Wattmeters

Objectives: At the end of this lesson you shall be able to
- **state the advantages of measuring power directly**
- **explain the construction and working of the induction type single phase wattmeter.**

Advantages of measuring power supply

Power in a single phase AC circuit can be calculated by using an ammeter, a voltmeter and a power factor meter with the help of the formula

Power in a single phase circuit = EI Cos ø watts.

To get an on the spot true power reading, a wattmeter is used. The power dissipated in the circuit can be read directly from the scale of the meter. The wattmeter takes the power factor of the circuit into account and always indicates the true power.

Types of wattmeters

There are three types of wattmeters in use as stated below.

- Dynamometer wattmeter
- Induction wattmeter
- Electrostatic wattmeter

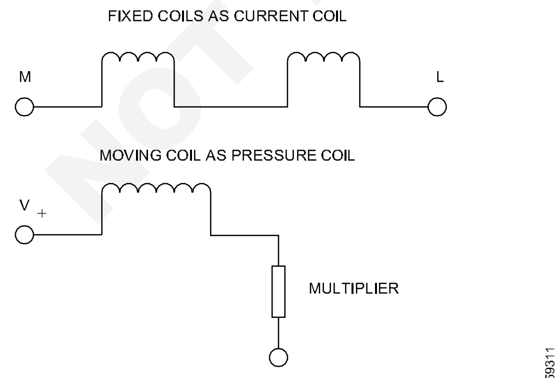
Among the three, the electrostatic type is very rarely used. Information given here is for the other two types only.

Dynamometer type, single phase wattmeter: This type is commonly used as a wattmeter.

Dynanometer used as a Wattmeter: The dynamometer is commonly used as a wattmeter to measure power in both AC and DC circuits and will have uniform scale.

When this instrument is used as a wattmeter, the fixed coils are treated as current coil, and the moving coil is made as pressure coil with necessary multiplier resistance (Fig 1).

Fig 1



DYNAMOMETER INSTRUMENT AS A WATT METER

Advantages

- This instrument can be used both in AC and DC.
- As this is an air cored instrument, the hysteresis and eddy current losses are eliminated.
- This instrument has better accuracy.
- When used as wattmeter, the scale is uniform.

DIsadvantages

- It is more expensive than PMMC and moving iron instruments.
- When used as voltmeter or ammeter the scale will not be uniform.
- It has a low torque/weight ratio-as such has low sensitivity.
- Sensitive for over loads and mechanical impact. Hence careful handling is necessary.
- It consumes more power than PMMC meters.

Induction type single phase wattmeter: This type of wattmeters could be used only in AC circuits whereas a dynamometer type wattmeter could be used in both AC and DC circuits.

Induction type wattmeters are useful only when the supply voltage and frequency are almost constant.

Construction: Induction wattmeters having two different types of magnetic cores (Figs 2a and 2b).

Both the types have one pressure coil magnet and one current coil magnet. The pressure coil carries a current proportional to the voltage whereas the current coil carries the load current.

A thin aluminium disc is mounted on a spindle in between the space of the magnets and its movement is controlled by springs. The spindle carries a weightless pointer at one end.

Working: The alternating magnetic fluxes produced by the pressure and current coils cut the aluminium disc and produce eddy currents in the disc. Due to the interaction between the fluxes and the eddy currents a deflecting torque is produced in the disc and the disc tries to move. Control springs attached to the two ends of the spindle control the deflection and the pointer shows the power in watts on a graduated scale.

Shaded rings provided in the pressure coil (shunt) magnet could be adjusted in order to cause the resultant flux in the magnet to lag in phase by exactly 90° behind the applied voltage.

Fig 2(a)

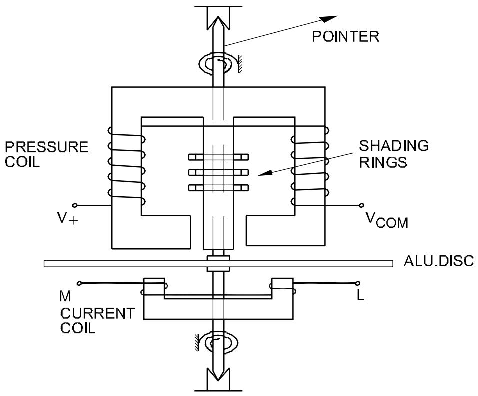
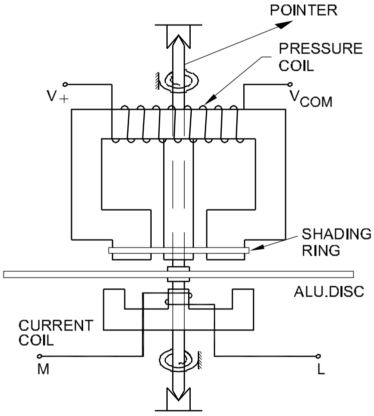


Fig 2(b)



ELN259312

Method of connecting wattmeter in single phase circuits - pressure coil connection to reduce erroneous measurement.

There are two ways of connecting the pressure coil of the wattmeter (Fig 3).

Both the methods shown in Figs 3a & b need correction in power measurement due to the reasons stated below.

In the method of connection shown in Fig 3a, the pressure coil is connected on the 'supply' side of the current coil, and hence, the error in power measurement is due to the fact that the voltage applied to the voltage coil is higher than that of the load on account of the voltage drop in the current coil. As such the wattmeter measures the load power in addition to the power lost in the current coil.

On the other hand, in the method of connection shown in Fig 3b, the current coil carries the small current taken by the voltage coil, in addition to the load current, thereby introducing errors in power measurement. As such the wattmeter measures the load power in addition to the power lost in the pressure coil.

If the load current is small, the voltage drops in the current coill will be small, so that the method of connection, shown in Fig 3a, introduces a very small error and, hence, preferable.

On the other hand, if the load current is large the power lost in the pressure coil will be negligible when compared to the load power in the method of connection shown in Fig 3b, and, hence, a very small error is introduced resulting in the preference of this connection.

Fig 3(a)

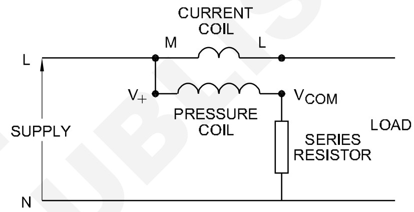
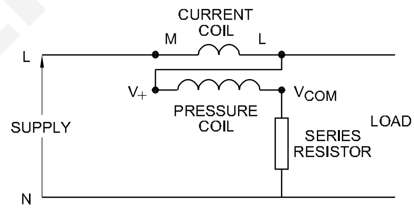


Fig 3(b)



ELN259313

3-Phase Wattmeter

Objectives: At the end of this lesson you shall be able to
- **describe the various types of 3-phase wattmeters, their connections**
- **state how to connect different types of 3 phase watt meter.**

In single-phase wattmeters there will be one set of pressure and current coils driving a single aluminium disc, whereas in 2-element, three phase wattmeters there will be two sets of pressure and current coils driving a single aluminium disc (Fig 1a) or driving two aluminium discs mounted on the same shaft (Fig 1b) thereby providing a torque proportional to the 3-phase power.

Fig 1(a)

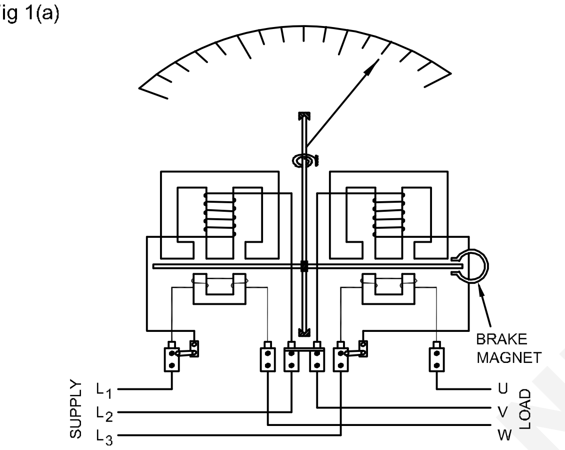
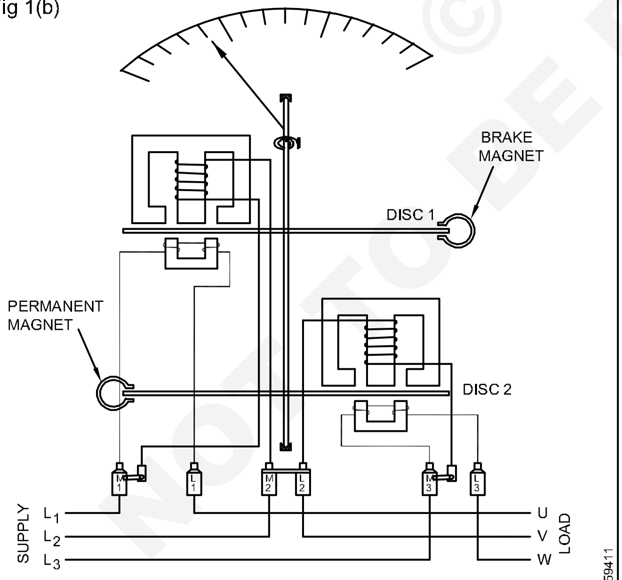


Fig 1(b)



2-ELEMENT 3-PHASE WATTMETER

On the other hand a 3-element, 3-phase wattmeter will have three sets of pressure and current coils kept at 120° to each other but driving a single aluminium disc (Fig 2) or alternatively 3 sets of pressure and current coils driving three discs one over the other but mounted on the same single spindle (Fig 3).

Fig 2

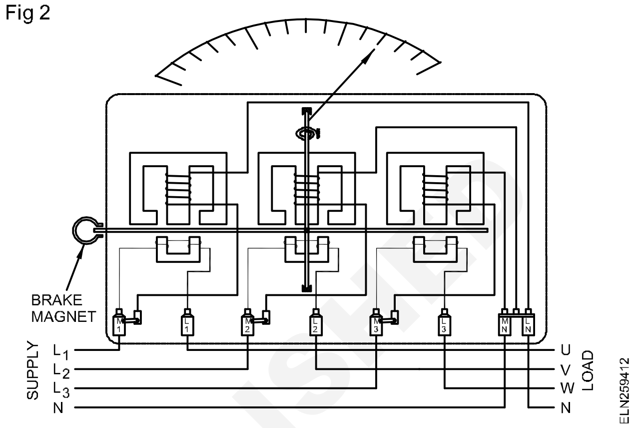
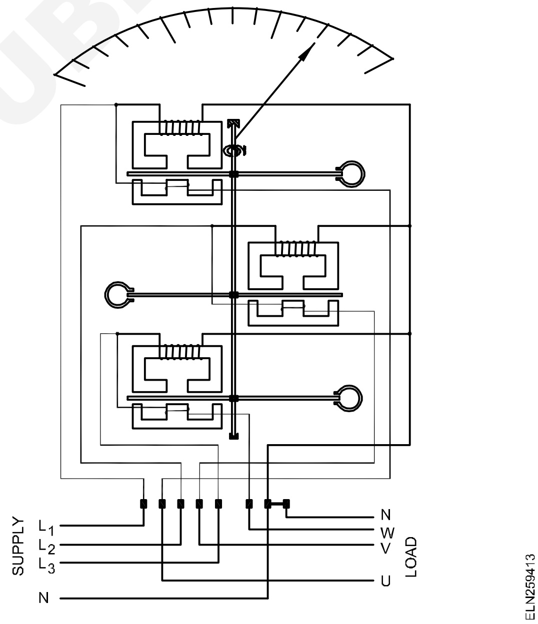


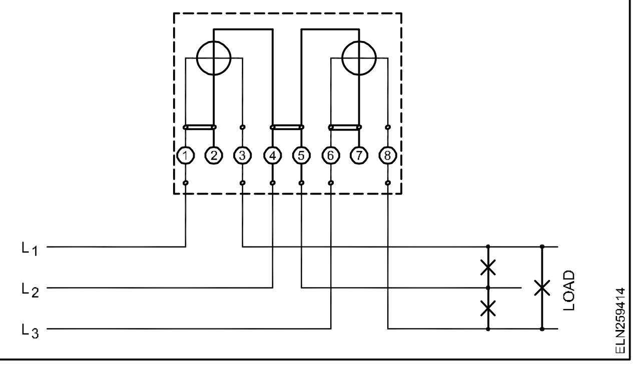
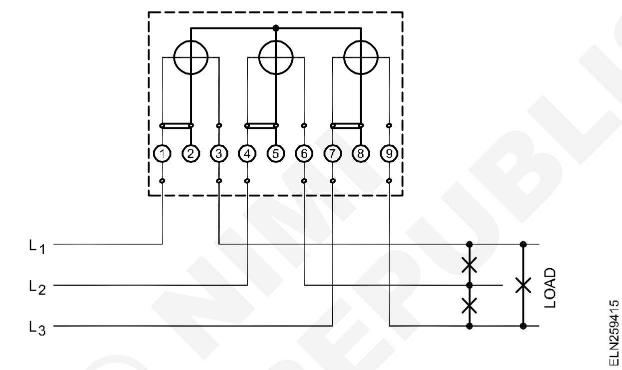
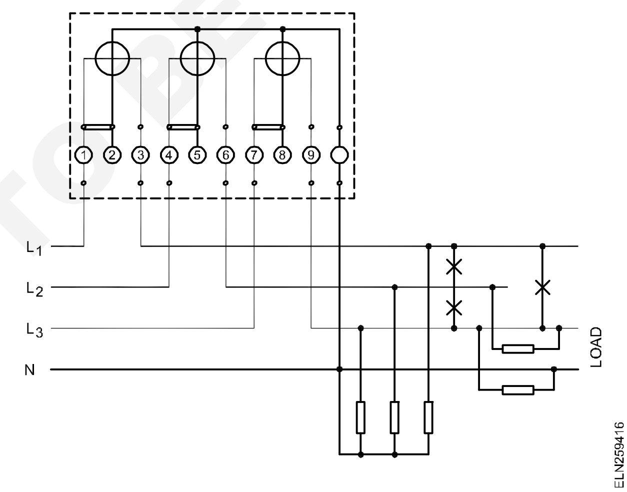
Fig 3



The principle and working of an induction type wattmeter are similar to the induction type energy meter. The only difference in construction between the energy meter and wattmeter is that the spindle of the wattmeter is spring-controlled, has a pointer but no train of gears.

However to summarise what has been learnt earlier the following table 1 is provided with connection diagram of 3-phase wattmeter Fig 4, Fig 5 & Fig 6

Table 1

Sl.No.	Types of 3-phase wattmeter	Circuit diagram	Application
1	2-element 3-wire type	Fig 4 	Balanced and unbalanced loads.
2	3-element 3-wire type	Fig 5 	Balanced loads.
3	3-element 4-wire type	Fig 6 	Un balanced loads.

Digital Wattmeter

Objectives: At the end of this lesson you shall be able to
- **describe the block diagram.**

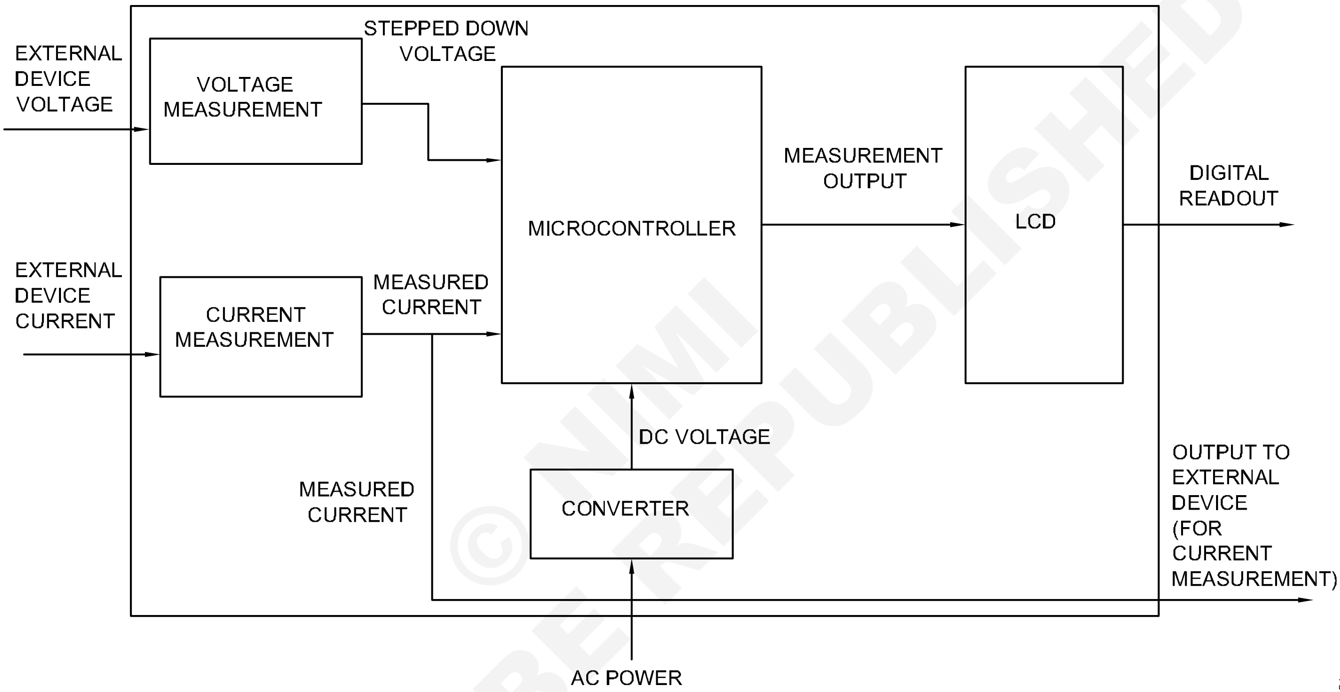
Digital wattmeter

The wattmeter is an instrument for measuring the electric power in watts of any given circuit. Electromagnetic wattmeters are used for measurment of utility frequency and audio frequency and audio frequency power; other types are required for radio frequency.

Fig 1 shows the block diagram of digital wattmeter.

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer microcontroller chip to determine watts. The computer can also perform statistics such as peak, average, low watts consumed. They can monitor the power line for voltage surges and outages. Digital electronic wattmeter, have become popular for conveniently measuring power consumption in household appliances with saving energy and money.

Fig 1



BLOCK DIAGRAM OF DIGITAL WATTMETER

ELN259421

Energy meter (analog)

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of single phase energy meters**
- **state and explain creeping error in energy meter.**

Necessity of energy meter: The electrical energy supplied by the Electricity board should be billed, based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

Principle of a single phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. (Fig 1) Torque is proportional to the power as in wattmeter.

Fig 1

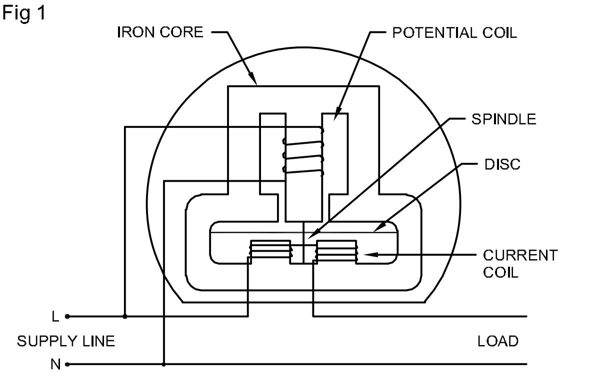


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

ELN259431

The watt-hour meter must take both power and time into consideration. The instantaneous speed is proportional to the power passing through it.

The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are (Fig 1).

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

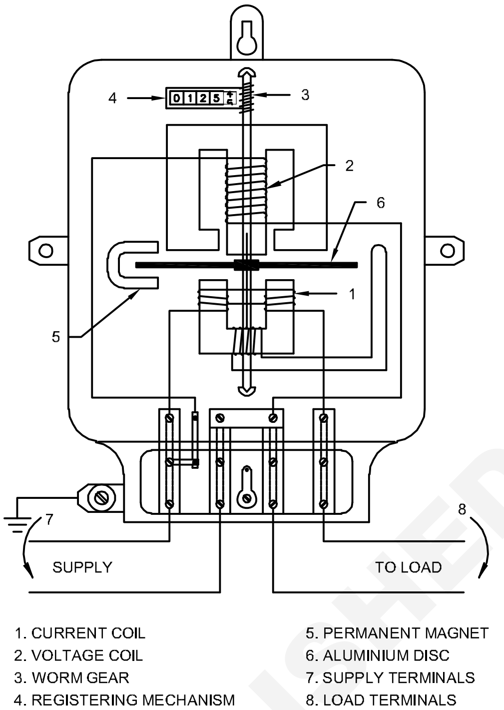
Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc (Fig 2) is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

Fig 2



INDUCTION TYPE ENERGY METER

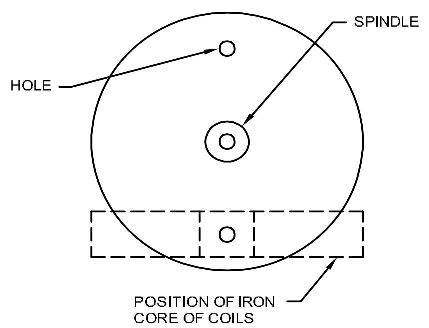
ELN259432

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diameterically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 3



ELN259433

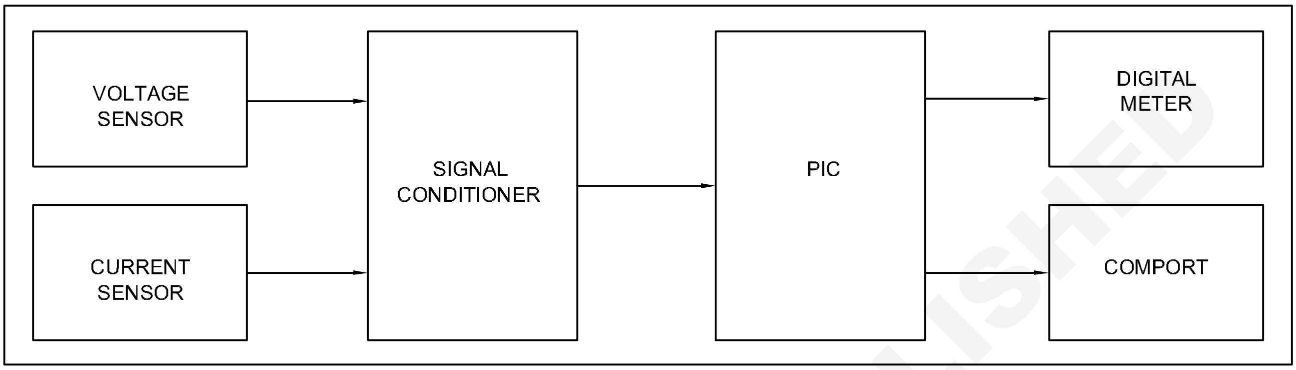
Digital Energy meters

Objectives: At the end of this lesson you shall be able to
- **describe the functional operation of digital type energymeter from block diagram.**

Electronic (Digital energy meter)

This meters measure the energy using highly integrated components and it digitizs the instantaneous voltage and current in a high-resolution sigma-delta analogue to digital converter (ADC), gives the instantaneous power in watts. Integration over time gives energy used, measured in kilo-Watt hour. The block diagram for a digital meter is shown in Fig 1. The two sensors, voltage and current sensors are employed.

Fig 1



The voltage sensor built around a step down element and potential divider network sensors both the phase voltage and load voltage.

The second sensor is a current sensor, which senses the current drawn by the load at any point in time .

It's inbuilt around a current transformer and other active devices (voltage comparator), which converts the sensed current to voltage for processing. The output from both sensors is then fed into a signal (voltage) conditioner which ensures matched voltage (or) signal level to the control circuit containing multiplexer. It enables sequential switching of both signal to the analogue input of the Peripheral Interface Controller (PIC).

The control circuit centred on a PIC integrated circuit. It contains ten bit analogue to digital converter (ADC), flexible to program and good for peripheral interfacing.

The ADC converts the analogue signals to its digital equivalent, both signals from the voltage and current sensors are then multiplied by the means of embedded software in the PIC.

The error correction is taken as the offset correction by determining the value of the input quality in the short circuited input and storing this value in the memory for use as the correction value device calibration.

The PIC is programmed in 'C' language. It stimulates to use the received data to calculate power consumption per hour, as well as the expected charges. These are displayed on the liquid crystal display (LCD) attached to the circuit.

Fig 2 shows the image of a digital energy meter.

Advantages

DIGITAL electronic meters are much more accurate than electromechanical meters. There are no moving parts and, hence, mechanical defects like friction are absent

Fig 2

DIGITAL TYPE

ELN259442

3-phase energy meter

Objectives: At the end of this lesson you shall be able to
- **list the various types of 3-phase energy meters**
- **describe the construction and working of a 3-phase 3-wire induction type energy meter**
- **describe the construction and working of a 3-phase 4-wire induction type energy meter**
- **state the application of a 3-phase 3-wire and 3-phase 4-wire energy meter.**

3-phase energy meters: Even though different types of energy meters are available, the induction type energy meter is most commonly used because it is simple in construction, less in cost and requires less maintenance. The function of a 3-phase energy meter is similar to that of a single phase energy meter.

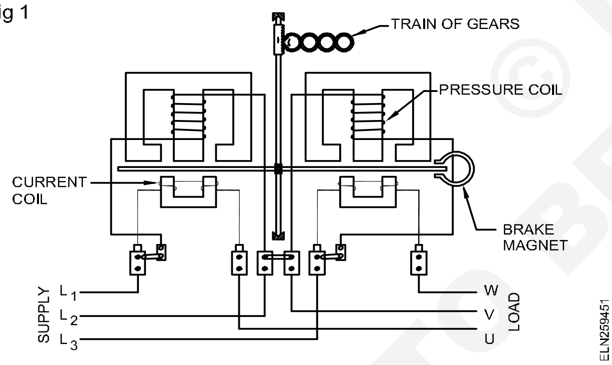
Types of 3-phase energy meters

There are two types of 3-phase energy meters mainly.

- Three phase 3-wire energy meters (3-phase 2- element energy meter)
- Three phase 4-wire energy meters (3-phase 3- element energy meter)

Two element 3-phase energy meters: This energy meter works on the principle of measurement of power by the two wattmeter method. Two elements of a current coil and two elements of a potential coil are used in this energy meter. These assemblies can be arranged on the different sectors in a horizontal position (Fig 1) with a single aluminium disc which rotates between the poles of a single braking magnet.

Fig 1

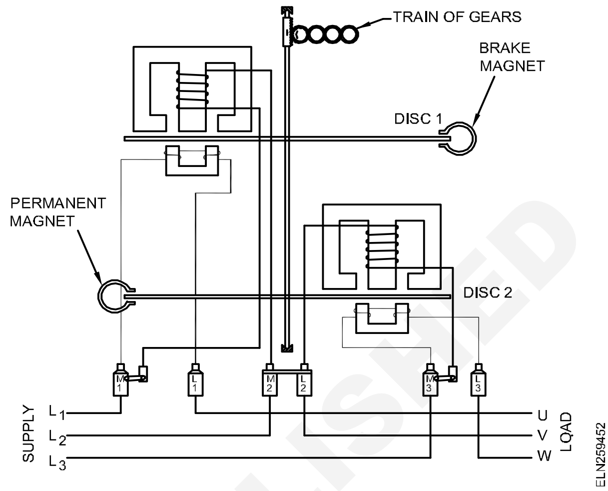


The two elements can also have individual driving discs on a common spindle. In this case they will have individual braking magnets (Fig 2). The second type usually preferred by the manufacturers due to the construction simplicity.

In both the cases the driving torque produced by individual elements are summed up. The recording mechanism which is attached to the train of gears i.e., cyclometer or counter type dial shows the sum of the energies that has passed through the elements. The two element energy meter is only suitable for a 3-phase 3-wire system but can be used for both balanced and unbalanced loads.

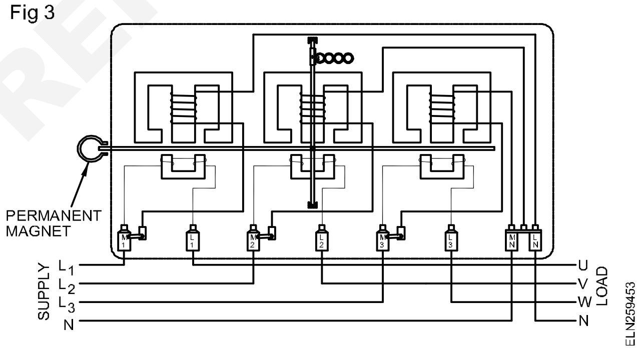
3-element 3-phase energy meter: This works on the same principle as that of the 3 wattmeter method of power measurement with a 3-phase load. Here 3 units, each with a current coil and a potential coil, are used. The potential coils of the 3 elements are connected in star to the supply lines with their common point connected to the neutral line of power supply.

Fig 2



The current coils are connected in series to the individual lines. As is the case with the two element energy meter, these three elements can be arranged in the different sectors of a common single aluminium disc which serves as a rotating part connected to driving dial (Fig 3).

Fig 3

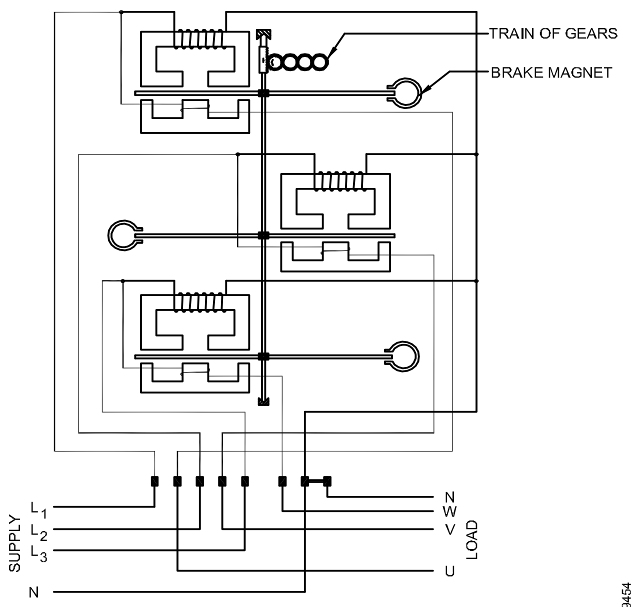


The three elements can also have a common spindle with three individual discs and braking magnets (Fig 4). Here also the 2nd type is usually preferred by manufacturers due to the easiness in construction. The driving torque produced by the three individual elements are summed up and the recording mechanism shows the sum of energies that has passed through the individual elements. This energy meter is suitable for the 3-phase 4-wire system.

Application of 3-phase energy meter: A two element 3-phase energy meter is used with three phase loads in which a neutral is not used such as for an industry or irrigation pumpset motors etc. having three phase loads only or with an 11kV 3-phase 3-wire supply to an industry.

A 3-phase 4-wire element energy meter is used with three phase load in which balanced or unbalanced loads are connected with individual phases and neutral such as for a large domestic consumer or for an industry having lighting loads also.

Fig 4



3-ELEMENT 3-PHASE ENERGY METER

Errors and corrrection in energy meter measurement

Objectives: At the end of this lesson you shall be able to
- **explain the errors caused by the driving system and the braking system in energy meters**
- **explain the different adjustments provided for correcting the errors in energy meters.**

Errors caused by the driving system

Incorrect magnitude of fluxes: This may be due to abnormal values of current or voltage. The shunt magnet flux may be in error due to changes in resistance of coil or due to abnormal frequencies.

Incorrect phase angles: There may not be a proper relationship between the various phasors. This may be due to improper lag adjustment, abnormal frequencies, change in resistance with temperature etc.

Lack of symmetry in magnetic circuit: If the magnetic circuit is not symmetrical, a driving torque is produced which makes the meter creep.

Error caused by the braking system

They are:

- changes in the strength of the brake magnet
- changes in the disc resistance
- self-braking effect of series magnet flux
- abnormal friction of the moving parts.

Adjustments are provided for correcting the errors in the energy meters so that they read correctly and their errors are within acceptable limits.

Preliminary light load adjustment: The rated voltage is applied to the potential coil with no current through the current coil and the light load device is adjusted until the disc just fails to start. The electromagnet is slightly adjusted to make the holes in the disc to take a position in between the poles of the electromagnets.

Full load unity power factor adjustment: The pressure coil is connected across the rated supply voltage and the rated full load current at unity power factor is passed through the current coils. The position of the brake magnet is adjusted to vary the braking torque so that the meter revolves at the correct speed within the required limits of error.

LAG adjustments (Low power factor adjustments): The pressure coil is connected across the rated supply voltage and the rated full load current is passed through the current coil at 0.5 P.F. lagging. The lag device is adjusted till the meter runs at the correct speed.

Rated supply voltage: By adjusting the rated supply voltage, with the rated full load current and unity power factor, the speed of the meter is checked and the full load unity power factor and low power factor adjustments are repeated until the desired accuracy limits are reached for both the conditions.

Light load adjustment: The rated supply voltage is applied across the pressure coil and a very low current (about 5% of full load current) is passed through the meter at unity power factor. Light load adjustment is done so that the meter runs at the correct speed.

Full load unity power factor: Light load adjustments are again done until the speed is correct for both loads i.e. full load as well as light loads.

Creep adjustment: As a final check on the light load adjustment, the pressure coil is excited by 110 percent of the rated voltage with zero load current. If the light load adjustment is correct, the meter should not creep under these conditions.

Multimeters

Objectives: At the end of this lesson you shall be able to
- **explain the construction of multimeter**
- **explain the working priniciple of analog multimeter**
- **explain the method of measuring direct / alternating voltages and current with a multimeter**
- **explain the method of measuring resistance by a multimeter**
- **explain the precautions to be observed while measuring voltage, current and resistance in the circuit.**

A single instrument used for measuring current voltage and resistance is known as a multimeter. It is a portable, multi range instrument.

It has a full scale deflection accuracy of ±1.5 %. The lowest sensitivity of multimeters for AC voltage range is 5 K ohms/ volts and for the DC voltage range it is 20 K ohms/volts. The lowest range of DC is more sensitive than the other ranges.

Figs 1 show typical multimeters.

Fig 1

Construction of a multimeter

A multimeter uses a single meter movement with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that function.

On some multimeters, two switches are used, one to select a function, and the other the range. Some multimeters do not have switches for this purpose; instead, they have separate jacks for each function and range.

Batteries/cells fixed inside the meter case provide the power supply for the resistance measurement.

The meter movement is that of the moving coil system as used in DC ammeters and voltmeters.

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of the main parts and controls (Fig 2).

Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch. In the example given in Fig 3 the switch is set to mA, AC.

Fig 2

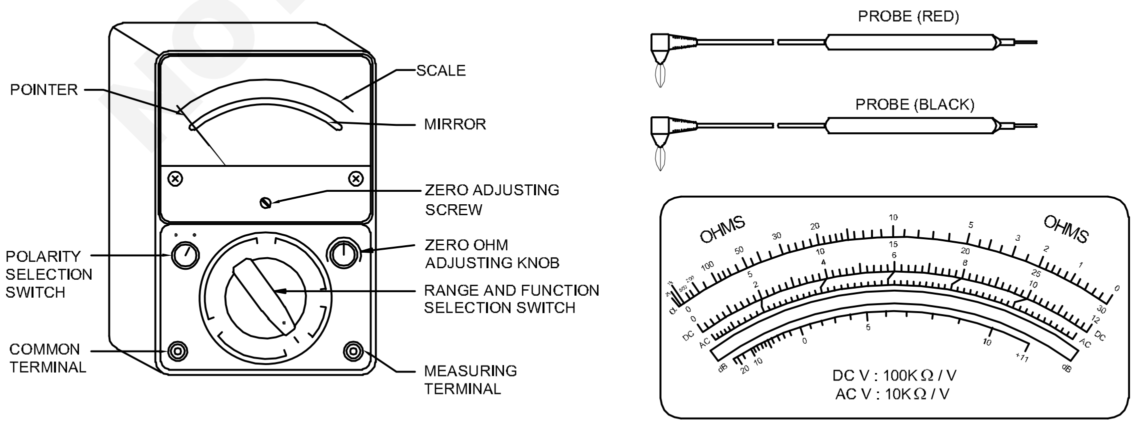
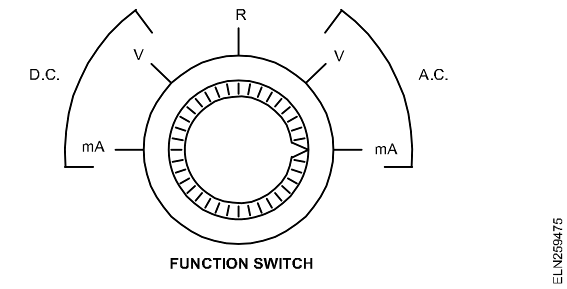
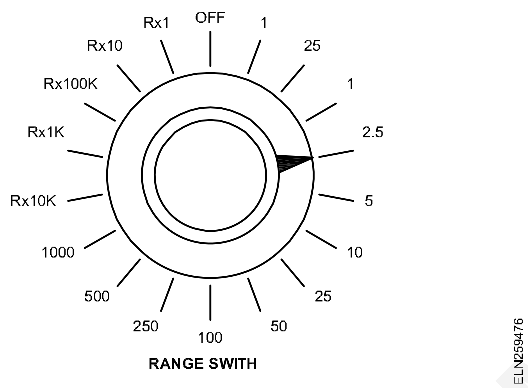


Fig 3



The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. In Fig 4, the switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

Fig 4

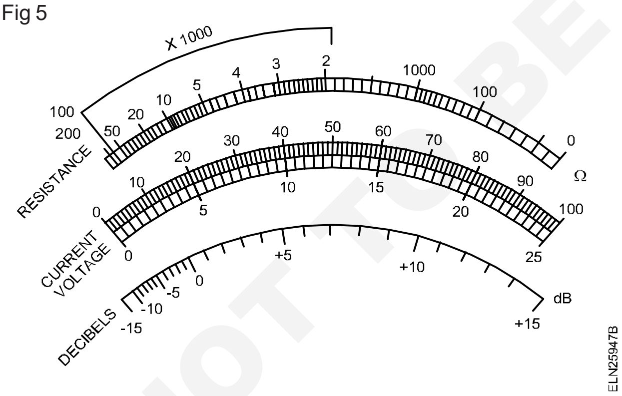


Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 5)

Fig 5



The scale of current and voltage is uniformly graduated.

The scale of the ohmmeter is non-linear.

The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter.(Fig 6)

Shunt resistors across the meter movement bypass current in excess of 0.05 mA at fsd. A suitable value of shunt resistor is selected through the range switch for the required range of current measurement.

A circuitry when working as a voltmeter. (Fig 7)

The voltage drop across the meter coil is dependent on the current and the coil resistance. To indicate voltages greater than 50 mV at fsd as per the circuit, multiplier resistances of different values are connected in series with the meter movement through the range switch for the required range of measurement.

A circuitry when working as an ohmmeter. (Fig 8)

To measure resistance, the leads are connected across the external resistor to be measured (Fig 8). This connection completes the circuit, allowing the internal battery to produce current through the meter coil, causing deflection of the pointer, proportional to the value of the external resistance being measured.

Zero adjustment

When the ohmmeter leads are open, the pointer is at full left scale, indicating infinite (¥) resistance (open circuit). When the leads are shorted, the pointer is at full right scale, indicating zero resistance.

The purpose of the variable resistor is to adjust the current so that the pointer is at exactly zero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large ones. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

Remember, an ohmmeter must not be connected to a circuit when the circuit's power is on. Always turn the power off before connecting the ohmmeter.

Fig 6

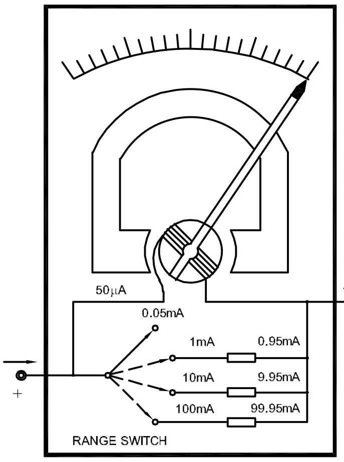


Fig 7

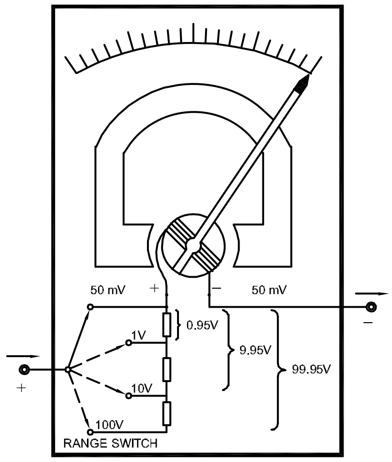
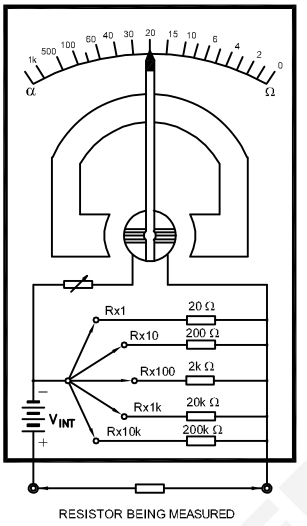


Fig 8



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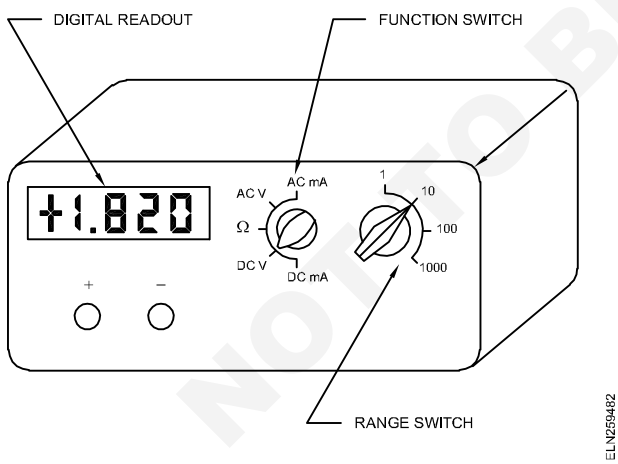
Digital multimeters

Objectives: At the end of this lesson you shall be able to
- **explain the method of measurement of voltage by using digital multimeter**
- **list and explain the types of digital multimeter**
- **state the application of digital multimeters.**

Digital Multimeter

In a digital multimeter the meter movement is replaced by a digital read out (Fig 1 and 2). This readout is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital, integrated circuits. Like the analog-type multimeter, the digital multimeter has a front panel switching arrangement.

Fig 1



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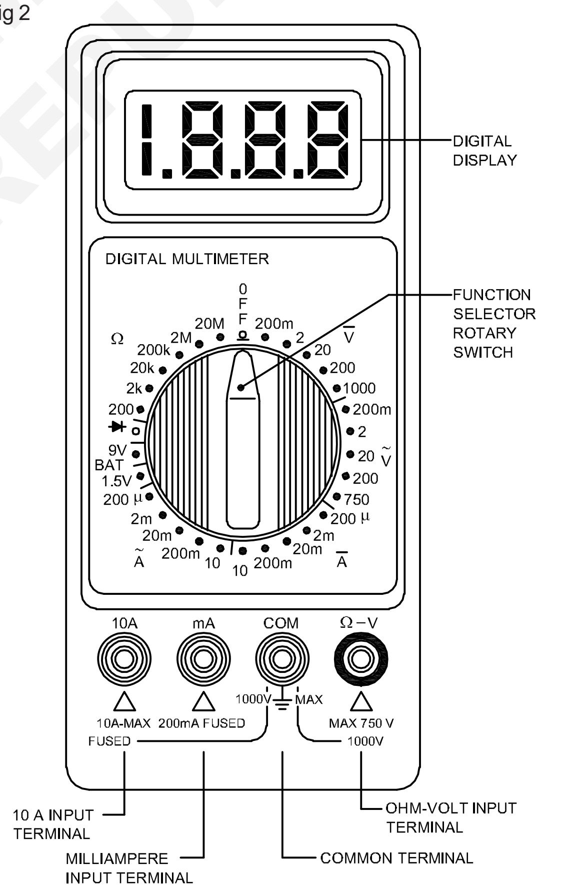
The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When DC quantities are measured the polarity is identified by '+ve' or '-ve' sign displayed to the left of the number indicating the probes are connected correctly by +ve sign and probes are reversely connected by -ve sign.

Fig 2



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DMM functions: The basic functions found on most DMMs are the same as those on analouge multimeters. That is it can measure:-

- ohms
- DC voltage and current
- AC voltage and current

Some DMMs provide special functions such as transistor or diode test, power measurement, and decibel measurement for audio amplifier tests.

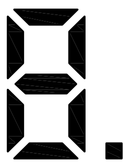
DMM displays: DMMs are available with either LCD (liquid -crystal display) or LED (light-emitting diode) read-outs. The LCD is the most commonly used read-out in battery-powered instruments due to the fact that it draws very small amount of current.

A typical battery-powered DMM with an LCD read-out operates on a 9V battery that will last from a few hundred hours to 2000 hours and more. The disadvantages of LCD read-outs are that (a) they are difficult or impossible to see in poor light conditions, and (b) they are relatively slow response to measurement changes.

LEDs, on the other hand, can be seen in the dark, and respond quickly to changes in measured values. LED displays require much more current than LCDs, and, therefore, battery life is shortened when they are used in portable equipment.

Both LCD and LED-DMM displays are in a seven segment format (Fig 3).

Fig 3



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Multimeter: Safety precautions: The following safety precautions should always be taken.

- Never use the ohmmeter section on a live circuit.
- Never connect the ammeter section in parallel with a voltage source.
- Never overload the ammeter or voltmeter sections by attempting to measure currents or voltages far in excess of the range switch setting.
- Check the meter test leads for frayed or broken insulation before working with them. If damaged insulation is found the test leads should be replaced.
- Avoid touching the bare metal clips or tips of the test probes.
- Whenever possible, remove the supply before connecting the meter test leads into the circuit.

Applications of Digital multimeter: A multimeter is used for testing and fault finding in electrical/electronic circuits, electrical appliances and machines. A multimeter is a portable handy instrument used for

- checking continuity of circuit, appliances and devices.
- measuring/checking the supply presence at the source
- for testing components like capacitors, diodes, and transistors for checking their condition.
- measuring the current drawn by the circuit.
- measuring resistance of the electrical appliances and devices.

Note: Some meters have provision also for temperature measurement with suitable sensing probes.

Frequency meter

Objectives: At the end of this lesson you shall be able to

- **state the types of frequency meters**
- **describe the principle, construction and working of a mechanical resonance (vibrating reed) type frequency meter.**

The following types of frequency meters are used for measuring power frequencies.

- Mechanical resonance type
- Electrical resonance type
- Electro-dynamic type
- Electro-dynamometer type
- Weston type
- Ratiometer type
- Saturable core type

The explanation given here is for mechanical resonance type frequency meter only as indicated below.

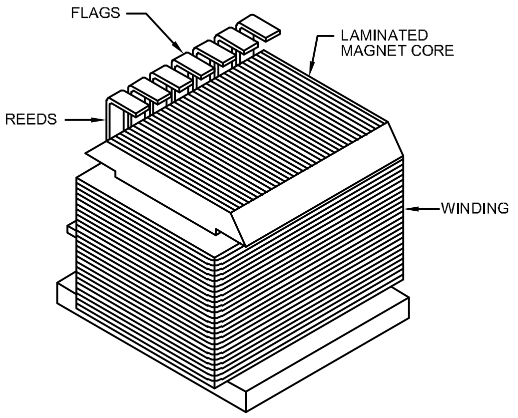
The trainees are advised to refer to books on electrical measuring instruments for learning about the other types of frequency meters.

Mechanical resonance type frequency meter (vibration reed type)

Principle: The vibration reed type frequency meter shown in Fig 1 works on the principle of natural frequency. Every object in the world has its natural frequency, depending upon its weight and dimensions. When an object is kept in a vibrating medium, it starts vibrating, if the frequency of the medium attains the natural frequency of the object.

If the vibrations are not controlled, the object may even get totally destroyed. A good example of this phenomenon is the shattering of window glass panes due to the vibration caused by low flying aircraft.

Fig 1



Construction: Mechanical resonance type frequency meters consist of an eletromagnet and a set of metallic reeds arranged in front of the electromagnet. The frequency meter is connected across the supply like a voltmeter, taking care about the voltage rating (Fig 2) .

Fig 2(a)

Fig 2(b)

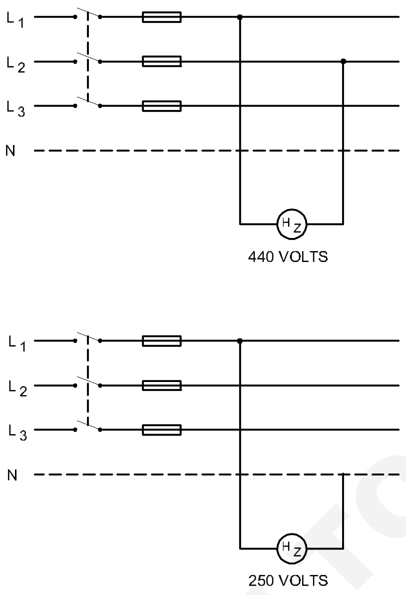
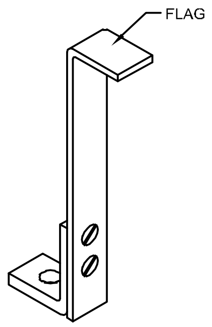


Fig 3 shows the shape of the reed and these reeds are of about 4mm wide and 0.5 mm thick. One end of the reed is fitted on a base, and the other overhanging end carries a white painted surface as the indicator and sometimes referred to as flag.

The reeds are arranged in a row and the natural frequency of the reeds differs by 1/2 cycle. This 1/2 cycle difference is possible between the reeds due to the difference in the weights of the reeds. The reeds are arranged in an ascending order (Fig 4a), and generally the natural frequency of the centre reed is the same as that of the supply frequency (50Hz).

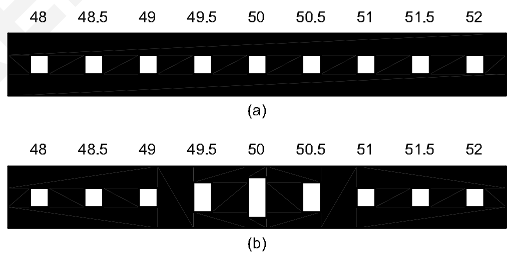
Fig 3



Working: When the frequency meter is connected to the supply, the electromagnet produces a magnetic field which alternates at the rate of the supply frequency. The reed, which has its natural frequency coincident with that of the alternating magnetic field, vibrates more than the adjacent reeds Fig 4(b).

The flag of this vibrating reed makes it possible to note the frequency of the supply from the scale marking of the frequency meter. Though the other reeds also vibrate, Fig 4(b), their magnitude will be much less than the reed whose natural frequency is exactly in coincidence with the supply frequency.

Fig 4



Advantages and disadvantages

The reed type frequency meter has the following advantages.

The indications are independent of i) the wave form of the applied voltage and ii) magnitude of the applied voltage, provided that the voltage is not too low. At a low voltage the flag indication of the reed will not be reliable.

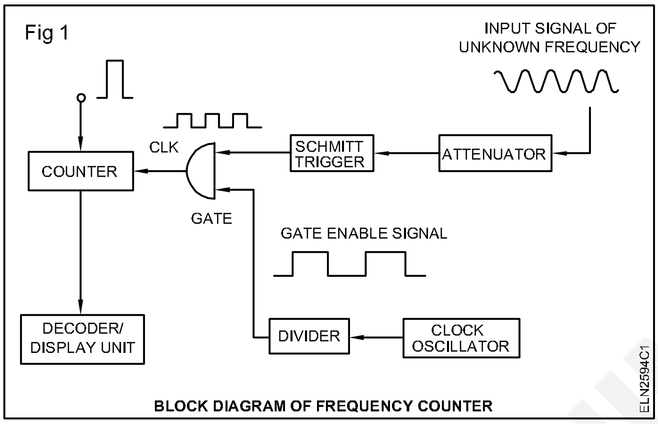
The disadvantages are the meter cannot read closer than half the cycle frequency difference between adjacent reeds and the accuracy greatly depends upon the proper tuning of the reeds.

Digital Frequency Meter

Objectives: At the end of this lesson you shall be able to
- **state the function of digital frequency meter**
- **describe the block diagram of digital frequency meters.**

A frequency counter is a digital instrument that can measure and display the frequency of any periodic waveform. It operates on the principle of gating the unknown input signal into the counter for a predetermined time.

If the unknown input signal were gated into the counter for exactly 1 second, the number of counts allowed into the counter would be the frequency of the input signal. The term gated comes from the fact that an AND or an OR gate is employed for allowing the unknown input signal into the counter to be accumulated. Fig 1



BLOCK DIAGRAM OF FREQUENCY COUNTER

Discription of block diagram:

The simplified form of block diagram of frequency counter is in Fig 1. It consists of a counter with its associated display/decoder circuitry, clock oscillator, a divider and an AND gate. The counter is usually made up of cascaded Binary Coded Decimal(BCD) counters and the display/ decoder unit converts the BCD outputs into a decimal display for easy monitoring.

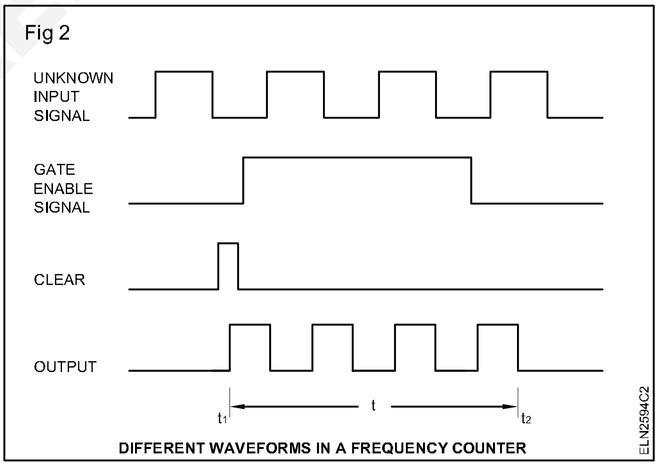
A GATE ENABLE signal of known time period is generated with a clock oscillator and a divider circuit and is applied to one leg of an AND gate.

The unknown signal is applied to the other leg of the AND gate and acts as the clock for the counter. The counter advances one count for each transition of the unknown signal, and at the end of the known time interval, the contents of the counter will be equal to the number of periods of the unknown input signal that have occurred during time interval, t.In other words, the counter contents will be proportional to the frequency of the unknown input signal.

For instance if the gate signal is of a time of exactly 1 second and the unknown input signal is a 600-Hz square wave, at the end of 1 second the counter will counts up to 600, which is exactly the frequency of the unknown input signal

The wave form in Fig 2 shows that a clear pulse is applied to the counter at t_0 to set the counter at zero. Prior to t_1, the GATE ENABLE signal is LOW, and so the output of the AND gate will be LOW and the counter will not be counting. The GATE ENABLE goes HIGH from t_1 t_0 t_2 and during this time interval $t=(t_2 - t_1)$ the unknown input signal pulses will pass through the AND gate and will be counted by the counter

After t_2, the AND gate output will be again LOW and the counter will stop counting. Thus, the counter will have counted the number of pulses that occurred during the time interval, t of the GATE ENABLE SIGNAL, and the resulting contents of the counter are a direct measure of the frequency of the input signal.



DIFFERENT WAVEFORMS IN A FREQUENCY COUNTER

Power factor meter

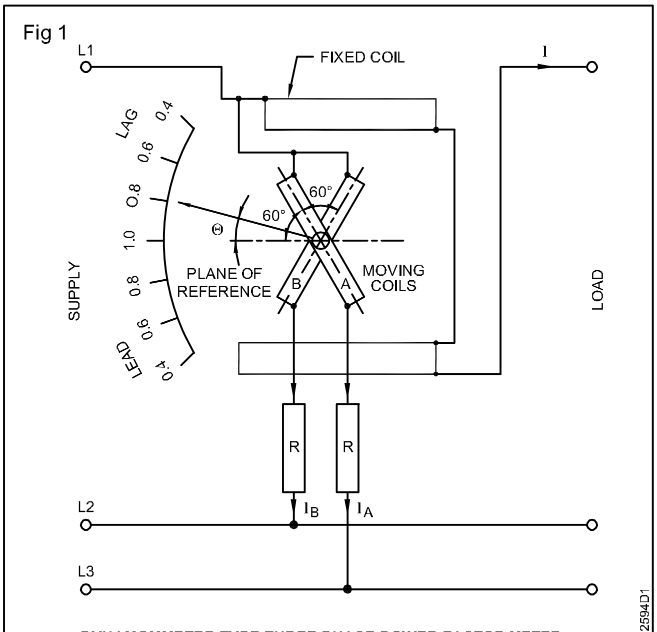
Objectives: At the end of this lesson you shall be able to
- **explain the construction and connection of 3-phase dynamometer type power factor meter**
- **explain the construction, connection and operation of a 3-phase moving iron type power factor meter**
- **explain the construction, connection and operation of a single phase moving iron type power factor meter.**

3-phase dynamometer type power factor meter for balanced load: Fig 1 shows the construction and connections of a 3-phase power factor meter used for balanced loads.

In this meter, the field coils are connected in series with the load along with one phase. The two moving coils are rigidly attached to each other at an angle of 120°. These coils are connected to two different phases. A resistance is connected in series with each coil.

Phase splitting through reactance is not necessary since the required phase displacement between currents in the two moving coils can be obtained by the supply itself.

Operation of the meter is in the same way as in a single phase meter. However this meter is suitable only for balanced loads.



DYNAMOMMETER TYPE THREE PHASE POWER FACTOR METER

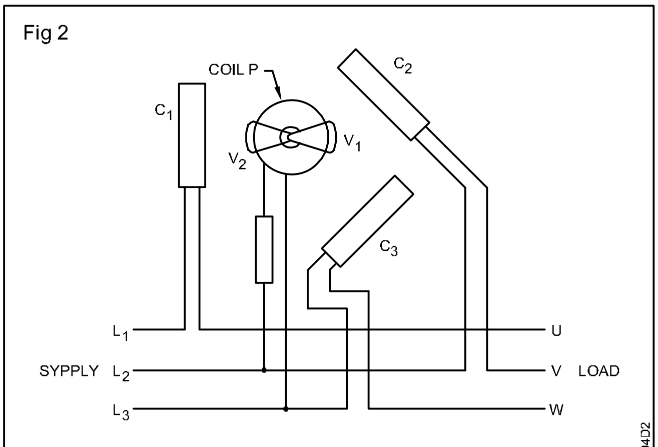
Since the currents in the two moving coils are both affected in the same way by any change in frequency or wave-form, this meter is independent of frequency and wave-form.

Moving iron power factor meters: This type of power factor meter is more popular than the dynamometer type due to the following advantages.

- Torque-weight ratio (working forces) is large compared to the dynamometer type meter.
- As all the coils are fixed there is no ligament connection necessary.
- The scale can be extended to 360°.
- This meter is simple and robust in construction.
- Comparatively cheaper in cost.

Fig 2 shows the construction and connection of a moving iron type power factor meter used for balanced loads.

There are three similar coils at C_1, C_2 and C_3 placed 120° degrees apart and connected to 3-phase supply directly (Fig 2) or through the secondary of the current transformers. Coil P is placed in the middle of the three coils C_1, C_2 and C_3 and connected in series with a resistance across two lines of the supply. Inside the coil P there are are two vanes V_1, and V_2 mounted at the ends of a freely moving spindle but kept at 180° to each other. The spindle also has damping vanes and the pointer .

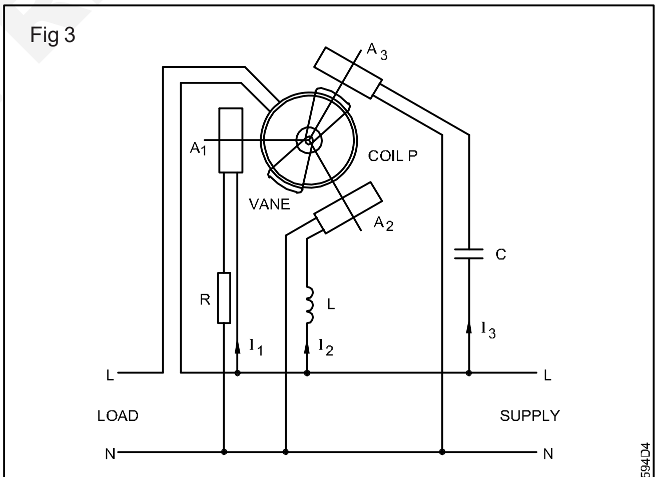


MOVING IRON TYPE POWER-FACTOR METER FOR A BALANCED 3-PHASE LOAD

The rotating magnetic field produced by the three coils C_1, C_2 and C_3 interacts with the flux produced by the coil P. This causes the moving system to take up an angular position depending upon the phase angle of the current.

Single phase moving iron power factor meter: A single phase moving iron power factor meter (Fig 3) uses a phase splitting network comprising of a capacitor, an inductor and a resistor.

3-phase power factor meters for unbalanced load: For measurement of power factor in 3-phase unbalanced systems 2-element or 3-element power factor meters with each element with a current coil and pressure coil is used. The pressure coils are (moving coils) similar to that of single phase P.F. meters are mounted one below the other on a single spindle. The pointer shows the resultant power factor.



SINGLE PHAGE MOVING IRON TYPE POWER FACTOR METER

Measurement of 3 phase power by single and two wattmeters

Objectives: At the end of this lesson you shall be able to
- **explain the measurement 3 phase power using single wattmeter**
- **explain the measurement of 3 phase power using two wattmeters**
- **calculate the power factor by two wattmeter method power measurement.**

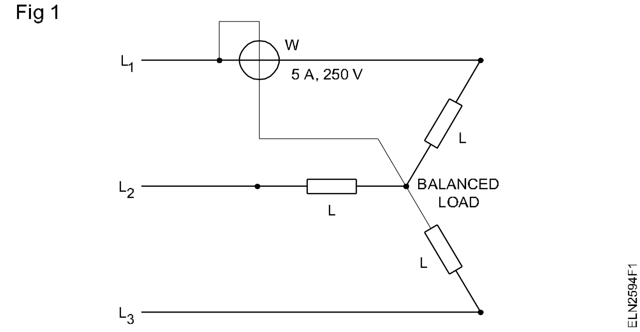
The measurement of power: The number of wattmeters used to obtain power in a three-phase system depends on whether the load is balanced or not, and whether the neutral point, if there is one, is accessible

- Measurement of power in a star-connected balanced load with neutral point is possible by a single wattmeter
- Measurement of power in a star or delta-connected, balanced or unbalanced load (with or without neutral) is possible with two wattmeter method

Single wattmeter method: Fig 1 shows the circuit diagram to measure the three-phase power of a star-connected, balanced load with the neutral point accessible the current coil of the wattmeter being connected to one line, and the voltage coil between that line and neutral point. The wattmeter reading gives the power per phase. So the total is three times the wattmeter reading.

$P = 3E_P I_P \cos \varphi = 3P = 3W$

Fig 1



The two wattmeter method of measuring power

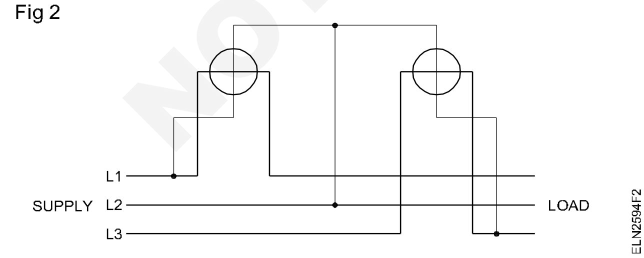
Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, if the load is unbalanced and the assumption that $I_U + I_V + I_W = 0$ will not be valid.

The two wattmeters are connected to the supply system (Fig 2). The current coils of the two wattmeters are connected in two of the lines, and the voltage coils are connected from the same two lines to the third line. The total power is then obtained by adding the two readings:

$P_T = P_1 + P_2$.

Consider the total instantaneous power in the system $P_T = P_1 + P_2 + P_3$ where P_1, P_2 and P_3 are the instantaneous values of the power in each of the three phases.

Fig 2



$P_T = V_{UN}\, i_U + V_{VN}\, i_V + V_{WN}\, I_W$

Since there is no fourth wire, $i_U + i_V + i_W = 0$; $i_V = -(i_U + i_W)$.

$P_T = V_{UN} i_U - V_{VN}(i_U + i_W) + V_{WN}\, i_W$

$= i_U(V_{UN} - V_{VN}) + i_W(V_{WN} - V_{UN})$

$= i_U V_{UV} + i_W V_{WV}$

Now $i_U V_{UV}$ is the instantaneous power in the first wattmeter, and $i_W V_{WV}$ is the instantaneous power in the second wattmeter. Therefore, the total mean power is the sum of the mean powers read by the two wattmeters.

It is possible that with the wattmeters connected correctly, one of them will attempt to read a negative value because of the large phase angle between the voltage and current for that instrument. The current coil or voltage coil must then be reversed and the reading given a negative sign when combined with the other wattmeter readings to obtain the total power.

At unity power factor, the readings of two wattmeter will be equal. Total power = 2 x one wattmeter reading.

When the power factor = 0.5, one of the wattmeter's reading is zero and the other reads total power.

When the power factor is less than 0.5, one of the wattmeters will give negative indication. In order to read the wattmeter, reverse the pressure coil or current coil connection. The wattmeter will then give a positive reading but this must be taken as negative for calculating the total power.

When the power factor is zero, the readings of the two wattmeters are equal but of opposite signs.

Self-evaluation test

1 Draw a general wiring diagram for the two-wattmeter method of three-phase power measurement.

Power factor calculation in the two -wattmeter of measuring power

As you have learnt in the previous lesson, the total power $P_T = P_1 + P_2$ in the two-wattmeter method of measuring power in a 3-phase, 3-wire system.

From the readings obtained from the two wattmeters, the tan ϕ can be calculated from the given formula

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$$

from which ϕ and power factor of the load may be found.

Example 1: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. Find the power factor of the circuit.

Solution

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$P_1 = 4.5$ KW

$P_2 = 3$ KW

$P_1 + P_2 = 4.5 + 3 = 7.5$ KW

$P_1 - P_2 = 4.5 - 3 = 1.5$ KW

$$\tan \phi = \frac{\sqrt{3} \times 1.5}{7.5} = \frac{\sqrt{3}}{5} = 0.3464$$

$\phi = \tan^{-1} 0.3464 = 19^0 6'$

Power factor Cos $19^0 6'$ = 0.95

Example 2: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. The latter reading is obtained after reversing the connection of the voltage coil of that wattmeter. Find the power factor of the circuit.

Soultion

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$$= \frac{\sqrt{3}(4.5 - (-3))}{(4.5 + (-3))}$$

$$= \frac{\sqrt{3}(4.5 + 3)}{(4.5 - 3)}$$

$$= \frac{\sqrt{3} \times 7.5}{1.5} = \sqrt{3} \times 5$$

$$= 1.732 \times 5 = 8.66.$$

$\phi = \tan^{-1} 8.66 = 83^o.27'$

since power factor (Cos $83^o 27'$) = 0.114.

Example 3: The reading on the two wattmeters connected to measure the power input to the three-phase, balanced load are 600W and 300W respectively.

Calculate the total power input and power factor of the load.

Solution

Total power = $P_T = P_1 + P_2$

P_1 = 600W.

P_2 = 300W.

P_T = 600 + 300 = 900

$$\tan \phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(600 - 300)}{600 + 300} = \frac{\sqrt{3} \times 300}{900}$$

$$= \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} = 0.5774$$

$\phi = \tan^{-1} 0.5774 = 30^o$

Power factor = Cos 30^o = 0.866.

Assignment

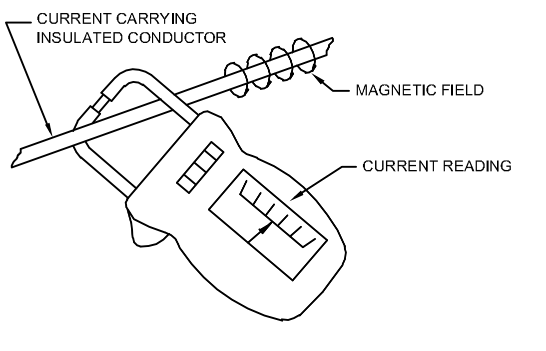
Two wattmeters connected to measure the power input to a balanced, three-phase load indicate 25KW and 5KW respectively.

Find the power factor of the circuit when (i) both readings are positive and (ii) the latter reading is obtained after reversing the connections of the pressure coil of the wattmeter.

Tong - tester (clamp - on ammeter)

Objectives: At the end of this lesson you shall be able to
- **state the necessity of tong-testers**
- **state the construction and working of a tong-tester**
- **state the precautions to be observed while using a tong-tester.**

A tong-tester is an instrument devised for the measurement of A.C current, without interrupting the circuit. It is also called clip-on ammeter, or sometimes a clamp-on ammeter (Fig 1).

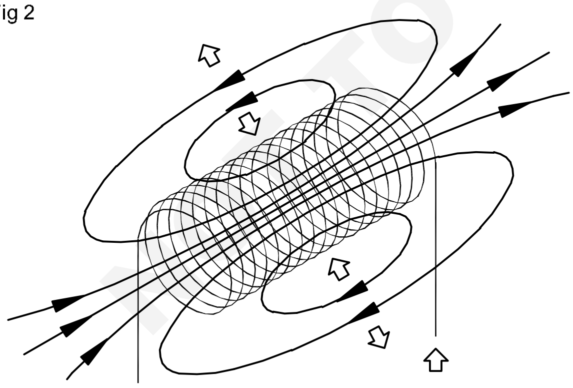
Fig 1


TONG-TESTER

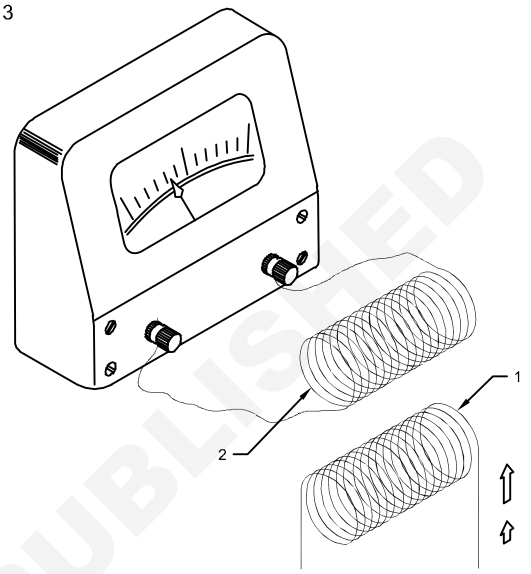
Working principle

The instrument can function only when current passes through its deflecting system. It works under the mutual induction principle.

Electromagnetic induction: When a changing flux is linked with the coil, an emf is induced in the coil. The current in a coil so produced changes as that of the changing magnetic flux. If an alternating current is flowing through the coil, the magnetic flux produced is also alternative i.e. changing continuously.(Fig 2)

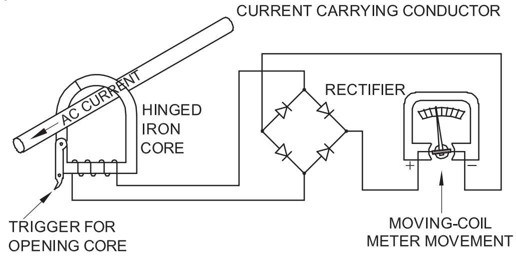
Fig 2


Placing another coil (2) in the changing flux of coil (1), an emf will be induced. (Fig 3)

Fig 3


This induced emf will send the current, causing deflection of the meter. Introduction of a magnetic core between the coils increases the induced emf. The coil (1) is called primary and the coil (2) is called secondary.

Construction: Fig 4 shows a tong-tester (the clamp-on ammeter) circuit. The split-core meter consists of a secondary coil with the split-core and a rectifier type instrument connected to the secondary. The current to be measured in the conductor serves as the primary of one turn coil. It induces a current in the secondary winding and this current causes the meter to deflect.

Fig 4


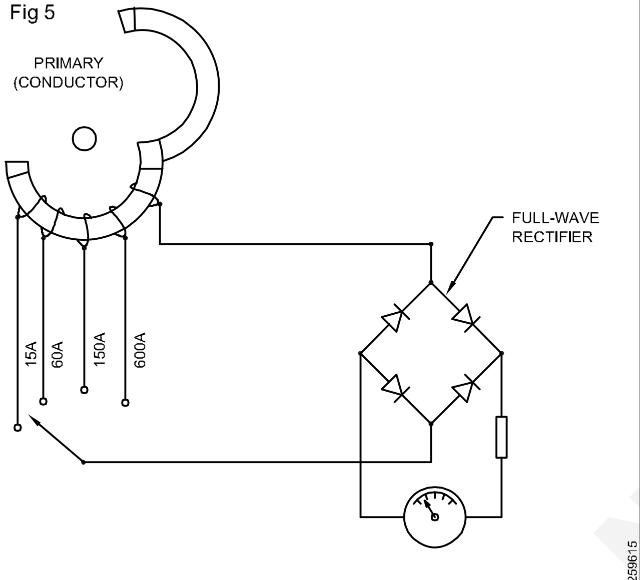
The core is so designed that there is only one break in the magnetic path. The hinge and the opening both fit tightly when the instrument closes around the conductor. The tight fit of the instrument ensures minimum variation in the response of the magnetic circuit.

To measure current with a clamp-on meter, open the jaws of the instrument and place them around the conductor in which you want to measure the current. Once the jaws are in place, allow them to close securely. Then, read the indicator position on the scale.

When the core is clamped around a current-carrying conductor, the alternating magnetic field induced in the core, produces a current in the secondary winding.

This current causes a deflection on the scale of the meter movement. The current range can be changed by means of a `range switch', which changes the taps on the transformer secondary (Fig 5).

Fig 5



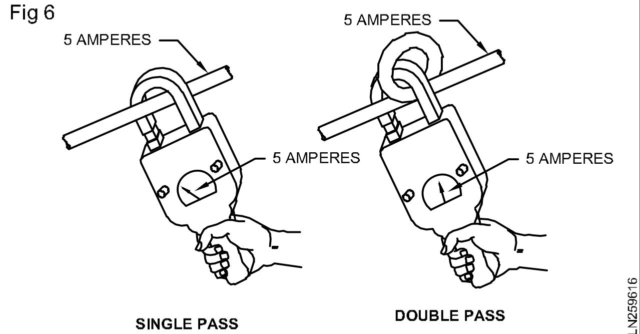
TAPPED-SECONDARY CIRCUIT

Safety: The secondary winding of the current transformer should always be either shunted or connected to the ammeter; otherwise, dangerous potential differences may occur across the open secondary.

Before taking any measurement, make sure the indication is at zero on the scale. If it is not, reset by the zero-adjustment screw. It is usually located near the bottom of the meter.

Looping the conductor more than once through the core is another means of changing the range. If the current is far below the meter's maximum range, we can loop the conductor through the core two or more times (Fig 6).

Fig 6



Application

1 For measuring the incoming current in the main panel board.

2 Primary current of AC welding generators.

3 Secondary current of AC welding generators.

4 Newly rewinded AC motor phase current and line current.

5 Starting current of all AC machines.

6 Load current of all AC machines and cables.

7 For measuring the unbalanced or balanced loads.

8 For finding the faults in AC, 3-phase induction motors.

Precaution

1 Set the ampere range from higher to low if the measuring value is not known.

2 The ampere-range switch should not be changed when the clamp is closed.

3 Before taking any measurement make sure the indication is at zero on the scale.

4 Do not clamp on a bare conductor for current measurement.

5 Seating of the core should be perfect.

Smartmeters - Automatic meter reading - Supply requirements

Objectives: At the end of this lesson you shall be able to
- **understand construction of smart meter**
- **explain the working of smart meter.**

Smart Meter

Now a days smartmeters are used to measure the electricity consumption of a building. Smart meters offer more detailed data than the old meters. They also give customers the updated power usage data. By this they control their power usage.

Smart meters measures not only energy but also measures voltage, frequency and KVA also. It delivers information wirelessly via low energy radio frequency waves to the competent authorities (EB).

Automatic meter reading

Automatic meter reading or AMR is the Technology of automatically collecting consumption, diagonastic and status data from energymetering devices and transferring that data to the central data base for billing, trouble shooting and analyzing.

AMR which works by translating the movement of mechanical dials on a meter into a digital signal, does not require physical access or visual inspection

An AMR meter works by creating a connection channel between a business customer and its energy supplier. For an AMR meter the communicartion only goes in one direction, to the supplier. The energy supplier will receive meter reading once per month, so there is no need for manual reading.

Smartmeters works by using a secure national communication network. Smartmeters are the new generation of energy meters while AMR is an attached device that transmits the meter reading.

The most note worthy advantages for using these system are increased efficiencies, outage detection, tamper notification and reduced labour cost, smart meters usually use wireless signals at 2.4 GHZ with a maximum power of less than one watt.

The smartmeters should have the following minimum basic features:

- Measurement of electrical energy parameters
- Bidirectional communication
- Integarated load limiting switch relay
- Tamper event deduction, recording and reporting
- Power event alarm
- Remote firmware upgrade
- Netmetering (kwh) features

Electrical supply requirements of smart meter

For smartmeters, selecting the appropriate power supplies is essential to ensure optimal safety standards and lower the chances of malfunctioning in field developments. For this reason the authorities should consider some of the power supply requirements for smart energy metering system application. Some of the factors to consider include the followig.

- 60 - 230V Ac stable input
- Transient power of 6.72 W
- EMI class B with surge voltage to (or) over 2KV

  (EMI - Electro magnetic interference)

Detecting /clearing the tamper notification on meter

Meter tampering means doing any act, which causes the meter to run slower or not at all and is basically theft of electricity from the authorities that supply electrical power.

The tamper notification (or) anti theft device is designed to detect the tamper in the energy meter of residential areas and notifies it to the power company through SMS.

The device detects the tampering through the reading of the to current sensors that are connected to a micro controller.

The power company will get notified, when one of the current sensors detects current, while the other one has not or there is a difference from the reading of the to current sensors. This systems also notifies the authority with an average time of 17.61 sec. Upon notification the power company immediately disconnect the line.

To detect electricity theft in an area, a temperature dependent predictive model which uses smart meter data and data from distribution transformer.

Distributed generation and prosumer

Distributed generation (DG) refers to a variety of technologies that generate electricity at (or) near where it will be used such as solar panels and combined heat and power. Distributed generation is generation of electricity located in the distribution grid.

A ‘prosumer’ is an individual who both consumes and produces energy. He also produce and share surplus energy whith grid and other users.

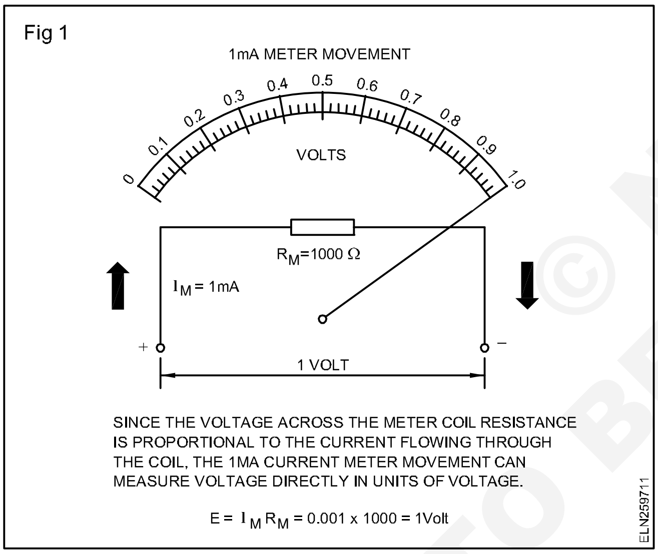
Extension of range of MC voltmeters - loading effect - voltage drop effect

Objectives: At the end of this lesson you shall be able to
- **state the function of the additional series resistance in a voltmeter**
- **calculate the value of the total resistance of the meter with respect to voltage and full scale deflection of current**
- **determine the resistance of a multiplier.**

Meter movement: A basic current meter movement by itself can be used to measure voltage. You know that every meter coil has a fixed resistance, and, therefore, when current flows through the coil, a voltage drop will be developed across this resistance. According to Ohm's Law, the voltage drop (E) will be proportional to the current flowing through the coil of resistance R ($E = IR$).

For example, in Fig 1 you have a 0-1 milliampere meter movement with a coil resistance of 1000 ohms. When 1 milliampere is flowing through the meter coil and is causing f.s.d. the voltage developed across the coil resistance will be:

Fig 1



$$E = I_M R_M = 0.001 \times 1000 = 1 \text{ volt.}$$

If only half that current (0.5 milliampere) was flowing through the coil, then the voltage across the coil would be:

$$E = I_M R_M = 0.0005 \times 1000 = 0.5 \text{ volt.}$$

It can be seen that the voltage developed across the coil is proportional to the current flowing through the coil. Also, the current that flows through the coil is proportional to the voltage applied to the coil. Therefore, by calibrating the meter scale in units of voltage instead of in units of current, the voltage in various parts of a circuit can be measured.

Although a current meter movement inherently can measure voltage, its usefulness is limited because the current that the meter coil can handle, as well as its coil resistance, are very low. For example, the maximum voltage you could measure with the 1 milliampere meter movement in the above example is 1 volt. In actual practice, voltage measurements higher than 1 volt will be required.

Multiplier resistors: Since a basic current meter movement can only measure very small voltages, The voltage range of a meter movement can be extended by adding a resistor, in series. The value of this resistor must be such that, when added to the meter coil resistance, the total resistance limits the current to the full-scale current rating of the meter for any applied voltage.

For example, suppose one wanted to use the 1-milliampere, 1000-ohms meter movement to measure voltages up to 10 volts. From Ohm's Law, it can be seen that, if the movement is connected across a 10-volt source, 10 milliamperes would flow through the movement and would probably ruin the meter ($I = E/R = 10/1000 = 10$ milliamperes).

But the meter current can be limited to 1 milliampere if a multiplier resistor (R_{MULT}) is added in series with the meter resistance (R_M). Since a maximum of only 1 milliampere can flow through the meter, the total resistance of the multiplier resistor and the meter ($R_{TOT} = R_{MULT} + R_M$) must limit the meter current to one milliampere. By Ohm's Law, the total resistance is

$$R_{TOT} = E_{MAX}/I_M = 10 \text{ volts}/0.001 \text{ ampere}$$
$$= 10{,}000 \text{ ohms.}$$

But this is the total resistance needed. Therefore, the multiplier resistance is

$$R_{MULT} = R_{TOT} - R_M = 10000 - 1000 = 9000 \text{ ohms.}$$

The basic 1-milliampere, 1000-ohms meter movement can now measure 0-10 volts, because 10 volts must be applied to cause a full-scale deflection. However, the meter scale must now be re-calibrated from 0-10 volts, or, if the previous scale is used all the reading should be multiplied by 10 (Fig 2).

Multiplying factor (M.F)

$$MF = \frac{\text{Proposed voltmeter range (V)}}{\text{Voltage drop across MC at FSD}} = \frac{V}{v}$$

Calculating the multiplier resistance using M F

$$R_{MULT} = (MF - 1)\, R_M$$

where

R_{MULT} = Multiplier resistance

M F = Multiplying factor

R_M = Meter resistance

Example : A 1 mA meter has a coil resistance of 1000 ohms. What value of multiplier resistor is needed to measure 100V?

$$MF = \frac{V}{v}$$

$$v = I_M \times R_M$$

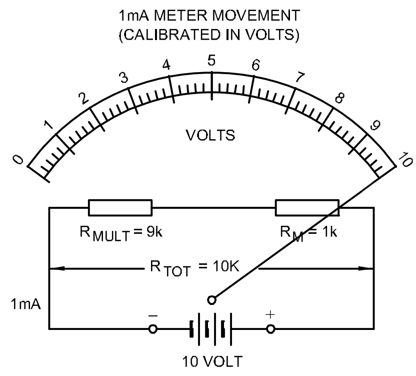
$$= 1 \times 10^{-3} \times 1000 = 1V$$

$$MF = \frac{V}{v} = \frac{100}{1} = 100$$

$$R_{MULT} = (MF - 1)R_M = (100 - 1)1000$$

$$= 99,000 \text{ ohms.}$$

Fig 2



BY CONNECTING A MULTIPLIER RESISTOR IN SERIES WITH THE METER RESISTANCE, THE RANGE OF A BASIC METER MOVEMENT CAN BE EXTENDED TO MEASURE VOLTAGES HIGHER THAN THE $I_M R_M$ VOLTAGE DROP ACROSS THE METER COIL.

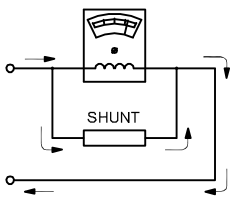
ELN259712

Extension of range of MC ammeters

Objectives: At the end of this lesson you shall be able to
- **define shunt used in ammeter**
- **calculate a shunt resistance to extend the range of an ammeter**
- **name the material used for shunt**
- **apply the use of terminals in standard shunts.**

Shunts: Moving coils of basic meters by themselves cannot carry large currents, since they are made of fine wire. To measure a current greater than that which the moving coil can carry, a low resistance, called a SHUNT, is connected across the instrument terminals (Fig 1).

Fig 1



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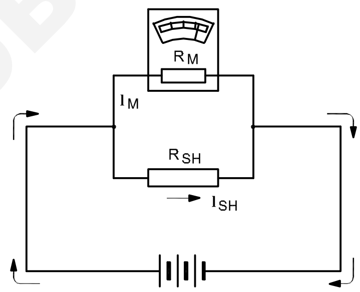
The shunt, therefore, makes it possible to measure currents much greater than that could be measured by the basic meter alone.

The shunt equation: A meter and shunt combination is identical to the parallel circuit shown in Fig 2. Instead of labelling the top resistor R_2, it can be labeled R_M, which represents the resistance of the moving coil. Resistor R_1 can be labelled R_{SH} to represent the resistance of the shunt. I_{R1} and I_{R2} then become I_{SH} and I_M to indicate the current flow through the shunt and through the meter. This means that the equation $I_{R1}R_1 = I_{R2}R_2$ can now be written as $I_{SH}R_{SH} = I_MR_M$.

Therefore, if three of these values are known, the fourth can be calculated. Since the shunt resistance R_{SH} is always the unknown quantity, the basic equation

$$I_{SH}R_{SH} = I_MR_M \text{ becomes } R_{SH} = \frac{I_MR_M}{I_{SH}}$$

Fig 2



THE METER AND SHUNT ACT LIKE R_1 AND R_2 IN PARALLEL. SO, $R_{SH} = \frac{I_MR_M}{I_{SH}}$

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From this equation, shunts can be calculated to extend the range of a current meter to any value,

where R_{SH} = shunt resistance

I_M = meter current

R_M = resistance of moving coil instrument

I_{SH} = current flow through shunt.

The value of current through the shunt(I_{SH}) is simply the difference between the total current you want to measure, and the actual full-scale deflection of the meter.

$I_{SH} = I - I_M$ where I = total current.

The meter and shunt act like R_1 and R_2 in parallel. So,

$$R_{SH} = \frac{I_MR_M}{I_{SH}}$$

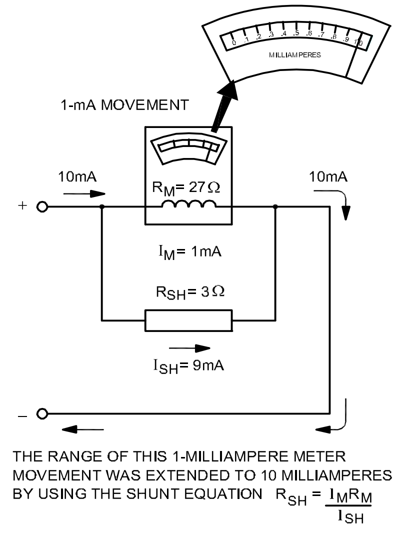
Calculating shunt resistance: Assume that the range of a one milliampere meter movement is to be extended to 10 milliamperes, and the moving coil has a resistance of 27 ohms. Extending the range of the meter to 10 milliamperes means that 10 milliamperes will be flowing in the overall circuit when the pointer is deflected full scale. (Fig 3)

I_M = 1 mA (0.001 A)

I = Current to be measured = 10mA

R_M = 27 Ohms

Fig 3



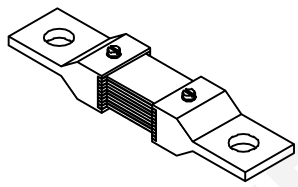
$I_{SH} = I - I_M$ = 10 mA – 1 mA

= 9 mA (0.009 A)

$$R_{SH} = \frac{I_M R_M}{I_{SH}} = \frac{0.001 \times 27}{0.009} = 3 \text{ ohms.}$$

Shunt material: The resistance of shunt should not vary due to the temperature. The shunt is usually made of Manganin which has negligible temperature coefficient of resistance. A high current shunt of a switch board instrument is shown in Fig 4.

Fig 4



HIGH CURRENT SHUNT FOR A SWITCHBOARD INSTRUMENT

ELN259726

Calibration of MI Ammeter and Voltmeter

Objectives: At the end of this lesson you shall be able to
- **define the term 'calibration'**
- **explain the calibration of voltmeter and ammeter.**

Calibration

In many industrial operations, measurement instruments must be trusted to provide the accuracy stipulated by the original design to assure a satisfactory product. This confidence is provided by a periodic testing and adjustment of the instrument to verify the required performance. This type of maintenance is called calibration.

Standards

Before calibration can begin, you must have the accurately known values of the measured quantities against which to compare the measurements made by the instrument being calibrated. Thus, for an instrument that is supposed to measure current of 1 milli ampere, you must have, for comparison, a source of current that is known to within at least that range or better. Only then you can say whether the instrument performs satisfactorily.

A very accurately known quantity used for calibration of instruments is known as a standard.

Calibration standards

Quantity	Standard
Voltage	Standard cell, high precision source
Current	Voltage standard and standard resistance standard milli volt source, gas filled/ mercury filled thermometers.

Calibrating DC and AC meters (Ammeter & Voltmeter)

Both DC and AC meters are calibrated in essentially the same way. To calibrate a DC meter, a very accurate DC current source is connected to the meter. The output of the current source must be variable, and some means must be available to monitor the output current of the source. Many sources have built-in meter for this purpose.

The output of the current source is varied in very small steps, and at each step the scale of the meter being calibrated is marked to correspond to the reading on the monitoring device. This procedure is continued until the entire scale of the meter is calibrated.

Same procedure is used to calibrate an AC meter, except that a 50/60 cps sine wave is used mostly. Also, you know that an a-c meter reads the average value of a sine wave, but it is desirable for the meter to indicate rms values. Therefore the rms equivalent are calculated and marked on the scale.

Thermocouple meters are calibrated on the basis of a sine wave. But the calibration is made at the frequency at which the meter will be used. At the extremely high frequencies at which it is used, a phenomenon known as skin effect occurs.

At these frequencies, the current in a wire travels at the surface of the wire, the higher the frequency, the closer the current moves to the surface of the wire. This effect increases the resistance of the thermocouple heater wire because the diameter of the wire becomes, in effect, smaller.

Thus the resistance of the heater wire varies with frequency. Since the resistance of the heater wire varies with frequency, thermocouple meters must be calibrated at specific frequencies.

Precautions to be observed when using an ammeter in measurement work

1 Never connect an ammeter across a source of EMF. Because of its low resistance it would draw damaging high currents and damage the delicate movement. Always connect an ammeter in series with a load capable of limiting the current.

2 Observe the correct polarity. Reverse polarity causes the meter to deflect against the mechanical stop and this may damage the pointer.

METER ACCURACY

METER	TYPICAL ACCURACY
Moving coil	0.1 to 2%
Moving iron	5%
Rectifier type moving coil	5%
Thermocouple	1 to 3%

Loading effect of voltmeter and voltage drop effect of ammeter in circuits

Objectives: At the end of the lesson you shall be able to
- **define the term 'multiplier'**
- **analyse the loading effect of the voltmeter**
- **analyse the effect of voltage drop across the ammeter in the resistance measurement.**

Multipiler

In the case of P.M.M.C. instruments, we have seen that the moving coil consists of fine gauge copper wire. This copper wire can carry very low current in the order of milli or micro amperes only.

The acceptable current which enables the instrument to read full scale is called full scale deflection current or F.S.D. current. When such a P.M.M.C. instrument is to be converted as a voltmeter, the moving coil has to be connected with a high resistance in series so that the current could be restricted within the F.S.D. current value. This series resistance is called **multiplier** resistance.

Let us study how the voltmeter sensitivity causes loading effect in the circuit by the voltmeter.

Loading effect of a voltmeter: The sensitivity of a voltmeter is an important factor when selecting a meter for a certain voltage measurement. A low sensitivity voltmeter may give an almost correct reading when measuring voltages in low-resistance circuits, but it is certain to produce very high errors in high resistance circuits. It is due to the fact that the voltmeter, when connected across a high resistance circuit, acts as a shunt for that portion of the circuit, and, thereby, reduces the equivalent resistance in that portion of the circuit.

As such, the meter will then give a lower indication of the voltage drop than what actually existed before the meter was connected. This effect is called the loading effect of a voltmeter and it is caused principally by the low sensitivity of the voltmeter.

The meter with the higher sensitivity of ohms/volt rating gives the most reliable result. It is important to realize the factor of sensitivity, particularly when voltage measurements are made in high-resistance circuits. Hence the following points are required to be followed while using a voltmeter.

- When using a multi-range voltmeter, always use the highest voltage range, and then decrease the range until a good up-scale (above mid-scale) reading is obtained.
- Always be aware of the loading effect. This effect can be minimised by using a voltmeter of high sensitivity and highest range in voltmeter.
- Before reading the meter, try to select a range in the multi-scale instrument such that the reading obtained is above mid-scale. The precision of the measurement decreases if the indication is at the low end of the scale.

Effect of voltage drop across the ammeter in resistance measurement: The ammeter/voltmeter method of measuring resistance is very popular since the instrument required for this is usually available in the laboratory.

In this method, two types of connections of meters are possible (Figs 1a and b).

Fig 1a

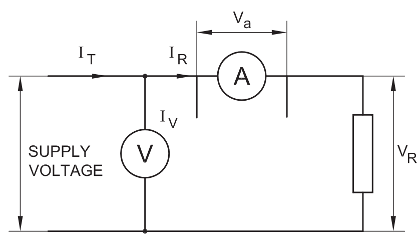
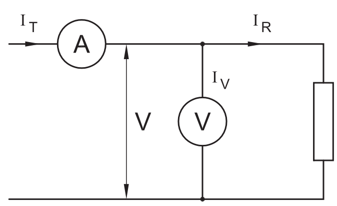


Fig 1b



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In both the cases, if readings of the ammeter and voltmeter are taken, then the measured value of resistance is given by

$$R_m \ \frac{\text{Voltmeter reading}}{\text{Ammeter reading}} = \frac{V}{I}$$

The measured value of resistance R_m, would be equal to the true value R, provided the ammeter resistance is zero and the voltmeter resistance is infinite, to make the circuit condition undisturbed.

However, in practice this is not possible, and hence, both the methods give inaccurate results. But the error in measurement could be reduced under different values of resistance to be measured as explained below.

Circuit (Fig 1a): In this circuit, the ammeter measures the true value of the current through the resistor. But the voltmeter does not read the true voltage across the resistance. On the other hand, the voltmeter measures the voltage drop across the resistance and also the ammeter.

Let R_a be the resistance of the ammeter.

Then the voltage drop across the ammeter $V_a = IR_a$

$$R_{mt} = \frac{V}{I} = \frac{V_R + V_a}{I_R} = \frac{IR + IR_a}{I_R}$$

$$= R + R_a \text{ ....Eqn.(1)}$$

true value of resistance $R = R_{m1} - R_a$ ... Eqn.(2)

From equation 2, it is clear that the measured value of resistance is higher than the true value. It is also clear from the above equation, that the true value is equal to the measured value only if the ammeter resistance R_a is zero.

$$\text{Relavtive error } e_r = \frac{R_{m1} - R}{R}$$

$$e_r = \frac{R_{m1} - (R_{m1} - R_a)}{R}$$

$$= \frac{R_a}{R} \text{ ....Eqn.(3)}$$

Conclusion: From equation 3, it is clear that the error in measurement would be small if the value of resistance under measurement is large as compared to the internal resistance of the ammeter. Therefore, the circuit shown in Fig 1(a) is most suitable for measuring high resistance values only.

Circuit (Fig 1b): In this circuit the voltmeter measures the true value of the voltage across the resistance but the ammeter measures the sum of currents through the resistance and the voltmeter.

Let R_V be the resistance of the voltmeter. Then the current through the voltmeter

$$I_V = \frac{V}{R_V}$$

Measured value of the resistance

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_V}$$

$$R_{m2} = \frac{V}{\frac{V}{R} + \frac{V}{R_V}} \text{ .....Eqn.(4)}$$

By multiplying the denominator and numerator

by $\frac{R}{V}$, Eqn.(4) becomes

$$R_{m2} = \frac{R}{1 + \frac{R}{R_V}} \text{ .....Eqn.(4)}$$

From equation 4, it is clear that the true value of resistance is equal to the measured value only if

- the resistance of the voltmeter R_V is infinite
- the resistance to be measured 'R' is very small when compared to the resistance of the voltmeter.

$$\text{Relative error } e_r = \frac{R_{m2} - R}{R}$$

By elimination process, we get

...Eqn.(5)

The value of R_{m2} is approximately equal to R.

$$\text{Therefore } e_r = \frac{-R}{R_V} \text{ .....Eqn.(6)}$$

Conclusion: From equation (6), it is clear that the error in measurement would be small if the value of resistance under measurement is very small as compared to the resistance of the voltmeter. Hence the circuit shown in Fig 1(b) should be used when measuring resistances of a lower value.

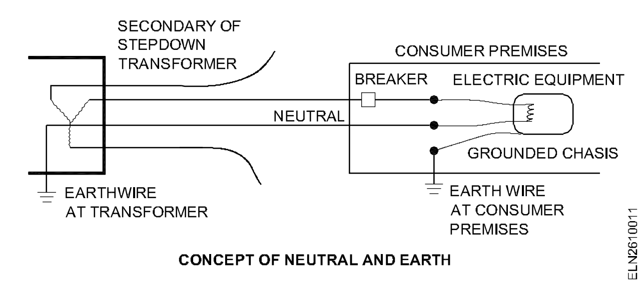
Concept of Neutral and Earth - Cooking range

Objectives: At the end of this lesson you shall be able to
- **state the concept of neutral and earth**
- **explain the domestic appliance**
- **explain the cooking range**
- **explain the parts of electric cooking range.**

Scan the QR Code to view the video for this exercise

Concept of neutral and earth (Fig 1)

Fig 1



CONCEPT OF NEUTRAL AND EARTH

Earth point is the point connected to the ground, i.e. earthed locally at the consumer premises while Neutral point is the star point of the secondary stepdown transformer feeding the consumer premises.

The role of Neutral point (Nuetral wire) is to close the circuit and carry the consumer load current (return current) back to the transformer. The earth point (earth wire at consumer premises) shall carry no current in normal situations.

The earth point (earth wire) is used to connect the metallic chassis of consumer equipment with the earth and isolate them from the live wires. Hence, the earth wire is used to ensure safety of equipment and personnel.

The earth wire will carry (short) currents in case of chassis of the equipment becomes electrified, i.e. a bare live conductor touches the metallic chassis. This short current will trip some circuit breaker in the way immediately.

The earth wire will carry (Leakage) small currents due to insulation deterioration, humidity and carbon deposit on the insulator. In this case a special breaker called ELCB (Earth Leakage Circuit Breaker) or RCCB (Residual Current Circuit Breaker) that is calibrated to trip at small currents (of the order of 6-30 mA for residual purposes and 300 mA for industrial purposes). Not all electric codes enforces the uses of ELCBs or RCCBs.

Domestic appliances:

Domestic appliance is an electrical equipment/machine used in houses for the various house hold tasks like cooking, washing and cleaning etc.

Standard safety norms: Trainees may be instructed to refer the international Electrotechnical commission (IECF 60335 -part 2 - section 64) for the standard safety norms related with domestic appliances for the further details.

Cooking range

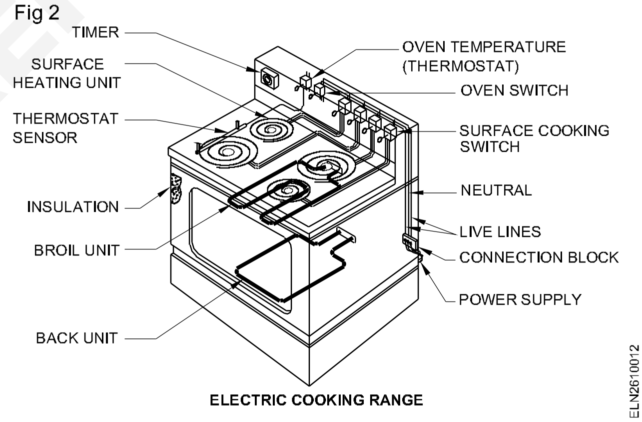
Electric cooking range is the combination of an oven and hot plate. The electric range consist of highly efficient heating elements, it gives better cooking control, has shelf oven, fingertip controls and designs to fit almost every possible kitchen need.

The surface heating units are set in the top of the range, the electric connections for these units are carried in the space between the top of the range (Fig 2). Oven controls are also kept in the top but in separate elevated pedestal.

The parts of a cooking range

Surface heating elements: In present day cooking range the nichrome element is encased in a metal tube with magnesium oxide insulation. This enclosed surface heating element (Fig 2) more efficient, more durable and safe to handle.

Fig 2



ELECTRIC COOKING RANGE

Step/Selector switches: A step switch is simply a rotary switch, which can select four or six different heats (wattages) Fig 3 and 4.

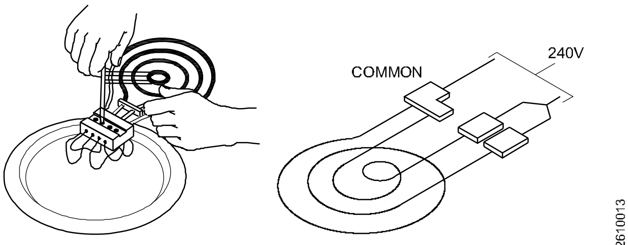
The step switch connected to two or three elements to 240 volts. The total circuit resistance or the voltage is changed to provide different heats.

High heat is obtained by connecting total elements in parallel. For low heat all the coils are connected in series (Figs 3 & 4).

Oven unit: The oven unit consists of two heating elements, an upper element and a lower element.

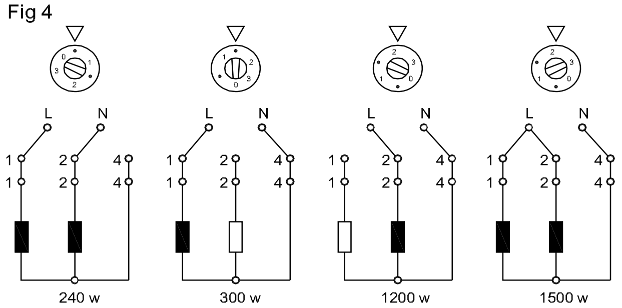
The oven heat is normally controlled by thermostat and timing device.

Fig 3



HEATING ELEMENTS

Fig 4

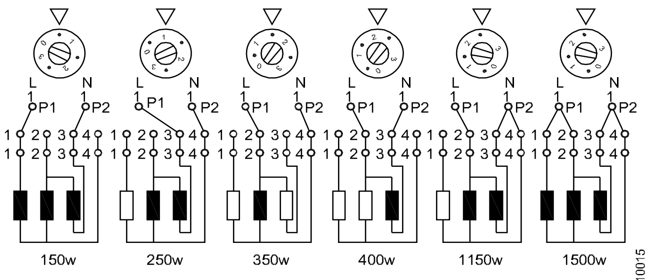


STEP/SELECTOR SWITCH-4 POSITION

In a oven electric circuit, the broil unit is constructed by stringing the element through the frame in two separate coils, whereas the bake unit is strung with only one coil.

Now-a-days instead of thermostat switch, the typical infinite-heat switches are used (Fig 5). This switch operates the internal heater causes the bimetal to open and close the switch that controls the range heater element. This bimetal heater is series the cooking range and must have the correct resistance for the element being controlled.

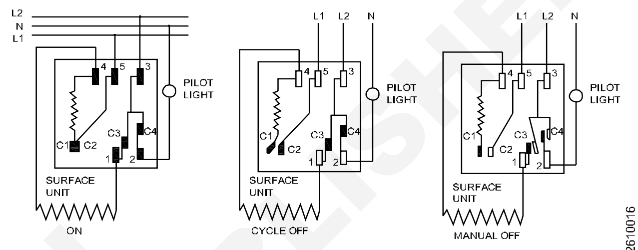
Fig 5



STEP/SELECTOR SWITCH-6 POSITION

A schematic diagram of a typical electric range is given in Fig 6.

Fig 6



TYPICAL INFINITE-HEAT SWITCHES

Geyser

Objectives: At the end of this lesson you shall be able to
- **explain geyser**
- **list the parts of a geyser from the schematic and constructional diagrams**
- **explain the construction and operation of a geyser**
- **explain the possible faults in a geyser and their remedies.**

Geyser

It is an electric water heater which heats and maintains the temperature of the water stored in it.

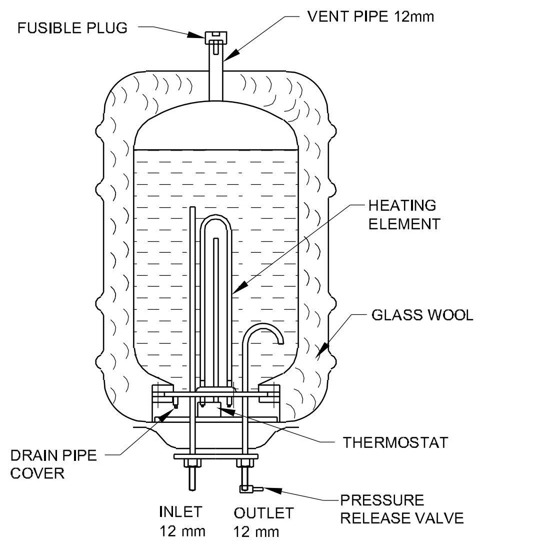
There are several types of water heaters. The most usual one is the geyser, which is more efficient as the hot water can be directly drawn through a tap at different points.

Construction of geysers: The construction of a hot water geyser or storage water heater is simple (Fig 1).

The outer casing is made of mild steel sheet. The inner tank is made of heavy gauge copper which is tinned to prevent corrosion. The space between the outer casing and the inner tank is filled with glass wool as heat insulation to avoid excess heat losses. Heating elements, thermostat, inlet and outlet pipes are fitted to the tank.

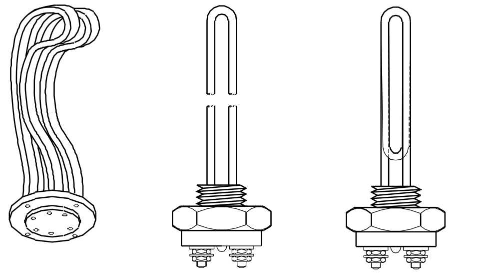
Heating elements are similar to those of immersion heaters but with different shapes to suit the tank sizes and the screw base. Fig 2 shows a few shapes of heating elements.

Fig 1



CONSTRUCTION OF GEYSER

Fig 2



DIFFERENT SHAPES OF HEATING ELEMENTS

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The rating of the heating elements depends on the capacity of the geyser. For up to 25 litres capacity, 1 KW elements are used while for 50 litres capacity 2 KW are used, for 100 litres capacity 3 KW are used.

Thermostats: Thermostats are used in water heaters to control the current to the heating elements and thereby regulate and maintain the water temperature between 32°C to 88°C.

A typical thermostat used in geysers: A thermostat used in a geyser is of tube and rod bimetal type (Fig 3).

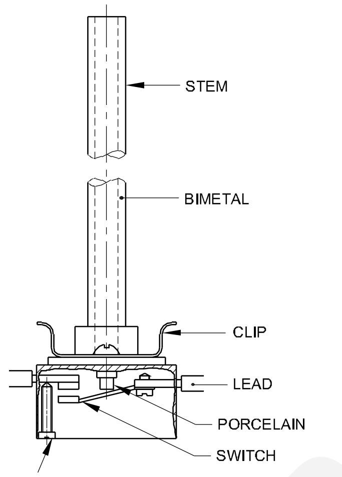
Thermostats are available in sizes of 8 mm diameter with a length of 175 mm, 275mm or 450 mm depending on the height of the geyser. Thermostats are fixed in a tube and are connected in series with the heating element.

The outlet pipe is provided with a `U' bend inside the tank as shown in Fig 1 to prevent complete draining of water from the geyser. A pilot lamp is fitted on the outer case indicating the automatic working of the unit.

A fusible plug is fitted on the top of the unit to protect the inner tank to release the excess pressure that may be developed due to failure of the thermostat.

Working: When a geyser is fitted initially, open the inlet cock, fill the innertank and maintain the water level . When switched `on' the heater heats the water. When the temperature of water reaches to a set value the thermostat disconnects the heater from the supply. (Fig 3) The water drawn from the outlet pipe reduces the temperature and hence the thermostat, re-connects the heater with the supply.

Fig 3



A TYPICAL TERMOSTAT USED IN WATER HEATER

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Care and maintenance: A geyser requires less maintenance. The scale deposits that may adhere to the inside surface should be removed. It depends on the amount and kind of mineral content in the water. The only care required is not to energise the geyser without initially filling with water.

Troubleshooting of geysers

The following chart lists out complaints, causes and possible remedies.

Troubleshooting in water heaters/geysers

Complaints	Causes	Test and remedy
No hot water	1 Blown fuse.	1 Replace fuse.
	2 Open circuit.	2 Check wiring all the way for broken wire or loose connections.
	3 Heater element burnt out.	3 Check elements for burn-out.
Constantly/repeatedly blowing the fuse	1 Grounded heating element.	1 Check the heater element for ground.
	2 Grounded lead wire.	2 Check wiring for grounds.
	3 Incorrect connections.	3 Check electrical connections all the way.
High consumption of power leading to increased electricity bill	1 Leaking faucets (taps).	1 Replace washers in all leaking faucets (taps).
	2 Excessively exposed hot water pipes.	2 Hot water lines should be as short as possible.
	3 Thermostat setting too high.	3 Reset thermostat. Setting should be 60°C to 65°C.
	4 Short to ground in heating element.	4 Check element for ground.
	5 Scale deposit on heating units.	5 Remove unit and check.

Washing machine

Objectives: At the end of this lesson you shall be able to
- **explain the washing machine**
- **state the types of washing machines and wash techniques**
- **state the function of mangle wringer for drying**
- **explain the function of drain pump and drive motor**
- **state the points to be noted while placing the washing machine at a suitable place.**

Washing machine

It is a domestic electric appliance which is used to soak, rinse, wash, wringle /dry the cloth/fabrics etc.

Types of washing machines: The modern washing machines can be divided roughly into three main groups according to their function.

They are

– Ordinary

– Semi automatic

– Fully automatic.

i Ordinary type

Ordinary without timer: This machine uses the pulsator type technique in which a disc is fitted to the motor.

It has only one tub and one motor the dirty cloth is loaded in the tub, water is filled manually in the tub, detergent is added. The motor is switched on the pulsator disc moves the cloth around the tub and the time duration of washing is decided by the operator.

Ordinary with timer: Similar to the ordinary type, but added with a clock timer to select the time of wash from 1 to 15 minutes.

ii Semi-automatic type

This type has two tubs. One for washing and rinsing, the other for spin drying the cloths. The washing tub operates at lower speed whereas the spin drier tub operates at a higher speed. The machine may contain either one or two motors.

iii Fully automatic type

In this type, the micro processor enables to programme the wash cycle. There will be only one tub. The machine could be programmed for wash cycle, detergent intake and water input. The machine does washing, rinsing and also dry the cloth and stops.

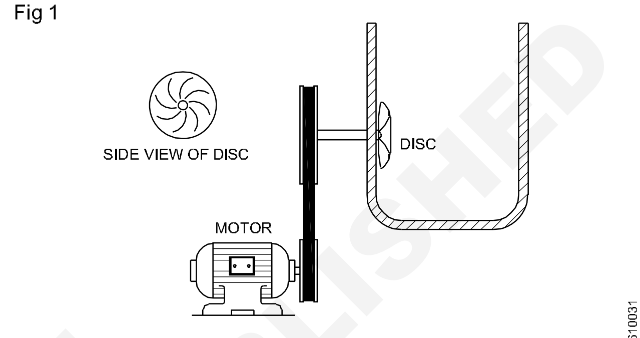
Further to the above types the washing machine could be further divided by the type of loading i.e. top loading and front loading. In some machines the water used for washing could be preheated with the help of an electric heater.

Types of wash techniques

In addition to the above classification, the washing machine could be catagorised according to the wash technique used as explained below.

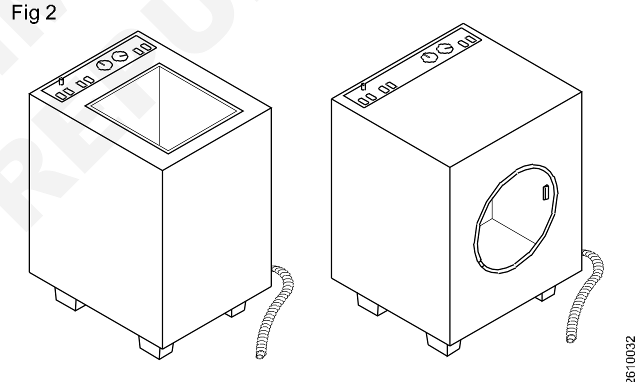
The pulsator wash technique (Fig 1)**:** This is the most common type pulsator wash technique, it has disc in concave shape used to rotate the clothes in water. Dirt is removed from the cloth by rubbing against tub wall surfaces and the disc. (Fig 1 & 2)

Fig 1



PULSATOR WASH TECHNIQUE

Fig 2



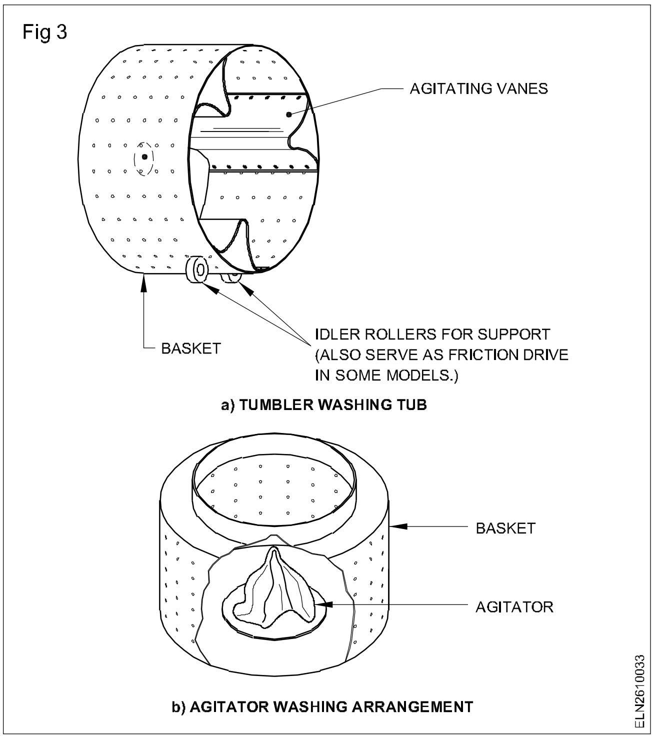
a) TOP LOADING b) SIDE LOADING

Tumbler type (Fig 3 a)**:** In the tumbler type the washing is carried out by tumbling the cloths with the help of a simple drum. Here the construction is simple and cloths are tumbled around the drum by virtue of the drum itself being rotated by means of a pulley at the rear or the friction drive of the idlers.

The agitator wash technique (Fig 3b)**:** An agitator which is long and cylindrical is installed at the centre of the washing tub. The water and cloths circulate around the agitator, thereby under going a thorough cleaning process. Not suitable for delicate fabric.

The air power wash technique: This machine uses air bubble technique to wash delicate fabrics smoothly.

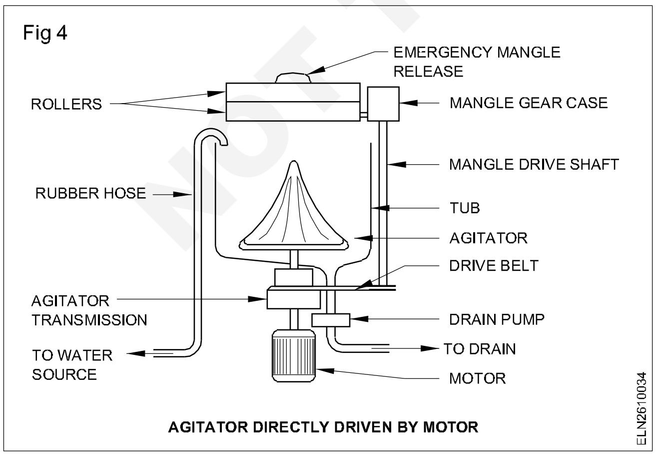
The chaos punch wash technique: A multifaceted method of washing, where in water is propelled upwards in the machine to prevent entanglement of garments punching, is done on clothes by forced water.



The water fall technique: This is more or less similar to chaos punch technique. This machine use jets of water which are pumped from below the pulsator in to the tub. The velocity and force of water removes the dirt. Most of the washing machines could be repaired by the electrician but micro processor controlled washing machine repair needs some more training and experience.

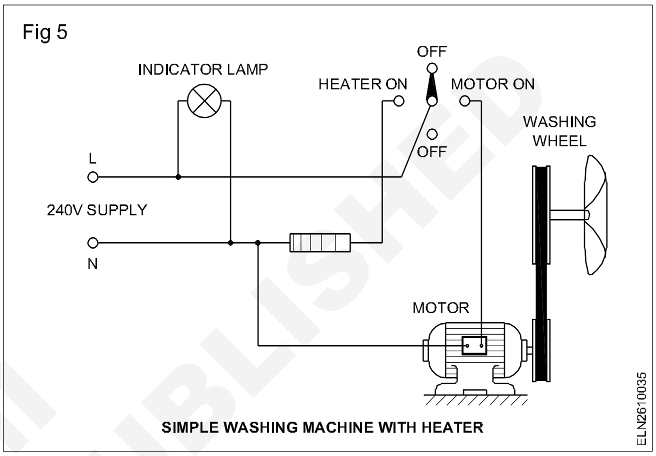
The conventional type with mangle wringer for drying: The conventional washing machines are relatively simple in operation and construction. The washing cycle in such a type of machine would consist of the user filling the central tub with water up to the water level mark. Soap and bleach are added.

Depending upon the types of the clothes to be washed the 'ON' time or the wash time of the machine is set and then 'the machine is switched 'ON'. Most machines have the agitator directly driven without any intermediate gears (Fig 4).



The wash is stopped by the timer setting on the machine. The agitator is brought to a standstill and the drain pump is operated or the valve for gravity draining is activated. For rinsing the clothes the machine is switched 'ON' for a time duration such that all the detergent or soap is removed off the clothes. This cycle is called the rinse cycle. The clothes are then put through the mangle wringer to press and roll out all the water from the clothes.

Some type washing machines having heater, is generally immersion rod type which is permanently fixed in the bottom of the washing machine. The purpose is to produce warm water for loosening stubborn dirt particles of the clothes for quick cleaning. In these types generally heater is not repairable, once found defective it has to be replaced. Fig 5 shows the connection diagram of simple washing machine with heater .



Precaution

i The agitator should be stopped during the drain period, because if it were to continue operating without water in the tub, the required force on the agitator to rotate the clothes in the absence of water would be many times more causing motor to overload.

ii The bottom cable should be protected from the damage by the rats by using a rust proof welded mesh.

The drive motor: The most popular type of motor used in a washing machine is a single phase 240 volts 50 Hz. capacitor start squirrel cage induction motor. These motors may range from 1/3 to 1/2 HP rating. These motors are normally protected from overload and overheating conditions by means of a bimetallic overload relay or a thermal switch. The motor is located in such a way that water leakages do not fall on to these motors.

Locating the machine: The machine should be so located that soft water is freely available, and outlet or water drain arrangement is also easily available. The supply board should have the rated 3 pin socket arrangement with proper earth brought to the 3 pin plug point. The flooring should be in level such that the machine rests properly to avoid unnecessary loading on the machine drum and vibrations.

Pump set

Objectives: At the end of this lesson you shall be able to
- **explain pump set**
- **explain the method of selection of the type of pump and capacity of the motor taking various factor into consideration**
- **explain the types of pumps and use the table for selecting a proper type and capacity for requirement**
- **state how to select a proper location of pump installation and select proper control devices**
- **state troubleshoot in pumps.**

Pump set

Pump set is a combination of an electric motor and a impeller/pump coupled together to pump the water from well (or) bore (or) sump etc.,

Selection of pump : The following points are to be considered before selecting a pump for lifting the water.

- The quantity of water to be lifted
- Height of water to be delivered
- The time for lifting.

Based on the above considerations the pump has to be selected along with the motor to lift the water from a well/ sump.

An illustration is given below to show how to calculate the required HP of the motor to a particular height and quantity of water to be lifted within a specified time.

Example: Calculation of HP for domestic pump set.

A pump driven by a single phase AC motor of 240V, 50 Hz has to deliver 1000 litre to a height of 30 metre within 15 minutes. Find the HP of the motor if the efficiency of the motor is 80%.

Given

Working voltage - 240V, 50 Hz

Quanity of water to be delivered - 1000 litre

Height of the water delivered - 30 m

Efficiency of motor - 80%

Time of delivery - 15 minute

Solution

Work done by the pump / minute =

$$\frac{\text{weight of the water x Height}}{\text{Time}} = \frac{1000 \times 30}{15} \text{ kgm/min.}$$

since 1 litre of water = 1 kg. of water

and 4500 kgm/minute = 1HP

$$\text{Pump output in HP} = \frac{1000 \times 30}{15 \times 4500} = 0.44 \text{ or } 0.5 \text{ HP}$$

$$\text{Input of the pump} = \frac{0.5 \times 100}{80} = 0.625 \text{ HP}$$

Next nearest HP of the motor recommended is 0.75 HP.

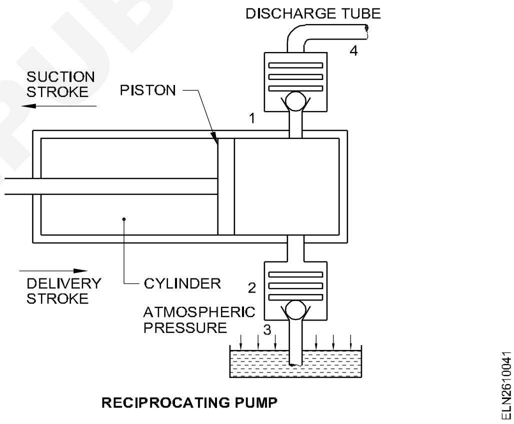
Pumps : Pumps can be classified mainly into two categories. They are

- Reciprocating pumps
- Rotary pumps.

Reciprocating pumps : In this type of pump, the main moving part has reciprocating motion only and hence the name. Fig 1 shows the main parts of a reciprocating pump.

When the piston moves towards left, a partial vacuum is created inside the cylinder. The check valve 1 in Fig 1 closes due to the suction effect of the vacuum, spring action and head of water in the discharge tube 4 but valve 2 Fig 1 opens and allows the water to fill the cylinder through the suction pipe 3 due to atmospheric pressure outside. This stroke of the piston is called suction stroke.

Fig 1



RECIPROCATING PUMP

On the other hand when the piston moves towards right ie discharge or delivery stroke the liquid inside the cylinder is pushed out through check valve 1 and delivery pipe 4. During the delivery stroke valve 2 remains closed by the action of spring and the water pressure inside the cylinder.

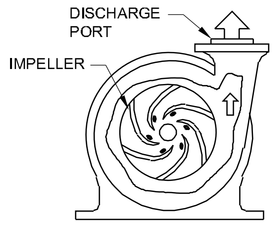
However, as the discharge of water takes place in this type of pump only during the discharge stroke, the pump creates a pulsating flow of water and not a continuous flow. This type of pump is called a piston pump.

Rotary pumps : There are very many varieties of this pump in the market. However centrifugal pumps, jet pumps and submersible pumps are the commonly used pumps for lifting water in houses.

Centrifugal pumps : Fig 2 shows the construction and operation of a centrifugal pump.

The operation of a centrifugal pump is based on centrifugal force. As the fluid being pumped enters the inlet or central section of the pump, the rotating action of the impeller vanes forces it to the outside of the pump casing (Fig 2).

Fig 2



FLUID FLOW IN A CENTRIFUGAL PUMP

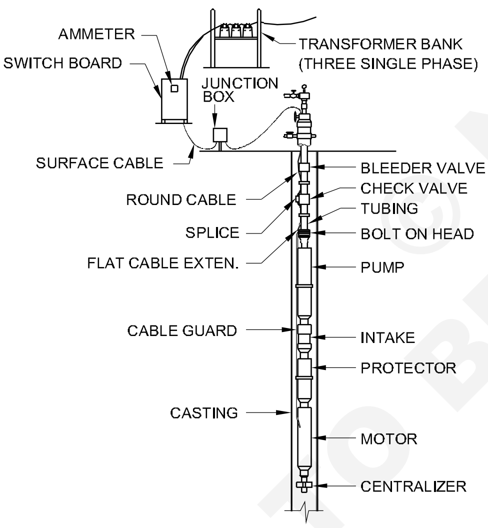
Because the fluid moves faster at the outer edge of the impeller the momentum increases. As more fluid enters the pump, more fluid momentum is built up in the casing that encloses the impeller. This momentum forces the fluid out of the pump discharge port.

The centrifugal pumps are used where large volumes of water are to be pumped at relatively low pressure.

Submersible pumps : This pump also comes under the category of centrifugal pumps and is found in use at places where water is found in great depth.

Submersible pumps have motor and pump in an axial length are submerged in water (Fig 3). Generally such pumps are used for borewells where the volume of water to be lifted exceeds the capacity of reciprocating pumps. The motor used in such types of pumps is of 3-phase.

Fig 3



ELECTRIC SUBMERSIBLE CENTRIFUGAL PUMP SYSTEM

The cables and motor windings have water proof sealing as they are immersed in water. Such pump sets will have following advantages.

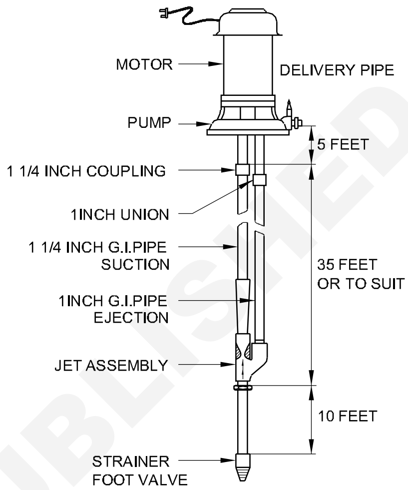
- Diameter is smaller.
- Motor and pump are submerged in water. Hence needs no space on ground level.
- The motor and pump are entirely connected through metal pipes for delivering water.
- Efficiency is more as the motor with the pump will be to the level of water or inside the water.
- Cooling is effectively done by water only.
- Can be used for lifting water from any depth of sump or borewell as suction pipe is not used.

Disadvantages

- Erection cost and initial cost of purchasing will be high.
- In case of any defects, it is necessary to remove entire unit along with the pipe line.
- Requires skilled worker for both erection and maintenance work.

Jet pumps : Another variety of centrifugal pump commonly used in the domestic wells an d borewells is the jet pump. In jet pumps, the motor and pump are assembled together in one block (Fig 4).

Fig 4



JET ASSEMBLY

The bottom portion of the pump has two connecting pipes. One is called suction pipe and the other is called ejection pipe. A portion of the water is sent through the ejection pipe to the jet assembly and it aids the water in the suction pipe to be lifted upwards by Venturi principle.

Suction, ejection and delivery pipes and motor capacity could be selected with the help of the performance Table 1.

Almost all types of pumps may be independent units to be coupled with an electric motor through belts or couplings or may be single(mono) blocks comprising both motor and pumps.

Location of pump set : The pump should be installed as near as possible to the water source in order to reduce the suction lift and to achieve better performance.

Ample space should be provided around the pump for easy inspection and maintenance whenever required.

Before starting the pump ensure that.

- Shaft rotates freely by hand.
- The gland box is properly tightened.
- The valve, if there is any on the delivery branch, is opened.

Check the following during running condition.

- The direction of rotation is correct.
- Pump is running smoothly.

- Leakage of stuffing box is normal ie., 50 to 60 drops per minute in gland packed pump.
- The ball bearings do not get excessively hot.

Trouble shooting in pumps : In case of trouble in pumps, with the help of the trouble shooting chart (Table 2), locate the fault and rectify the defects.

Table 1

Troubleshooting chart

Sl.No.	Problems	Probable reason
1	Pump does not deliver water.	Pump casing and suction pipe is not primed.
2	Delivered water is not enough.	Delivery head is too high. Suction lift is too high.
3	Not enough pressure.	Impeller/suction pipe choked. Wrong direction of rotation. Leakage in suction pipe. Gland packings/mechanical seal worn out. Foot valve choked/not immersed in water. Impeller damaged. Wearing of shaft sleeve.
4	Pump takes too much power.	Damaged ball bearing. Head is much lower. Mechanical friction is more in the rotating part. Shaft bent. Stuffing box is too tight (gland is too tight).
5	Pump leaks excessively.	Gland packings/mechanical seal worn out. Shaft sleeve worn out. Gland packings/mechanical seal are not in proper position.
6	Pump is noisy.	Hydraulic cavitation. Foundation is not rigid. Shaft bent. Rotating parts are loose or broken. Bearing worn out.

Automatic electric iron

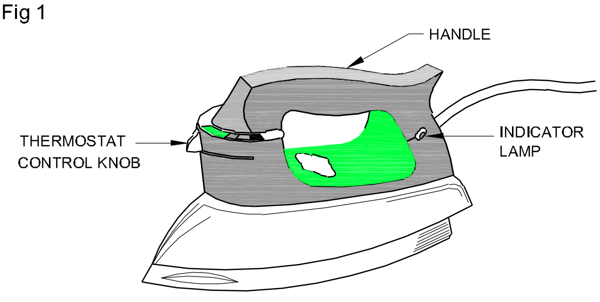
Objectives: At the end of this lesson you shall be able to
- **state the difference between non-automatic and automatic irons**
- **describe the construction of a bimetal thermostat**
- **illustrate the working of an adjustable thermostat**
- **list the possible faults, their causes and corrective action to be taken in an automatic iron.**

Automatic electric iron

The difference between an automatic iron and the ordinary (non-automatic) iron is that the automatic type has a thermostatic device to regulate the temperature. The other parts are more or less the same in both the types of irons. (Fig 1)

Automatic irons are fitted with a thermostatic switch to regulate the heat to a specific predetermined value. The thermostatic switch disconnects the supply when the predetermined value is reached and reconnects the supply when the iron cools down. A turning knob with a dial just below the handle, marked as rayon, cotton, silk, wool etc. can be operated to select the preset temperature.

Fig 1



AUTOMATIC ELECTRIC IRON

They are two types of automatic electric iron, they are:

1 Dry Automatic Iron

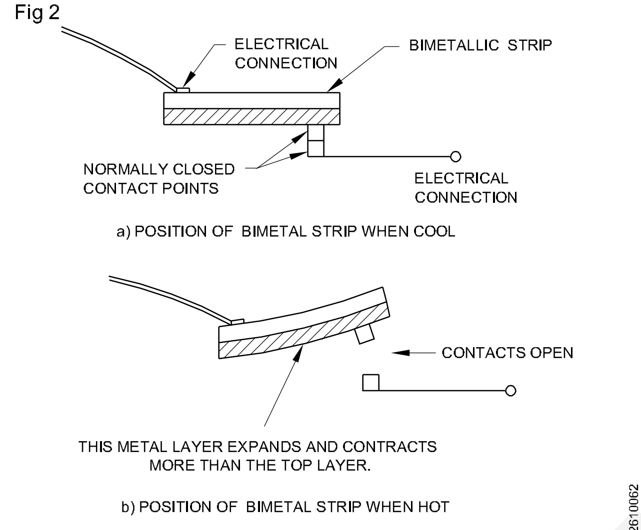
2 Spray/Steam Automatic Iron

Thermostats

A thermostat is a switch which can be designed to close or open a circuit at predetermined temperature. One of the simplest and most dependable components in the modern heating appliances is the BIMETAL THERMOSTAT. It controls the temperature in stoves, toasters, food warmers, irons etc. It serves as a safety device to prevent overheating of the appliances.

Bimetal thermostat (Fig 2)

Fig 2



A SIMPLE BIMETAL THERMOSTAT

In the thermostat there is a bimetal strip made of two strips of metal with different expansion rates welded together. The metal strip expands when heated and contracts when cooled. One metal in the bimetal strip has a high rate of expansion when heated, and the other has a low rate.

When a bimetal strip is heated, both the metals in the strip expand but the one at the bottom with a higher rate of expansion expands faster and forces the upper half to curl up or bend away from the contact point (Fig 2b). The strip curls or bends enough to break the contact, opening the circuit.

As the strip cools, it straightens and restores contact with the stationary point. The bending of the bimetal strip on heating, is towards the side that has the smaller expansion rate.

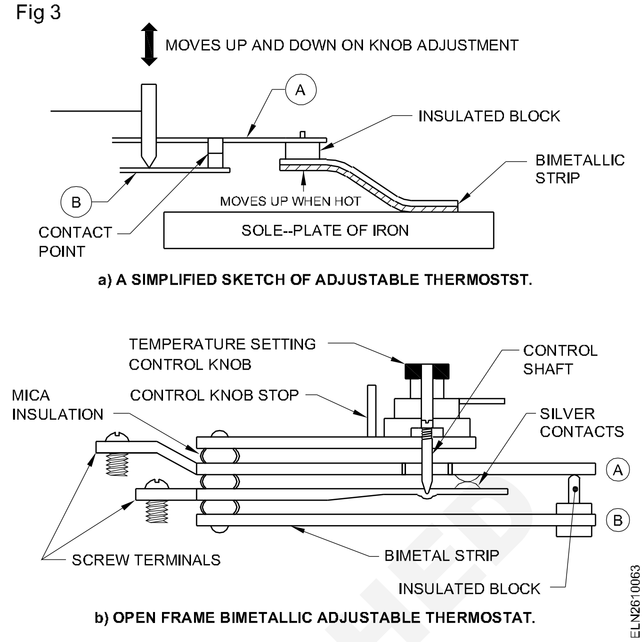
Adjustable thermostat (Fig 3)

The operation of the thermostat is as follows. The strip B (Fig 3 (a) part B) along with the silver contact is designed such that it has upward tension whereas the control shaft moves the strip B either upward or downward depending upon the temperature setting.

The strip A (Fig 3(a) part A) along with its silver contact is designed such that it has downward tension. But its downward movement is restricted by the insulated block.

In the 'OFF' position of the temperature setting control knob, the strips A and B will be away from each other, keeping the silver contacts in an opened condition, thereby, keeping the heating element circuit open.

Fig 3



When the temperature setting control knob is set to minimum position, the control shaft moves up and allows the strip B and its silver contact to move upwards to some distance and make contact with the silver contact of the strip A.

Thus the heating element circuit is closed, the iron heats up. The bimetal strip which is also heated, bends upwards and the insulated block pushes the strip A, thereby, separating the silver contacts and the heating element circuit opens.

When the iron cools down, the bimetallic strip also cools and comes back to the straight position. The downward movement of the insulated block allows silver contact strip A to come in contact with the silver contact strip B; thereby the circuit is closed and the iron heats up.

A lamp fitted near/into the handle of the iron goes off when the desired temperature is attained.

Steam/spray irons (IS 6290)

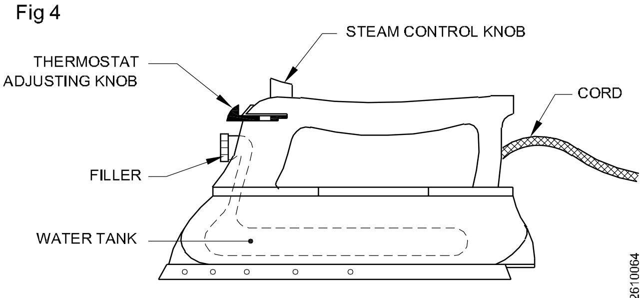
Electrically there is no difference between steam irons and dry irons. A steam iron has a small reservoir mounted above the heating element. A control valve on this allows the water to drip slowly into recesses in the sole-plate.

A check valve keeps the water from going back up into the tank. When the water hits the hot position of the sole-plate, it is converted to steam and goes out through holes in the bottom of the sole-plate. Fig 4 shows a diagram of the construction of a typical steam iron.

Method of repair

In most of the steam irons, the heating element is sealed along with the sole-plate. When the element is found to be open or shorted, the sole-plate along with the sealed heating element has to be replaced. Apart from defective power cord set and thermostat as found in the irons, the steam iron may develop problems in the water/steam container parts due to the following reasons:

Fig 4



OUTLINE OF A TYPICAL STEAM IRON

i The consumer might have used tap water instead of distilled water to fill the water tank in steam irons. This may result in deposit of salts in the tank and clog the entry and exit points.

ii The consumer might have left the iron with water for some period resulting in salt and rust formation.

The salt deposit can be removed by filling the tank with diluted vinegar and plugging the iron to the power supply. A number of attempts may have to be made to clear the deposits.

Troubleshooting chart

(Dry Iron)

Trouble	Possible causes	Corrective action to be taken
No heat	No power at outlet. Defective cord or plug. Loose terminal connections. Broken lead in iron. Loose thermostat control knob. Defective thermostat. Defective heater element. Open thermal fuse.	Check outlet for power. Repair or replace. Check and tighten the terminals. Repair or replace lead. Clean and tighten. Replace thermostat. Replace the element if separate. If cast in, replace sole-plate assembly. Replace.
Insufficient heat	Low line voltage. Incorrect thermostat setting. Defective thermostat. Loose connection.	Check voltage at outlet. Adjust and recalibrate thermostat. Replace thermostat. Clean and tighten connections.
Excessive heat	Incorrect thermostat setting. Defective thermostat.	Adjust and recalibrate thermostat or replace. Replace thermostat.
Blisters on sole-plate	Excessive heat.	First repair the thermostat control. Then replace or repair the sole-plate, depending on its condition.
Tears clothes.	Rough spot, nick,scratch, burr on sole-plate.	Remove these spots with fine emery and polish the area with buff.
Iron do not turned off automatically.	Thermostat switch contacts are welded together	Check the thermostat switch contact. Open them by force. The contact points should be in open condition at off position of the control knob.
Sticks to clothes.	Dirty sole-plate. Excessive starch in clothes. Wrong setting of the thermostat knob. Iron too hot for fabric being ironed.	Clean. Iron at a lower temperature. Use less starch next time. Set the knob to correct temperature. Lower the thermostat setting.
Iron gives shock.	Disconnected earth connection. Weak insulation of heating element. Earth continuity with common earth not available.	Check earth connection and connect properly. Check insulation resistance of heating element; if necessary replace element. Check the main earth continuity and connect properly.

Electric kettle

Objectives: At the end of this lesson you shall be able to
- **explain electric kettle and its types**
- **list and state the parts of an electric kettle**
- **describe the method of fitting a new element**
- **state the general care and maintenance.**

Electric kettle

Electrical kettle is a heating device which is used to heat the liquid (like water, milk, etc) poured in it.

There are two types of electric kettles:

– Saucepan type

– Immersion heating type.

Saucepan type: The construction of the sauce pan type kettle is given in Fig 1. The parts are as follows.

1 Bolt, nut and washer holding bottom cover

2 Heating element

3 Asbestos sheet

4 Sole-plate

5 Pressure plate

6 Bottom cover

7 Handle

8 Top lid

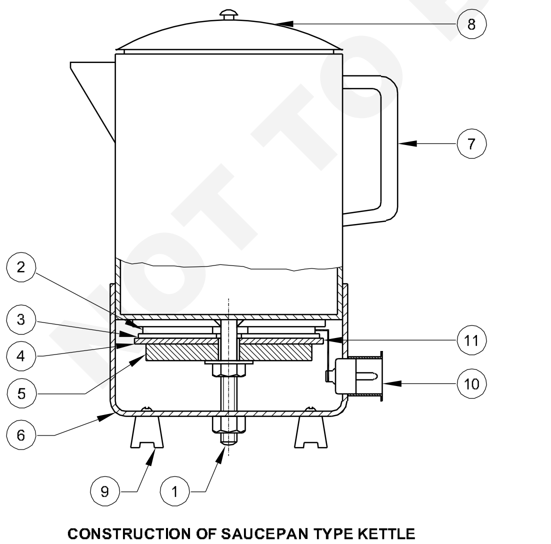
9 Ebonite leg

10 Outlet socket

11 Brass strips

Bottom cover: The bottom cover is fitted to the central bolt of the body by a nut and washer. (Fig 1).

Fig 1



CONSTRUCTION OF SAUCEPAN TYPE KETTLE

Heating element: In its general construction, the heating element is made of Nichrome ribbon. The Nichrome ribbon is wound over mica. This is placed between two circular mica pieces, so that the Nichrome wire may not come in contact with any metallic part of the kettle. The two ends of the elements are connected to the outlet socket terminals of the kettle through two brass strips.

Asbestos sheet: This is placed below the element and mica insulation to serve as a heat insulator. It reduces the heat loss in the kettle in addition it gives increased insulation.

Sole-plate: The sole plate is a cast iron plate neatly ground to have a flat surface and its main function is to keep the element in close contact with the container and to avoid deformation of the element when heated.

Pressure plate: This is made of cast iron and fitted by a nut on the middle bolt. The pressure plate holds the sole plate in position.

Method of fitting new element: Dismantle the kettle by the following steps.

– Invert the kettle and loosen the bottom cover holding nut. Take out the nut and remove the bottom cover.

– Remove the brass strip connections of the elements at the socket terminal sides.

– Remove the terminal socket by loosening the fitting screws.

– Open the nut of the pressure plate.

– Take out the pressure plate, sole-plate, asbestos sheet and then the heating element.

– Replace with a new heating element having the correct size and rating.

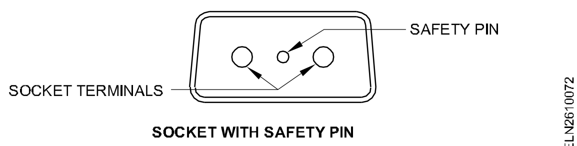
– Reassemble the kettle.

– Test the insulation resistance for any earth fault and insulation failure.

Immersion type: The heating element in this type is of tubular immersion heating design. In some kettles an ejector type safety device is incorporated in the socket terminal side.

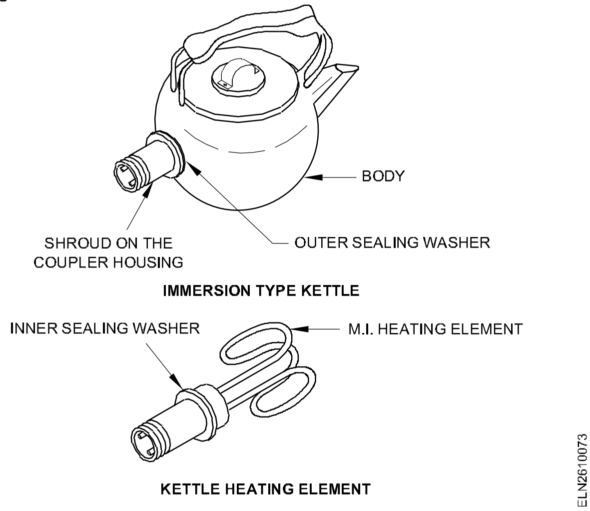
In case the kettle is switched ON without water the safety pin (Fig 2) which is soldered against a spring which is under tension comes out and pushes the plug out. This safety pin can be placed in position by soldering. The heating element is concealed inside a hollow tube and mineral insulated (Fig 3).

Fig 2



SOCKET WITH SAFETY PIN

Fig 3



New elements can be fitted to most types of kettles without difficulty.

Fitting a new element: A new element should be fitted in the following manner.

- Hold the element in one hand and unscrew the shroud on the coupler housing.
- Slide out the outer fibre sealing washer.
- Twist the element assembly inside the kettle and pull it out gently through the top.
- Take the old element to an electric shop to make sure that the replacement is of the exact design and wattage.
- Remove stubborn scales inside the kettle with a blunt knife without knocking the metal surface.
- Put an inner sealing washer, usually made of fibre, on the new element.
- Take care to fit new washers at the coupler housing in the correct order. Reassemble.

Care and maintenance

- Never empty a kettle while it is still switched 'ON'.
- Remove the plug from the socket before carrying out maintenance or repairs.
- Never pour water into a kettle which has just boiled dry, which apart from danger to the users, may damage the element.
- The metal portion of the kettle should be earthed using a 3-pin plug and a 3-pin appliance socket.
- Replace cracked or damaged sealing washer.
- Check for the good condition of asbestos sheet. Replace with a new one, if damaged during removal.
- Immediately replace the defective plug, socket or cable, if once noticed.
- Earth clips of the appliance power cord plug should snugly fit into the inner side of the appliance socket to have perfect earth connection. Check for proper fitting and cleanliness.

Induction Heater

Objectives: At the end of this lesson you shall be able to
- **explain induction heater**
- **explain construction, advantages and disadvantages of induction heater.**

An induction heater uses an electromagnetic field to heat food. When the heater is turned on, an electric current passes through a coil of metal, creating a magnetic field. This magnetic field then penetrates the metal of a cooking pan, inducing a current in the pan. The current then dissipates energy in the form of heat, cooking the food in the pan. (Fig 1)

Fig 1

What is induction?

Electromagnetic induction, which is often referred to simply as induction, signifies the production of an electric current across an electric conductor, caused by a changing magnetic field. Electricity and magnetism are not two disjointed things; they are two entities originating from the same underlying phenomenon - electromagnetism.

Due to this, a change in a magnetic field leads to the generation of electric current. Similarly, a change in the electric field across a conductor produces a magnetic field. The latter is the working principle behind induction heater, which is pretty much all you need to know to understand the working of induction cooktops.

Induction heater

Inside view of an induction heater (Fig 2)

An induction heater looks like any other ceramic cooktop, with different zones for placing pans and pots of varying sizes. It consists of a tough, heat-resistant glass-ceramic plate on which the user places pots and pans that need to be heated. Directly underneath the plate there is an electromagnetic coil of metal that is electronically controlled. This is the main component responsible for heating the vessels kept above the heater.

When you switch on the power supply of the heater, an electric current passes through the coil. The electric current passing through the coil produces a magnetic field in all directions around the coil, including directly above it (where pots and pans are placed). (Fig 3) Note that until this point, no heat is generated, as the magnetic field being produced doesn't produce any heat unless a third object - the cooking pan - is introduced into the mix.

Fig 2

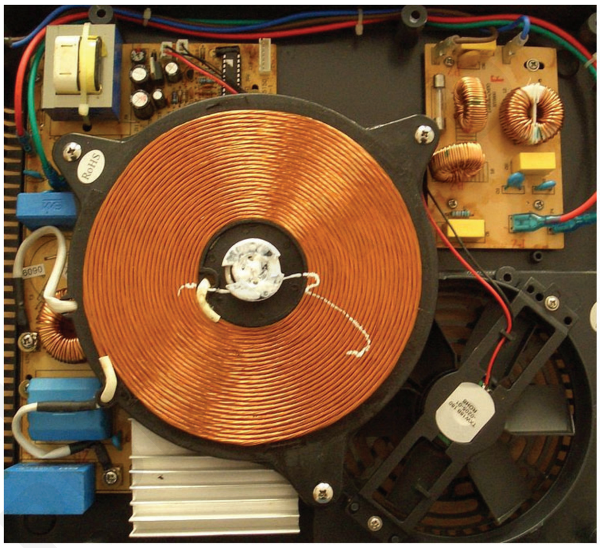
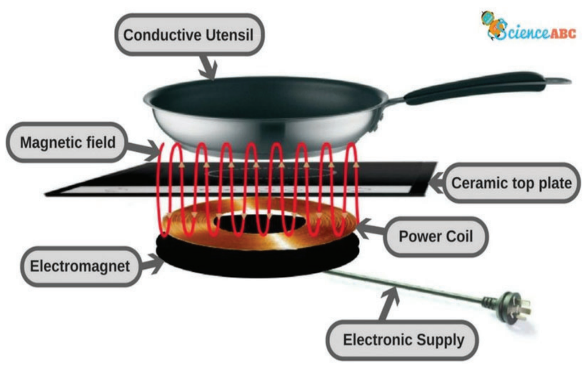


Fig 3



When a heater pan (made of a suitable material) is placed on the cooktop, the magnetic field produced by the coil penetrates the metal of the pan too. This fluctuating magnetic field now causes an electric current to flow through the material of the pan too. The current 'induced' on the surface of the pan in this way is called an eddy current, which is different from the electric current flowing through wires. Eddy currents are actually loops of electric current that are induced in a metallic field due to a changing magnetic field nearby.

This induced current travels around the metallic structure of the pan, dissipating some of its energy in the form of heat. This is the heat that raises the temperature of the pan placed on the cooktop and cooks the food inside the pan by heat transfer through conduction and convection.

Advantages and disadvantages of induction heater

1 Induction heaters are very energy-efficient, in that they transfer most of the energy to the cooking pan with minimal loss of energy. (Fig 4)

2 Also, induction cooktops heat stuff up very quickly, unlike regular stoves, which lose a great deal of energy to their surroundings.

3 They are also pretty easy to clean and operate and safe to use.

Fig 4

Disadvantages

A major drawback of induction heater is that they only work with pans and pots that are 'compatible' with them. The containers and vessels placed on the cooktop should contain iron in some form (e.g., stainless steel), as it's the only metal that efficiently produces eddy currents and generates heat through magnetic fields. Therefore, glass, aluminium and copper cookware cannot be used on induction heater.

In a nutshell, using an induction heater is a smart thing to do if you care about electrical efficiency, speedy heating, better cooking control and higher levels of safety. As for the suitability of your existing cookware for induction cooktops, just try sticking a magnet to them. If it sticks, then the pan/pot is fit to be used.

Food Mixer

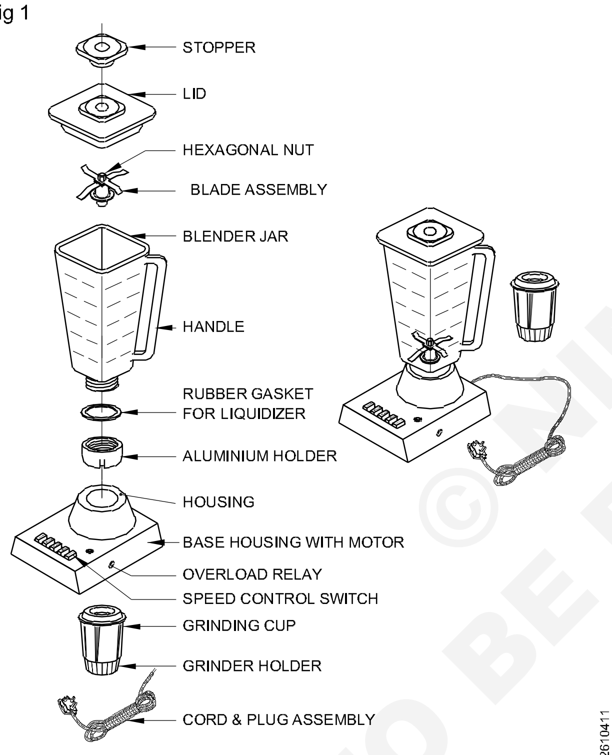
Objectives: At the end of this lesson you shall be able to
- **explain the food mixer and its features**
- **state the maintenance and service procedures of mixer**
- **list their common problems, causes and suggest remedial measures.**

Food mixer

It is an electric domestic appliance which is used to mix, juice, grind and blend the fruits and food grains.

A medium sized universal motor is used in it. Fig 1 shows an exploded view of a mixer.

Fig 1



EXPLODED VIEW OF A FOOD MIXER

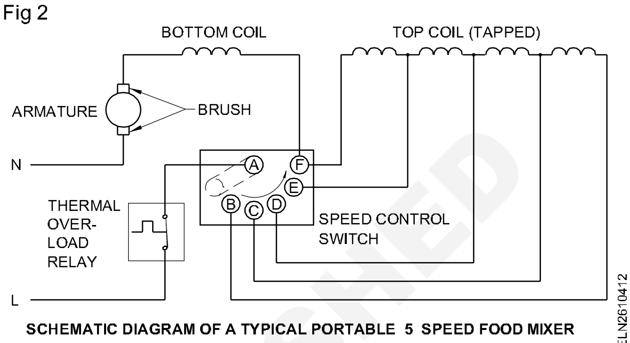
Features of the food mixer

The motor housing differs widely depending on the manufacturer. Special care to be taken for vibration-free running. Safety features such as overload trip, jar mounting lock (fixing) and proper lid closing are included in the appliances.

An AC universal motor is housed in the base. The jar contains the cutting knives which is the heart of the blending action. Fig 2 shows a schematic diagram of a typical mixer.

A food mixer power rating ranges from 100 to 750 watts. The revolution of the food mixer is 3000 to 14000 revolutions per min. The desired speed is selected on the control switch.

Fig 2



SCHEMATIC DIAGRAM OF A TYPICAL PORTABLE 5 SPEED FOOD MIXER

The time rating of running the mixer varies from 1 minute to 60 minutes depending upon the type. A tapped field coil enables speed selection through a rotary or push button switch.The food mixer normally runs at 3 speeds.

Maintenance and servicing of a food mixer: The manufacturer's service manual, if available, read it a number of times and follow the instruction. First listen to the complaint from the customer and make a note of it. Visually check the mixer right from the plug to the speed selector switch connections and enter the details in the maintenance card.

Test the mixer with and without the power cord for the continuity and insulation resistance. The insulation resistance value for the individual part should not be less than 1 Megohm. the power cord should be 3-core and the plug and socket should be of 3-pin/socket type with effective earth.

But double insulated (PVC body) mixers may have two core cable and 2-pin plug type. A damaged plug or power cord should be replaced. Check the brush tension and make it normal. Check the brush length; if found short by 2/3rd of its original length, replace it with the same specification brush or a brush obtained from the manufacturer of the mixer.

Check the switch for its proper function. Better to replace a faulty one with a new one having the same specification. Before opening the motor assembly, check the couplings for their proper form. Check the ply of the shaft and vertical movement to get an idea of the condition of the bearings.

Tight bearing may be due to misalignment, bend in the shaft, dried grease or lubricant, dirt, damaged commutator or due to damaged bearing.

Check the winding for burnt smell or discoloured look. Ascertain through the tests whether the winding is shorted, open or has lost its insulation resistance value. If required rewind or get the rewinding done from outside agencies.

While tightening the screws on the motor housing, spin the armature with your fingers at intervals during the assembling process to ensure that it is not getting bound.

Fix the jar/container on the drive coupling.

Connect the supply cord as per the circuit diagram.

Test the mixer for continuity and insulation resistance. Minimum acceptable insulation resistance value is 1 Megohm.

Connect the supply, and test for its working.

Repairs

Some of the common troubles encountered in the repair of mixers are given in the Table 1 which also gives the possible causes and their remedies.

Table 1

Trouble Shooting Chart

Problem	Possible cause	Corrective action
Mixer does not run.	a) Overload trip might have tripped.	a) Reset the overload relay and advice the customer not to overload the mixer in future.
	b) No power at the outlet.	b) If the mixer is running in your shop but not running at the customer's house ask the customer to get the socket repaired.
	c) Defective power cord or plug.	c) Test, repair or replace the power cord/plug.
	d) Locked shaft.	d) Unplug the supply and try to rotate the shaft by hand. Clean the bearings; lubricate the bearings as advised by the manufacturer. If the shaft is still tight, recondition or replace the bearings. The shaft might have got bent. Replace the shaft or armature assembly.
	e) Worn out brushes.	e) Replace the brushes and loose springs
	f) Open circuited.	f) Check the field and armature windings. If found defective get it rewound or replace.
Blows fuse when switched on.	a) Shorted power cord.	a) Replace the cord.
	b) Locked shaft.	b) As in 'd' above.
	c) Defective armature or field coils.	c) Test the windings for short. If short is found, rewind or replace.
	d) Poor insulation resistance.	d) Check, test and repair.
	e) Low capacity fuse.	e) Check the capacity of the fuse against the mixer rating. Replace if required.
Mixer runs but becomes hot.	a) Overloading of mixer.	a) Bring down the load in the mixer or advise the customer to go for a higher capacity mixer.
	b) Time rating of mixer is exceeded.	b) Check the duration the mixer is switched on by the customer and compare with the mixer rating. Advise accordingly.
	c) Bent shaft and rotor is rubbing the stator.	c) Check, repair or replace if required.
	d) Improper coupling.	d) Check, repair or replace if required.
	e) Shorted winding.	e) Check, test and rewind if required.
Bad sparking at motor brushes.	a) Struck or worn out or loose brushes.	a) Check, reshape the brushes, replace the springs or reposition the brushes for proper tension.
	b) Pittings or uneven commutator surface.	b) Use sand paper or turn the commutator on a lathe.

Problem	Possible cause	Corrective action
Mixer gives shock.	a) Water leaking and coming in contact with live terminals. (Double insulated mixers with plastic body and two pin plug. No earth connection).	a) Check the drain hole in the coupler head assembly for blockage. Check the jar examine for leakage due to loose shaft or worn out bearing, ebonite washer breakage. Repair or replace.
	b) Vent hole in the mixer body clogged.	b) Clean the vent hole.
	c) Damaged power cord.	c) Check and replace if required.
	d) Absence of earth connection.	d) Check the earth connection in the mixer motor, power cord and at socket. Repair and re-do the earth connection if required.
	e) Live parts coming in contact with metal body.	e) Check with a Megger and take corrective action if required.

Wet grinder

Objectives: At the end of this lesson you shall be able to
- **explain the wet grinder**
- **state the different types of wet grinders**
- **explain the parts of a wet grinder**
- **explain the possible faults in wet grinders and their remedies.**

Wet grinder

It is a domestic electrical appliance, which is used to grind the wet grains.

Types: There are three types of wet grinders

– Conventional (regular) wet grinder.

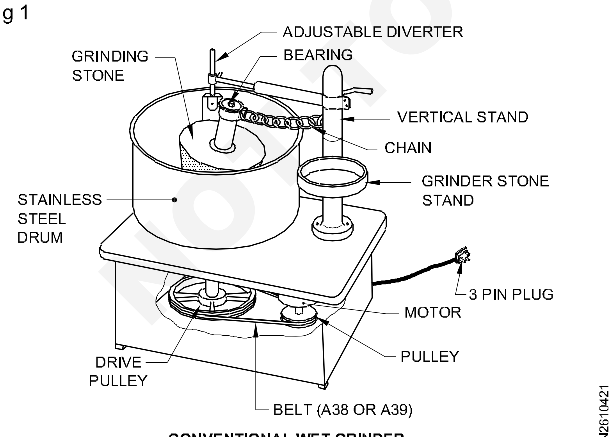
– Table top wet grinder.

– Tilting wet grinder.

Conventional (regular) wet grinder (Fig 1)

The most common wet grinder used in houses is the container rotating type wet grinder.

Fig 1



CONVENTIONAL WET GRINDER

Parts

The important parts of a wet grinder are :

– Motor

– grinding stone

– container

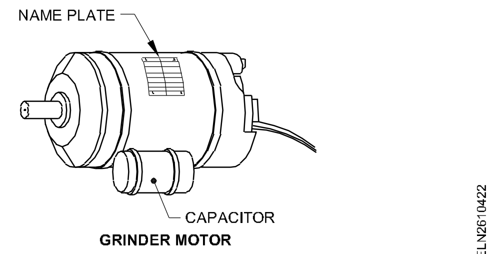
– pulley

– belt

– frame and stand

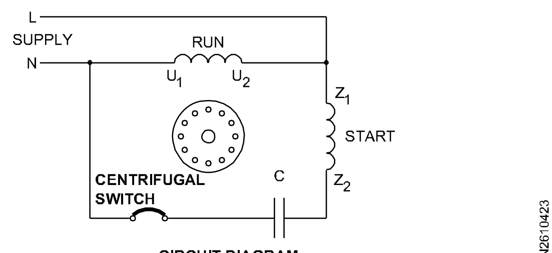
Motor: The motor used in the wet grinders is usually the capacitor start-induction motor (Fig 2 & 3). It has two windings. Both the starting and running windings are energised to start the motor, when the 70 to 80 % of the rated speed is reached, the starting winding is switched off by the centrifugal switching system. The motor then operates only on running winding.

Fig 2



GRINDER MOTOR

Fig 3

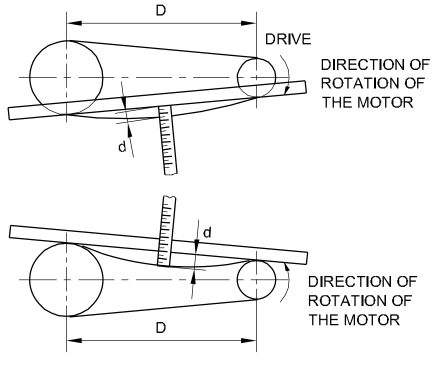


CIRCUIT DIAGRAM

Stone: The grinder stone consists of two parts of stones. One male and one female. The male part grinds the grains during rotation against conical cavity in the base (female stone). This female part is actually attached to the stainless steel container which rotates when the motor is energised. Both the stones are manufactured with hard granite which is usually whitish black in colour.

Pulley: The drum speed is lower than the motor speed, normally 500 to 600 r.p.m. The motor speed is normally 1450 r.p.m. and the speed of the drum is reduced by using a larger diameter pulley than the driven pulley, usually in the ratio of 1:3. The transmission of force between the driver pulley and the driven pulley is through a V belt of type No A 36 or A 39 (Fig 4).

Fig 4



ARRANGEMENTS OF PULLEY AND BELT

Frame and stand: The grinding stones, motor pulleys are all housed in a rectangular frame with sunmica or stainless steel covering or plastic moulding for decoration as well as safety. A separate vertical stand is provided on one side of the grinder for holding the male grinding stone. If the MS frame is used, it is usually to be chromium plated.

Wet grinder- maintenance and servicing: In wet grinders, the trouble may be classified into two types. Electrical faults and Mechanical faults. Some mechanical faults create electrical faults too.

Some common problems and their rectifications are given in the Table 1.

Safety measures

- Make sure power is turned off before working on electrical equipment.
- Plug to be removed from the socket.

Maintenance practices: An electrical machine or appliance to be maintained according to the programme already made. Certain maintenance practices to be observed are,

– Daily maintenance

– Monthly maintenance

– Yearly maintenance

Table 1

Sl.No.	Complaints	Causes	Test and remedy
1	Motor does not start	Short-circuited windings. Grounded winding. Open circuited windings. Broken wire from line cord to windings. Defective capacitor. Blown fuse. Excessive load. Defective centrifugal switch.	Rewind the windings. Rectify or rewind the windings. Solder the joints; if not possible rewind the windings. Solder the broken wire in the line cord or change the line cord. Replace the correct capacitor. Find the cause and replace the fuse. Reduce the load. Rectify or replace the defective switch.
2	Motor starts but heats up rapidly	Centrifugal switch not opening. Short-circuited winding. Grounded winding.	Rectify or replace the centrifugal switch. Rewind the windings. Rectify or rewind the windings.
3	Motor runs too hot	Short circuited windings. Grounded winding. Bearing too tight. Short capacitor. Worn out bearings.	Rewind the windings. Rectify or rewind the windings. Clean and relubricate the bearing. Replace the capacitor. Replace the bearings.
4	Motor runs slow.	Insufficient lubrication or foul lubrication that tends to bind the motor shaft.	Clean and re-lubricate the bearing.
5	Motor runs intermittently	Intermittently open line cord.	Repair or replace the line cord.

6	Motor is noisy	Worn out bearings. Excessive end play. Bent shaft. Unbalanced rotor. Burrs on shaft. Loose parts. Worn out belts. Misalignment. Worn out centrifugal switch. Rotor rubs stator.	Clean and lubricate or replace the bearings. If necessary, add additional end play washers. Straighten or replace the shaft. Balance rotor. Remove burrs. Tighten the parts. Replace the belts . Align pulleys correctly. Replace centrifugal switch. Find the cause and rectify.
7	The user gets a shock	Contact between live parts and body of the motor. Broken ground strap. Poor ground connection.	Rectify isolation between body and the live parts of the motor. Replace ground strap. Inspect and repair ground connection.
8	Motor fuse blows	Grounded or short-circuited windings. Low capacity of fuses Grounded near the switch end of the winding.	Rectify or rewind the windings. Replace with proper capacity of fuses. Repair or rewind the winding.
9	Smoke from motor (motor burnt out)	Overload. Shorter windings. Faulty centrifugal switch. Frozen bearing. Short capacitor.	Reduce the load. Rewind the windings. Repair or replace the centrifugal switch. Clean and lubricate or replace the bearing. Replace the capacitor.
10	Rotor rubs stator	Dirt in motor. Burrs on rotor or stator. Worn out bearings. Bent shaft.	Clean the motor. Remove burrs. Replace the bearing. Straighten or replace the shaft.
11	Excessive bearing wear	Belt too tight tension Dirty bearings Insufficient lubrication Thrust over load Bent shaft	Correct the mechanical condition. Clean and lubricate or replace the bearing Lubricate with appropriate lubricant. Reduce thrust load Straighten or replace the shaft.
12	Motor does not start but will run in either direction when started manually	Defective capacitor. Contacts of centrifugal switch not closed. Starting winding open.	Replace the capacitor. Clean the contacts of the centrifugal switch and check for operation. Replace, if found defective. Solder the open joints or rewind the winding.
13	Motor slows down and runs with insufficient power under working condition.	Short circuited windings. Open circuited windings. Shaft bent.	Rewind the windings. Solder the joints; if not possible, rewind the windings. Straighten or replace the shaft.
14	Reduction in power of the motor. Gets too hot	Short-circuited or grounded windings. Sticky or tight bearings Interference between stator and rotor.	Rectify or rewind the windings. Clean and re-lubricate the bearings. Install new bearings.
15	Radio interference	Faulty ground Loose connections Defective suppression	Rectify poor ground connections. Tighten loose connections. Check filter, capacitors, chokes, if possible or replace the complete filter unit.

Daily maintenance: The parts are to be cleaned with cloth and the stone bearing is to be oiled. Inspect the belt tension and vibration.

Monthly maintenance: Oil and grease the main shaft of the grinder. Insulation test is to be carried out and recorded in the sheet provided.

Yearly maintenance: The electrical machine must be removed and overhauled. Insulate the winding by applying varnish. Check all the mechanical parts and rectify the defects, if any.

Transformer - Principle - Classification - EMF Equation

Objectives: At the end of this lesson you shall be able to
- **explain a transformer**
- **explain the construction of two winding transformer.**

Transformer

Transformer is a static electric device which transfer the electric energy from one circuit to other without changing the frequency and power.

The three-phase synchronous generator is used extensively to generate bulk power. The voltage levels at which this power is generated is typically in the range 11 kV to 22 kV. Electrical power is to be provided at a considerable distance from a generating station. It is possible to transmit the generated power directly but this results in unacceptable power losses and voltage drops.

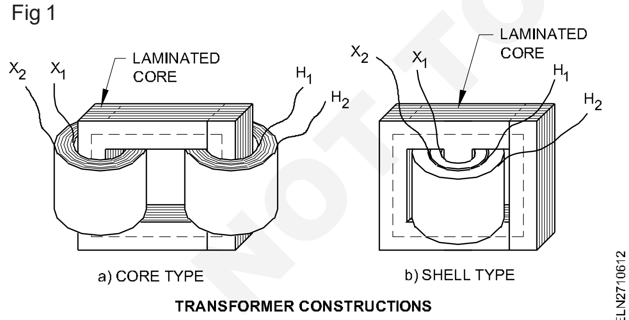
Transmission voltages vary up to the 400 kV level. This is made possible by power transformers. At the receiving end this high voltage must be reduced because ultimately it must supply three phase load at 415V or single phase load at 240V.

The transformer makes it possible for various parts of a power system to operate at different voltage levels.

> **Standard safety norms: Trainees can be instructed to refer the standard safety norms related with transformer in the International Electrotechnical commission (IEC - 60076-1) for the further details.**

Construction: There are basically two types of iron-core construction. Fig 1a shows a **core type** transformer. It consists of two separate coils, one on each of the two opposite legs of a rectangular core.

Fig 1



TRANSFORMER CONSTRUCTIONS

Normally, this is not a desirable design. Its disadvantage is the large leakage fluxes associated with it. The large leakage fluxes cause poor voltage regulation. Therefore, to ensure that most of the flux set by the primary will link the secondary, the construction Fig 1b is employed. This is called **shell type** construction.

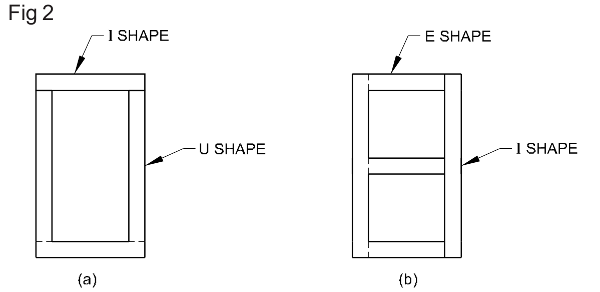
Here the two windings are wound concentrically. The higher voltage winding is wound on top of the lower voltage winding. The low-voltage winding is then located closer to the steel. This arrangement is preferable from an electrical insulating point of view. From the electrical viewpoint there is not much difference between the two constructions.

Cores may be built up of lamination silicon steel sheet. Most laminating materials have an approximate alloy content of 3% silicon and 97% iron. The silicon content reduces the magnetizing losses. Particularly, the loss due to hysteresis is reduced. The silicon makes the material brittle. The brittleness causes problems in stamping operation.

Most laminated materials are cold-rolled and often specially annealed to orient the grain or iron crystals. This provides very high permeability and low hysteresis to the flux in the direction of rolling. Transformer laminations are usually 0.25 to 0.27 mm thick for 50 Hz. operation. The laminations are coated on one side by a thin layer of varnish or paper to insulate them from each other.

Coils are pre-wound, and the core design must be such that it permits placing the coil on the core. Ofcourse, the core must then be made in atleast two sections. The laminations for the core-type transformer of Fig 1a may be made up of (L and ⅂) shaped laminations, as shown in Fig 2a. The core for the shell type transformer is normally made up of E and I shaped laminations (Fig 2b).

Fig 2



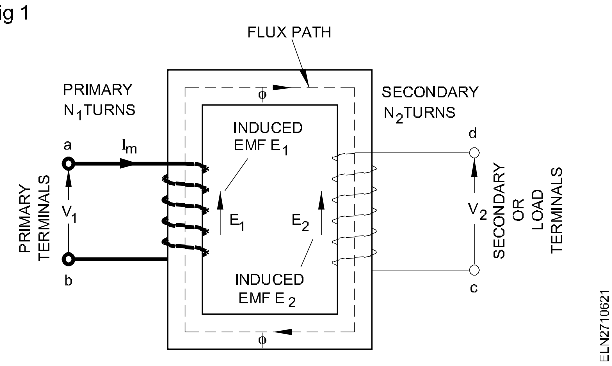
CORE CONSTRUCTION BUILT OF SEPARATE LAMINATIONS

Transformer principle

Objectives: At the end of this lesson you shall be able to
- **explain the principle of the operation of a transformer**
- **derive the EMFequation of a two-winding transformer**
- **derive the transformation ratio of a transformer.**

Let us consider an ideal transformer (Fig 1) whose secondary is open and whose primary is connected to a sinusoidal voltage V_1.

Fig 1



Working principle

The transformers work on the principle of mutual induction of Faraday's law of electro - magenetic induction.

The applied voltage causes a small current to flow in the primary winding. This no-load current is meant to build up a counter-electromotive force equal and opposite to the applied voltage.

Since the primary winding is purely inductive and there is no output, the primary draws the magnetizing current I_m only. The function of this current is merely to magnetise the core. The I_m is small in magnitude and lags V_1 by 90°. This alternating current I_m produces an alternating flux φ which is proportional to the current and hence is in phase with it (I_m). This changing flux is linked with both the windings. Therefore, it produces self-induced EMF (E_1) in the primary which lags the flux 'φ' by 90°. This is shown in vector diagram Fig 2.

The flux 'ø' produced by the primary links with the secondary winding and induces an EMF (E_2) by mutual induction which lags behind the flux 'ø' by 90°Fig 2. As the EMF induced in primary or secondary per turn is same the secondary EMFwill depend on the number of turns of the secondary.

When secondary is open circuit, its terminal voltage 'V_2' is the same as the induced EMF (E_2). On the other hand, the primary current at no load is very small, hence the applied voltage 'V_1' is practically equal and opposite to the primary induced EMF (E_1). The relationship between primary and secondary voltages Fig 2.

Hence we can say that

$$\frac{\textit{Total}\text{ emf indued in seconday' }E_2}{\textit{Total}\text{ emf induced in primary' }E_1\text{'}}$$

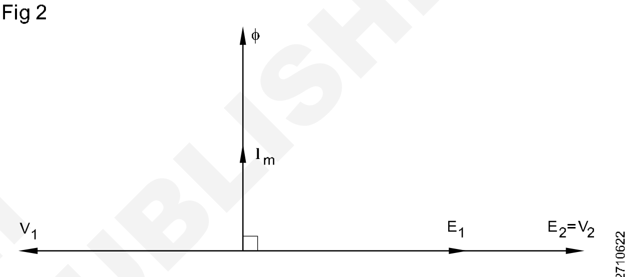
$$=\frac{N_2\times\text{emf per turn}}{N_1\ \text{xemf per turn}}\qquad \text{OR}$$

$$\frac{E_2}{E_1}=\frac{N_2}{N_1}$$

$$as\ E_1 = V_1 \text{ and } E_2 = V_2$$

$$\text{We have } \frac{V_2}{V_1}=\frac{N_2}{N_1}$$

Fig 2



VECTOR DIAGRAM OF AN IDEAL TRANSFORMER

Ideal Transformer on Load: When the secondary is connected to a load, secondary current flows this in turn makes the primary current to increase. How this happens is explained below.

The relationship between primary and secondary currents is based upon a comparison of the primary and secondary ampere turns.

When the secondary is open circuit, the primary current is such that the primary ampere turns are just sufficient to produce the flux 'ø' necessary to induce an EMF (E_1) that is practically equal and opposite to the applied voltage 'V_1'. The magnetising current is usually about 2 to 5 percent of the full load primary current.

When a load is connected across the secondary terminals, the secondary current - by **Lenz's law** - produces demagnetising effect. Consequently the flux and the EMFinduced in the primary are reduced slightly.

But this small change may increase the difference between applied voltage 'V_1' and the induced EMF (E_1) by say 1 percent in which case the new primary current would be 20 times the no load current.

The demagnetising ampere turns of the secondary are thus nearly neutralized by the increase in the primary ampere turns and since the primary ampere turns on no load are very small compared with the full load ampere turns.

Therefore Full load primary ampere turns $\simeq$ full load secondary ampere turns i.e $I_1N_1 \simeq I_2N_2$

so that $\frac{I_1}{I_2} \simeq \frac{N_2}{N_1} \simeq \frac{V_2}{V_1}$ **Transformation ratio**

From the above statement, it is clear that the magnetic flux forms the connecting link between the primary and secondary circuits and that any variation of the secondary current is accompanied by a small variation of the flux and therefore of the EMFinduced in the primary, thereby enabling the primary current to vary approximately, proportional to the secondary current.

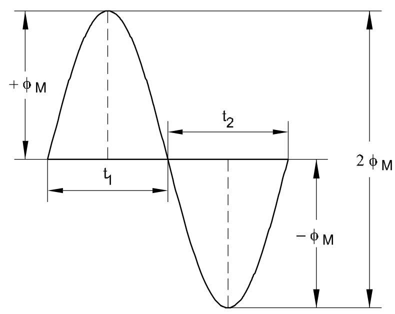
EMF equation of a transformer: Since the magnetic flux set up by the primary winding links the secondary winding, an EMF will be an induced E_2, in the secondary, in accordance with Faraday's law, namely, $E = N\,(\delta ø/\delta t)$. The same flux also links the primary itself, inducing in it an emf, E_1. The induced voltage must lag the flux by 90°, therefore, they are 180° out of phase with the applied voltage V_1.

Since there is no current in the secondary winding, $E_2 = V_2$. The primary voltage and the resulting flux are sinusoidal; thus the induced quantities E_1 and E_2 vary as a sine function. The average value of the induced voltage is given by

$$E_{avg} = \text{turns} \times \frac{\text{change in flux in a given time}}{\text{given time}} \quad ...(1)$$

Referring to Fig 3, it is seen that the flux change in time interval t_1 to t_2 is $2\phi_m$ where ϕ_m is the maximum value of the flux, in webers. The time interval represents the time in which this flux change occurs and equals one-half cycle of ($\frac{1}{2f}$) seconds, where f is the supply frequency, in hertz.

Fig 3



SINUSOIDAL FLUX WAVE IN CORE

It follows that

$$E_{avg} = N \times \frac{2\phi_m}{\frac{1}{2f}} = 4fN\phi_m \quad ...(2)$$

where N is the number of turns on the winding.

The effective or rms voltage for a sine wave is 1.11 times the average voltage, thus

$$E = 4.44\ f\ N\phi_m \quad ...(3)$$

Since the flux links with the primary and secondary windings, the voltage per turn in each winding is the same. Hence

$$E_1 = 4.44\ f\ N_1\phi_m \quad ...(4)$$

and

$$E_2 = 4.44\ f\ N_2\phi_m \quad ...(5)$$

where N_1 and N_2 are the number of turns in the primary and secondary windings respectively.

Transformer - simple calculations

Objective: At the end of this lesson you shall be able to
- **explain rating of transformer**
- **calculate the voltage, current and turns of primary from the secondary data and vice versa.**

Rating of transformer

The capacity of the transformers are always rated by its apparent power (volt amp - VA (or KVA), not by its true power (watt (or) KW) (ie.) KW = KVA x Cosϕ .

Example 1: A 100 KVA 2400/240V, 50 Hz. transformer has 300 turns on the secondary winding. Calculate (a) the approximate value of primary and secondary currents (b) the number of primary turns and (c) the maximum flux ϕ_m in the core.

Data given : Transformer rating 100 KVA

Frequency f = 50 Hz

Primary voltage V_P = 2400 V

Secondary voltage V_S = 240 V

Secondary turns N_S = 300

Known: E_P = ($4.44 \times f \times N_P \times \phi_m$) volts

$$\frac{V_P}{V_S} = \frac{I_S}{I_P} \cong \frac{E_P}{E_S} \cong \frac{N_P}{N_S}$$

$$V_P I_P = V_S I_S = KVA$$

Find: Primary current I_P

Secondary current I_P

Primary turns N_P

Maximum flux Φ_m

Solution

(a) $I_P \text{ (full load)} = \dfrac{KVA \times 1000}{V_p} = \dfrac{100000}{2400} = 41.7A$

and $I_S = \dfrac{100000}{240} = 417A$

(b) $\dfrac{V_P}{V_S} = \dfrac{2400}{240} = 10 = \dfrac{N_P}{N_S}$

Therefore, $N_P = 10 \times N_S$

$= 10 \times 300 = 3000$ turns.

(c) $4.44 \times f \times N_P \times \phi_m = E_P$

$$\Phi_m = \frac{2400}{4.44 \times 50 \times 3000} = 0.0036 \text{ Wb.}$$

Classification of transformers

Objectives : At the end of this exercise you shall be able to

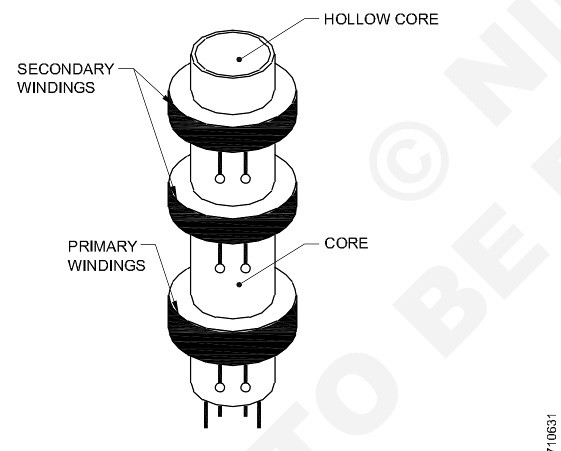
- **state the classification of transformers based on various factors.**

Classification of Transformers

1 Classification based on the type of Core Material used

- **Air core transformers** : Fig 1, air core transformers consists of a hollow non magnetic core, made of paper or plastic over which the primary and secondary windings are wound. These transformers will have values of k less than 1. Air core transformers are generally used in high frequency applications because these will have no iron-loss as there is no magnetic core material.

Fig 1



AIR CORE TRANSFORMER

2 Classification based on the shape of core

- **Core type transformers**: In Core type of transformer, the primary and secondary windings are on two separate sections/limb of core. (Fig 1 in chart 1)
- **Shell type transformers**: In this type, both the primary and the secondary windings are wound on the same section/limb of the core.These are widely used as voltage and power transformers. (Fig 2 in chart 1)
- **Ring type transformers**: In this, the core is made up of circular or semicircular laminations (Fig 3). These are stacked and clamped together to form a ring. The primary and secondary windings are then wound on the ring. The disadvantage of this type of construction is the difficulty involved in winding the primary and secondary coils. Ring type transformers are generally used as instrument transformers for measurement of high voltage and current.

3 Classification based on the Transformation ratio

- **Step-up Transformers**: Transformers in which, the induced secondary voltage is higher than the source voltage given at primary are called step-up transformers.
- **Step-down Transformers**: Transformers in which, the induced secondary voltage is lower than the source voltage given at primary are called step-down transformers.
- **Isolation transformers**: Transformers in which, the induced secondary voltage is same as that of the source voltage given at primary are called one-to-one or isolation transformers. In these transformers the number of turns in the secondary will be equal to the number of turns in the primary making the turns ratio equal to 1.

4 Single phase and three phase transformers

Transformers Fig 4 of Chart 1 are designed for use with single phase AC mains supply. Such transformers are known as single phase transformers. Transformers are also available for 3 phase AC mains supply. These are known as poly-phase transformers. Refer Fig 5 in Chart 1. Three phase transformers are used in electrical distribution and for industrial applications.

5 Classification based on application

Transformers can also be classified depending upon their application for a specialized work. There are innumerable number of applications, However a few of these are listed below:

Instrument Transformers - used in clip - on current meters, overload trip circuits etc.,

Constant voltage transformers - used to obtain stabilized voltage supply for sensitive equipments

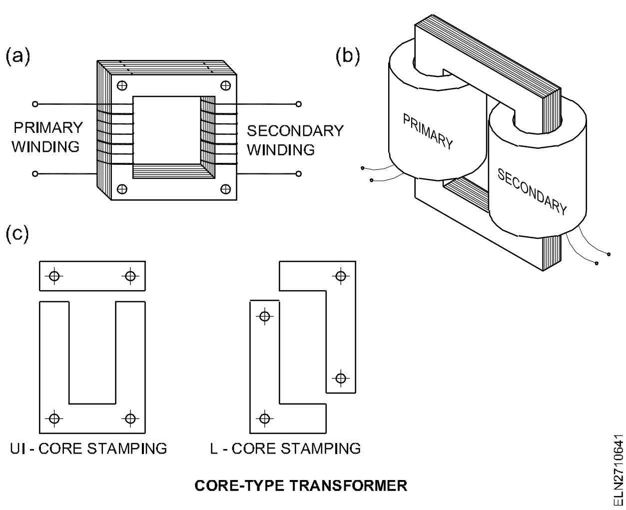
Ignition transformers - used in automobiles

Welding transformers - used in welding equipments

Dry Type Transfomers : Dry type, or air-cooled, transformers are commonly used for indoor applications where other transformer types are considered too risky.

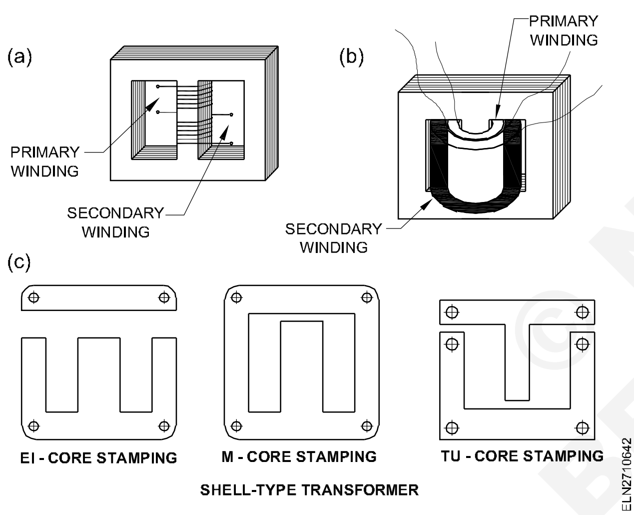
Chart - 1
Types of transformers

Fig 1 **CORE - TYPE TRANSFORMER**



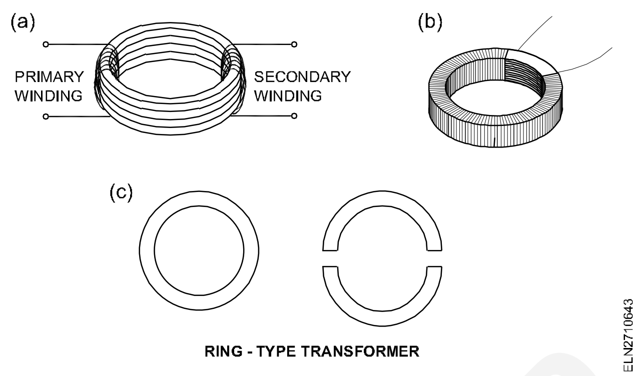
CORE-TYPE TRANSFORMER

Fig 2 **SHELL - TYPE TRANSFORMER**



SHELL-TYPE TRANSFORMER

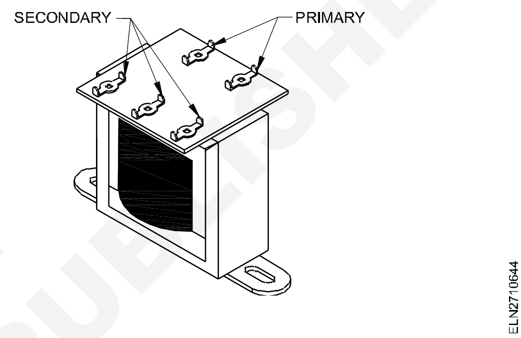
Fig 3 **RING - TYPE TRANSFORMER**



RING - TYPE TRANSFORMER

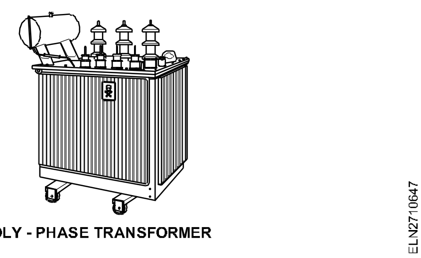
SINGLE PHASE TRANSFORMER

Fig 4



POLY - PHASE TRANSFORMER

Fig 5



POLY - PHASE TRANSFORMER

Parts and their functions of transformer

Objectives: At the end of this lesson you shall be able to
- **list out the mainparts of transformer**
- **explain the parts of a distribution transformer.**

Distribution transformer: Fig 1 shows the essential parts of a distribution transformer.

The important components of a distribution transformer are briefly described below:-

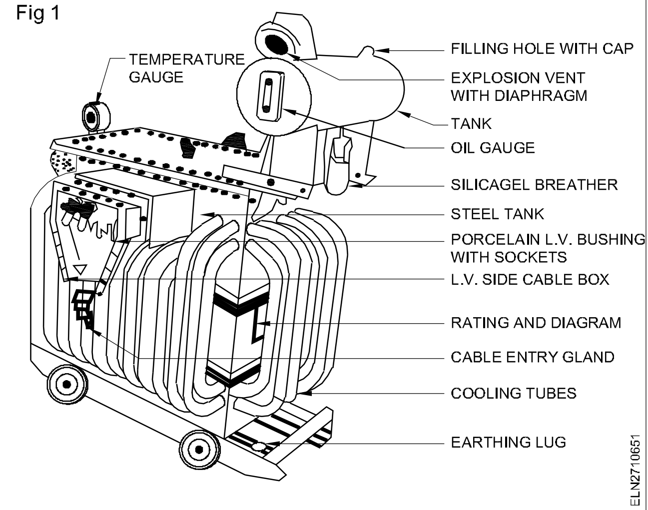
The important components of transformer are : -

1 Steel tank
2 Conservation tank
3 Temperature gauge
4 Explosion vent
5 Cooling tubes
6 Tap changer
7 Bushing termination
8 Silical gel breather
9 Buchholz relay

1 Steel tank

It is a fabricated M.S plate tank used for housing the core, winding and for mounting various accessories required for the operation of a transformer. Core is built from cold rolled grain oriented silicon steel lamination. The L.V winding is normally close to the core and the H.V winding is kept around the L.V winding.

Fig 1



2 Conservator tank

It is in the shape of a drum, mounted on the top of the transformer. An oil level indicator is fitted to the conservator tank. Conservator is connected to the transformer tank through a pipe. The conservator carries the transformer oil to a specified level. When transformer is heated up due to normal load operation, the oil expands and the level of oil in conservator tank is increased or vice versa. A pipe connected to the top of the conservator tank allows the internal air to go out or get in through the breather.

It reduces the oxidation of oil when it get contact with air.

3 Temperature gauge

It is fitted to the transformer which indicates the temperature of the transformer oil.

4 Cooling tubes

In earlier discussions, we found that the transformer is heated up, when the transformer is connected to the supply is due to iron loss and copper loss. To keep down the temperature of the windings, when the transformer is put on load, the heat generated inside the transformer should be radiated to the atmosphere. To dissipate the heat produced inside the winding and core, the transformer tank is filled with an insulating oil. The oil carries the heat to the cooling pipes where the heat is dissipated to atmosphere due to surface contact with air.

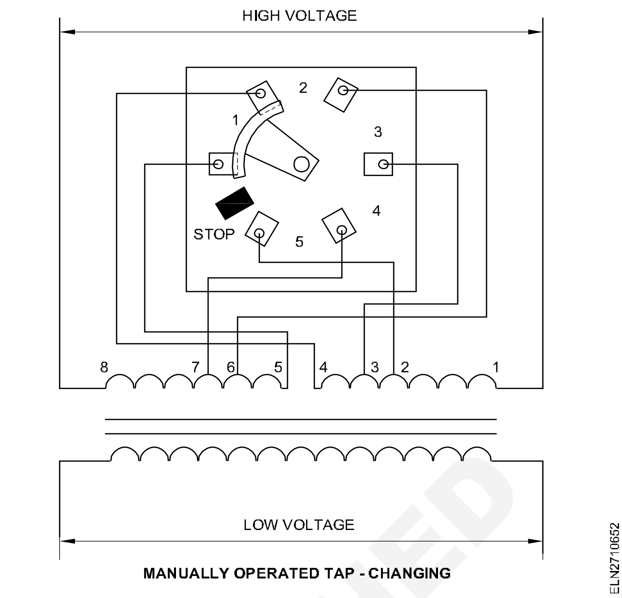
5 Tap changer

When voltages are transmitted over long distances there will be voltage drop in the conductors, resulting in lower voltage at the receiving end. To compensate this line voltage drops in the conductors, it is customary to increase the sending end voltage by tap changing transformers. These transformers may have several winding taps in their primary winding (Fig 2).

6 Porcelain bushing of transformer

This type of Transformer Bushings are used in several power industries for their robustness and they are also very cheap. Porcelain offers very good and reliable electrical insulation for a wide range of voltages as well as they have high dielectric strength too.

Fig 2



A porcelain bushing is a hollow cylindrical shaped arrangement made by porcelain discs which is fitted to the top portion of the transformer. And the energised conductors are passed through the centre portion of the bushings.

After inserting the conductor, the ends of the porcelain bushings are tightly sealed with glaze and this arrangement ensures a prevention from any type of moisture.

The entire bushing arrangement is checked and it should not contain any leakage paths. If the operating voltage level is very high then the vacuum space of the Transformer Bushing is filled with insulating oil.

7 Protective - devices / parts of transformers:

1 Breather

Transformer oil deterioration takes place due to moisture. Moisture can appear in a transformer from three sources, viz. by leakage through gasket, by absorption from air in contact with the oil surface or by its formation within the transformer as a product of deterioration as insulation ages at high temperature.

The effect of moisture in oil is to reduce the di-electric strength, especially if loose fibres or dust particles are present.

Methods available to reduce oil contamination from moisture are:

- by the use of silica gel breather
- by the use of rubber diaphragm
- by using sealed conservator tank
- by using gas cushion
- by using thermosyphon filter

Silica gel breather

Silica gel breather is a protective device fitted to the conservator through a pipe and allows the moisture free air to and fro into the conservator when the transformer oil get heated and cools down.

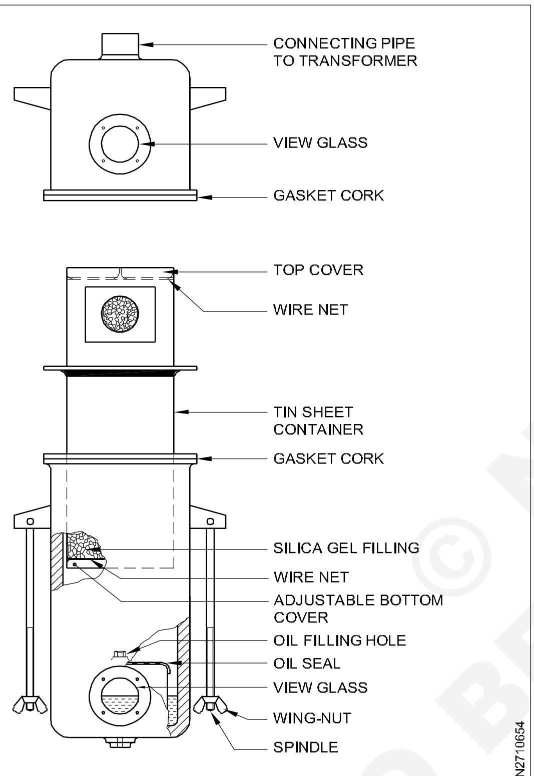
As the load and heat on a transformer reduces, air is drawn in to the conservator through a cartridge pakced with **silica gel crystals**.

The silica gel effectively dries the air and thus prevent the moistured dust entering into transformer oil. The fresh silica gel is available in blue colour. The colour of the silica gel changes to pure white or light pink colour as it absorbs moisture from air.

To recondition silica gel either it can be dried in sun or it could be dry roasted on a frying pan kept over a stove.Fig 3 & 4 show a cross-sectional view of such a silica gel breather.

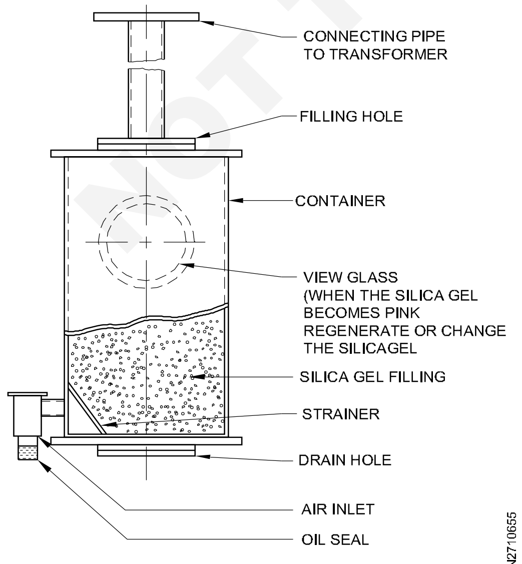
The oil seal at the bottom of the breather absorbs the dust particles that are present in the air entering the conservator.

Fig 3



SILICA GEL BREATHER

Fig 4



SILICAL GEL BREATHER

2 Buchholz relay

Buchholz relay is a gas operated - protective device which is connected between the transformer oil tank and the conservator tank.

If a fault is present inside a transformer, it may be indicated by the presence of bubbles (gas) in the transformer oil. Presence of gas could be viewed from class in window of by the Buchholz relay.

The relay comprises of a cast iron chamber which have two floats Fig 5. Top float assembly operates during initial stages of gas/air bubble formation due to minor fault in the transformer.

When sufficient gas bubbles formed around the top float, the float operates in pneumatic pressure principle to close an electric circuit through mercury switch which causes the siren or alarm bell to operate to caution the operator.

On hearing the alarm sound the operator takes necessary preventive steps to safeguard the transformer.

If any major fault like earth, fault etc, occurs in the transformer then the production of gas bubbles are more severe and hence the bottom float activates the mercury switch and closes the relay contacts.

Closing of the bottom relay contacts trips the transformer circuit breaker and opens the transformer from main line to protect the transformer from further damage.

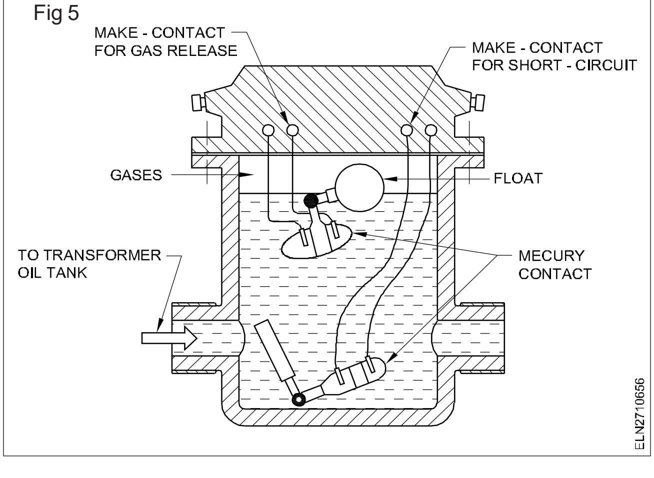
3 Explosion vent

It is a pressure release device fitted to the transformer. The mouth of the explosion pipe is tightly closed using either a thin glass or laminated sheet.

If, by any, chance the transformer is overheated either due to short circuited or sustained overload, the gases produced inside the transformer tank creates tremendous pressure which may damage the tank.

On the other hand the pressure built inside the transformer may break the glass/laminated diaphragm of the explosion pipe and thereby the tank can be saved from total damage.

Fig 5



Autotransformer - principle - construction - advantages - applications

Objectives: At the end of this lesson you shall be able to
- **state the principle of auto-transformer**
- **describe the construction of auto-transformer**
- **state the advantages, disadvantages and appliations of auto-transformer.**

Auto transformer

- The auto transformer is a transformer having single winding which acts as primary as well as secondary winding.
- The auto transformer works on the principle of self inductance of Faraday's Law of electro - magnetic induction.

The induced voltage per turn was the same in each and every turn linking with the common flux in the core.

Therefore, fundamentally it makes no difference in the operation whether the secondary induced voltage is obtained from a separate winding linked with the core, or from a portion of the primary turns. The same voltage transformation results in both the situations.

Construction

An ordinary two winding transformer may also be used as an auto-transformer by connecting the two windings in series and applying the voltage across the two, or merely to one of the windings.

It depends on whether it is desired to keep the voltage down or up, respectively.

Figs 1 and 2 show these connections.

Considering Fig 1, the input voltage V_1 is connected to the complete winding a - c and the load R_L is across a portion of the winding, that is, b - c. The voltage V_2 is related to V_1 as in a conventional two winding transformer, namely,

$$V_2 = V_1 \times \frac{N_{bc}}{N_{ac}}$$

Where N_{bc} and N_{ac} are the number of turns on the respective windings. The ratio of voltage transformation in an autotransformer is the same as that for an ordinary transformer.

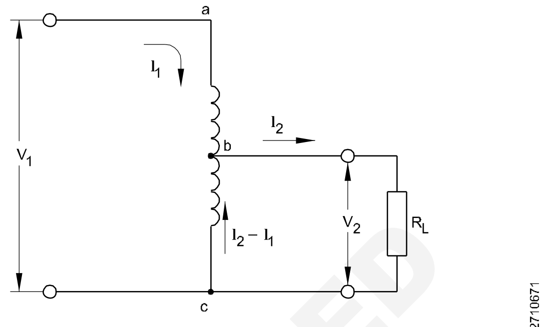
$$a = \frac{N_{bc}}{N_{ac}} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

with a < 1 for step down.

Advantages : Auto-transformers:

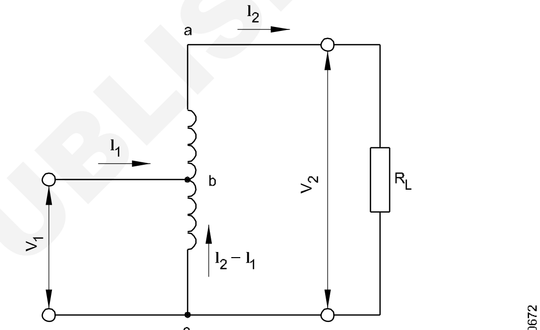
- less cost
- have better voltage regulation
- are smaller

Fig 1



AUTOTRANSFORMER STEP-DOWN

Fig 2



AUTOTRANSFORMER STEP-UP

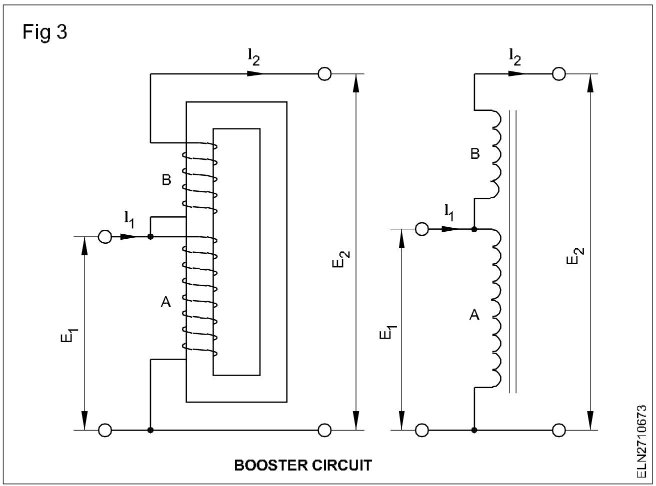
- are lighter in weight
- are more efficient when compared with two winding transformers of the same capacity.

Disadvantages: Auto-transformers have two disadvantages.

- An auto-transformer does not isolate the secondary from the primary circuit.
- If the common winding bc becomes open circuit, referring to Fig 1 or 2, the primary voltage can still feed the load. With a step-down auto-transformer this could result in burnt out secondary load and/or a serious shock hazard, particularly if the step down ratio is high.

Application: The common applications are:

- fluorescent lamps (where supply voltage is less than the rated voltage)
- reduced voltage motor starter
- series line boosters for fixed adjustment of line voltage (Fig 3)
- servo-line voltage correctors.



Instrument transformers - current transformer

Objectives: At the end of this lesson you shall be able to
- **state the necessity, types and principle of the instrument transformer**
- **explain the construction and connection of the current transformer**
- **state the precautions to be followed while using the current transformer.**

Necessity of instrument transformers: Transformers used in conjunction with measuring instruments for measurement purposes are called **'instrument transformers'**. the actual measurements are done by the measuring instruments only.

Where the current and voltage are very high, direct measurements are not possible as, these current and voltage are too large for reasonably sized instruments and the cost of the meter will be high.

The solution is to step-down the current and voltage with instrument transformers, so that, they could be metered with instruments of moderate size.

These instrument transformers electrically isolate the instruments and relays from high current/voltage lines thereby reducing danger to the men and equipment. To obtain perfect isolation, the secondary of the instrument transformers and the core should be grounded.

Type of instrument transformers: Three are two types of instrument transformers.

- Current transformer
- Potential transformer

The transformer used for measurement of high current is called 'current transformer' or simply 'CT'

the transformer used for high voltage measurement is called 'voltage transformer or potential transformer' or simply 'PT' in short.

Principle: Instrument transformers work on the principle of mutual induction similar to the two winding transformers.

In the case of an instrument transformer, the following design features are to be considered.

Core: In order to minimise the error, the magnetizing current must be kept low. This means the cores should have low reactance and low core losses.

Winding: The winding should be close together to reduce the secondary leakage reactance; otherwise the ratio error will increase. In the case of a current transformer the winding must be so designed as to withstand the large short circuit current without damage.

Current transformers - types of construction and connection

The following are the different types of current transformers.

Wound type current transformer: This is one in which the primary winding is having more than one full turn wound on the core (Fig 1)

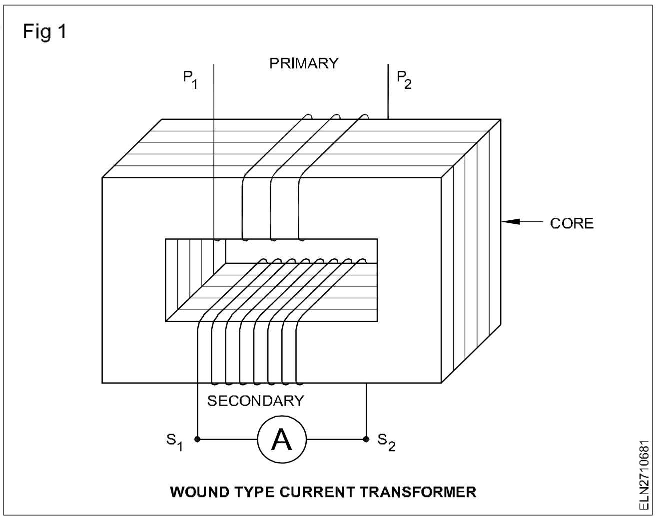


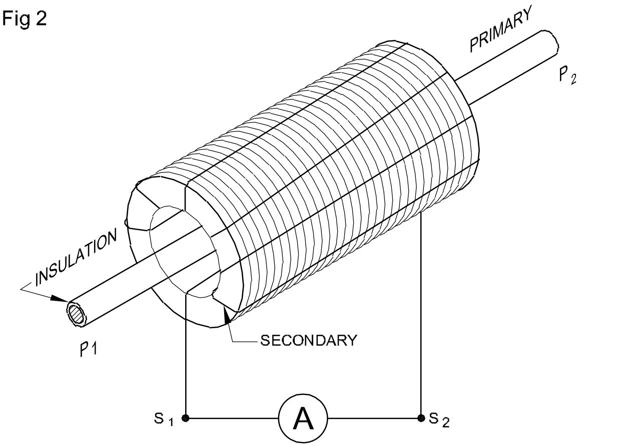
Fig 1 shows the connections of a wound type current transformer having a rectangular type of core. In general the ammeter is arranged to give full scale deflection with 5A or 1A when connected to the secondary of the current transformer.

The ratio between the primary and secondary turns of the current transformer decides the primary current which could be measured with fixed secondary current rating of 5 or 1 amp.

For example if the primary current is 100 amps and there are two turns in the primary, then the full load primary ampere turns is 200. Consequently, to circulate 5 amps in the secondary, the number of secondary turns must be 200/5, that is 40 turns.

Ring type current transformer: This has an opening in the centre to accommodate a primary winding through it Fig 2 shows a ring type current transformer with single turn primary. In this current transformer, the insulated conductor that carries the current to be measured passes directly through an opening in the transformer assembly.

Fig 2



RING TYPE CURRENT TRANSFORMER

If there are 20 turns in the secondary having a current range of 5 amps, this current transformer according to the transformation ratio, could measure a primary current of 100 amps.

Clamp on or clip on ammeters work on this principle only but the core is made such that it can open to pass the insulated conductor and then get closed to complete the magnetic circuit.

Bar type current transformer: This is one in which the primary winding consists of a bar of suitable size and secondary winding and core assembly material forming an integral part of the current transformer (Fig 3).

Dry type current transformer :This is one which does not require the use of any liquid or semi-liquid material for the purpose of cooling.

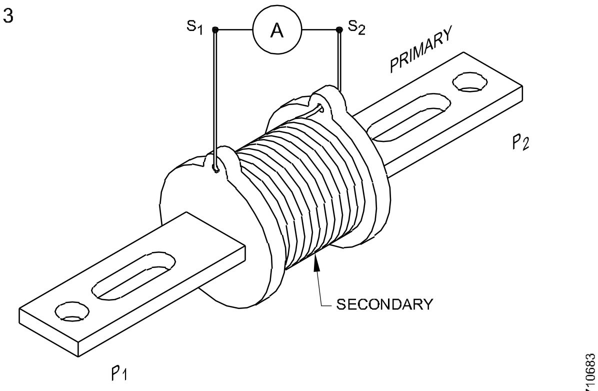
Oil immersed current transformer: This is one which requires the use of an oil of suitable characteristic as insulating and cooling medium.

General terms used

Accuracy class: Accuracy class is a designation assigned to a current transformer the errors of which remain within the specified limits under prescribed conditions of use. The standard accuracy classes for measuring current transformers shall be 0.1, 0.2, 0.5, 1.0, 3.0 and 5.0.

Precautions while using the current transformer : In a current transformer the secondary current depends upon the primary current. Futher the secondary of the current transformer could be assumed to be almost short circuited as the ammeter resistance is extremely low.

Fig 3



BAR TYPE CURRENT TRANSFORMER

In any case, the secondary winding of the current transformer should not be open circuited. This may happen when the ammeter become open circuited or when the ammeter is removed from the secondary.

In such cases the secondary should be short circuited. If the secondary is not short circuited, in the absence of secondary ampere-turns, the primary current will produce abnormally high flux in the core thereby heating up the core and resulting in burning out the transformer.

Further secondary will produce a high voltage across its open terminals endangering safety. In addition to earthing non-current carrying metal parts of the current transformer, we have to earth one end of the secondary of the current transformer to prevent a high static potential difference in case of open circuit. It also serves as a safeguard in case of insulation failure.

Specification of a current transformer: While purchasing a current transformer, the following specifications need to be checked.

- Rated voltage, type of supply and earthing conditions (for example, 7.2 kV, three phase, whether earthed through a resistor or solidly earthed).
- Insulation level
- Frequency
- Transformation ratio
- Rated output
- Class of accuracy
- Short time thermal current and its duration

Standard values of rated primary current: The standard values in amperes of rated frequency are 10, 15, 20, 30, 50, 75 amperes and their decimal multiples.

Standard values of rated secondary current: The standard values of rated secondary current shall be either 1 ampere or 5 amperes.

Potential transformer

Objectives: At the end of this lesson you shall be able to
- **explain the construction and connection of the potential transformer**
- **state specification of PT.**

Potential transformer

Construction and connection: The construction of a potential transformer is essentially the same as that of a power transformer. The main difference is that the volt-ampere rating of a potential transformer is very small.

To reduce the error in a potential transformer, it is required to provide a short magnetic path, good quality of core materials, low flux density and proper assembling and interlaying of cores.

To reduce resistance and leakage reactance, thick conductors are used and the two windings are kept as close as possible.

The core may be of shell or core type construction. Shell type construction is normally used for low voltage transformers.

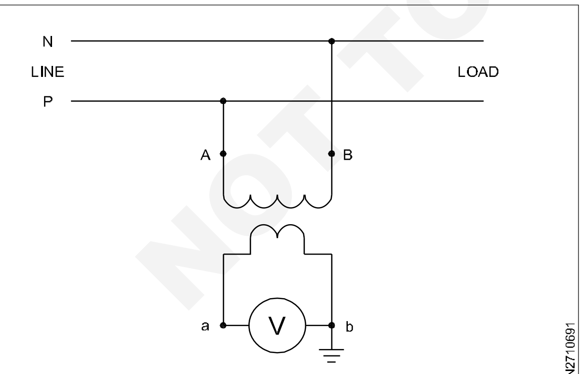
The primary and secondary windings are coaxial to reduce the leakage reactance to the minimum. In order to simplify the insulation problem, generally a low voltage winding (secondary) is put next to the core.

The primary winding may be of a single coil in the case of low voltage transformers but in the case of high voltage transformers the winding is divided into a number of short coils.

Fig 1 shows the connections of a potential transformer. In general, the voltmeter connected to the secondary of the potential transformer is arranged to give full scale deflection at 110 volts.

The ratio between the primary and secondary turns of the potential transformers decides the primary voltage which could be measured with the fixed secondary voltage rating of 110 volts (Fig 1).

Fig 1



CONNETION OF POTENTIAL TRANSFORMER

If the primary turns are four, the secondary turns are two and the primary is connected to a voltage source of magnitude 220 volts, the secondary voltage will be 110 volts according to the transformation ratio.

Precautions to be followed while using a potential transformer: The assembly comprising of the chasis frame work and the fixed part of the metal casing of the voltage transformer shall be provided with two separate, readily accessible, corrosion-free terminals marked legibly as earth terminals.

Specification of a potential transformer: While purchasing a potential transformer, the following specifications need to be checked.

- Rated voltage, type of supply and earthing conditions (for example 6.6 KV, 3 phase solid earthed)
- Insulation level
- Frequency
- Transformation ratio
- Rated output
- Accuracy class
- Winding connection
- Rated voltage factor
- Service conditions including whether voltage transformers are for indoor or outdoor use, whether for use at unsually low temperatures, altitudes (if over 1000 metres), humidity and any special conditions likely to exist or arise, such as exposure to steam or vapour, fumes, explosive gases, excessive dust, vibrations etc.
- Special features, such as limiting dimensions.
- Whether the voltage transformer is required for connection between the star point of the generator and earth.
- Any additional requirement for voltage transformers for protective purposes.
- Whether the installation is electrically exposed or not.
- Any other information.
- Three phase assembly with one multi-tap secondary

Standard rating of potential transformer

Rated frequency: The rated frequency shall be 50 Hz.

Rated primary voltage: The rated primary nominal system voltage of a 3-phase transformer. 0.6, 3.3, 6.6, 11, 15, 22, 33, 47, 66, 110, 220, 400, and 500 KV.

The standard value of primary voltage of a single phase transformer connected between one line of a 3-phase system and neutral point shall be $\frac{1}{\sqrt{3}}$ times of the above values of the nominal system voltages.

The rated secondary voltage: The rated value of secondary voltage for a single phase transformer or for a 3-phase transformer shall be either 100 and 110V.

Transformer losses - OC and SC test - efficiency - Voltage Regulation

Objectives: At the end of this lesson you shall be able to
- **state the type of losses occured in transformer**
- **explain Iron (No - load) losses and copper (load) losses in transformer.**

Losses

There are two type of losses occured in the transformer such as iron (core) loss (Hysterisis + eddy current) and copper (Ohmic) or load loss

Iron (or) No-load losses: The no load losses consist of two components i.e hysteresis and eddy current loss.The hysteresis loss due to the cyclic variation of the magnetic flux in the ferrous metal.

The eddy current occurs because of the changing flux in the core,(according to Lenz's law) inducing a voltage in the core. As a result, circulating eddy currents set up in the core with subsequent I^2R loss. This is also called as **iron loss (or) core loss (or) constant losses**.

As the core flux in a transformer remains practically constant at all loads, the core-loss is also constant at all loads. This is also known as no-load losses.

Hysteresis loss W_h = $K_h B^{1.6}{}_m$ watts

Eddy current loss W_e = $K_e f^2 K_f B_m{}^2$

where K_h = the hysteresis constant

K_f = the form factor

K_e = the eddy current constant

These losses are minimised by using steel of high silicon content (from 1.0 to 4.0 percent) for the core and by using very thin laminations.

Silicon steel has a high saturation point, good permeability at high flux density, and moderate losses. Silicon steel is widely used in power transformers, audio output transformers and many other applications.

The input power of a transformer, when on no-load, measures the core-loss.

Copper (or) Load losses: This loss is mainly due to the ohmic resistance of the transformer windings. The load current through the resistances of the primary and secondary windings creates I^2R losses that heat up the copper wires and causes voltage drops. This loss is also called **copper losses (or) variable losses**. Copper losses are measured by the short circuit test.

> **The core loss in a transformer is a constant loss for all load conditions. The copper loss varies proportionally to the square of the current.**

Open Circuit (O.C) test of a transformer

Objective: At the end of this lesson you shall be able to
- **explain the method of conducting an open circuit test**
- **calculate the exact iron loss.**

The open circuit

The open circuit test is performed to determine the no-load losses or the core losses.

In this test, a rated voltage is applied to one winding, usually the low-voltage winding for safety reasons, while the other is left open-circuited. The input power supplied to the transformer represents mainly core losses. Since the no-load current is relatively small the copper loss may be neglected during this test.

The circuit instruments are shown in Fig 1. The wattmeter indicates the core loss. The voltmeter will register the rated voltage. The ammeter reading in conjunction with voltage will provide the necessary data to obtain information about the magnetizing current.

The core loss can be measured on either side of the transformer. For instance, if a 3300/240V transformer were to be tested the voltage would be applied to the secondary side, since 240V is more readily available.

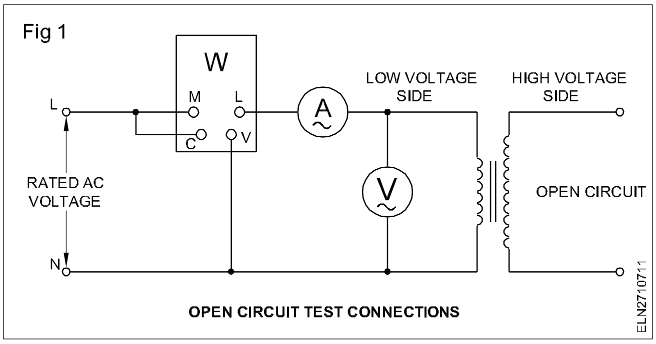
The core loss measured on either side of the transformer would be the same, because 240V is applied to a winding that has fewer turns than the high voltage side. Thus the volt/turn ratio is the same. This implies that the value of the maximum flux in the core is the same in either case. The core loss depends on the maximum flux.

The frequency of the o.c. test supply should be equal to the rated frequency of the transformer.

The actual (exact) iron loss (W_i) can be calculated by the formula

Iron loss = $W_i = W_0$ - no load copper loss

$W_i = W_o - (I_0)^2 R$



W0 = Wattmeter reading on no load

No Load copper loss = $(I_0)^2$ R

R = Resistance of winding in which the OC test calculated

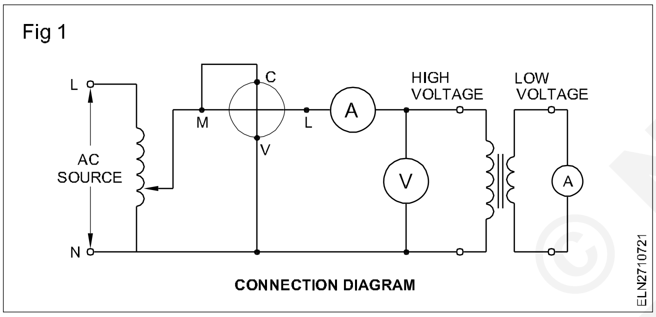
I_0 = No - load current

Short circuit (S.C) test of a transformer

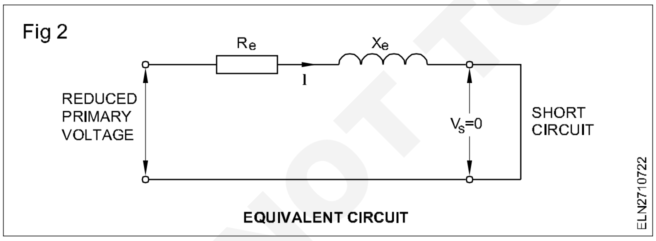
Objectives: At the end of this lesson you shall be able to
- **explain the method of conducting the short circuit test on a single phase transformer**
- **calculate the equivalent resistance and equivalent reactance of the transformer, with respect to high voltage circuit**
- **calculate the copper loss.**

Short circuit test:

A short circuit test is required to determine the transformer equivalent circuit parameters and copper losses. The connected diagram for the short circuit test is shown in Fig 1.



The low voltage side of the transformer is short circuited. A reduced voltage applied on the high voltage winding of the transformer such that the rated current flows through the ammeter. In this condition the impedance of the transformer is merely as equivalent impedenence (Fig 2).



The test is performed on the high voltage side because it is convenient to apply a small percentage of the rated voltage. In the case of a 3300V/240V transformer, it is easier and more accurate to deal with 5% of 3300V than with 5% of 240V.

With the primary voltage greatly reduced, the flux will be reduced to the same extent. Since the core loss is somewhat proportional to the square of the flux, it is practically zero.

Thus a wattmeter used to measure the input power will indicate the copper losses only; the output power is zero. From the input data obtained from the instruments, the equivalent reactance, can be calculated. All the values calculated are in terms of high voltage side.

R_e is equivalent resistance

X_e is equivalent reactance

R_{eH} is equivalent resistance on high voltage side

X_{eH} is equivalent reactance on high voltage side

Z_{eH} is equivalent impedance on high voltage side

$$R_{eH} = \frac{P_{SC}}{I^2_{SC}} \text{ ohms}$$

$$Z_{eH} = \frac{V_{SC}}{I_{SC}} \text{ ohms}$$

$$\text{and } X_{eH} = \sqrt{Z^2_{eH} - R^2_{eH}} \text{ ohms}$$

where I_{sc}, V_{SC} and P_{SC} are the short circuit amperes, volts and watts respectively, and R_{eH}, Z_{eH} and X_{eH} are equivalent Resistance, Impedance and Reactance respectively in terms of high voltage side.

Efficiency of transformer

Objectives: At the end of this lesson you shall be able to
- **calculate efficiency from the losses**
- **state the condition for maximum efficiency**
- **define all-day efficiency of a distribution transformer.**

Efficiency of transformer:

In general, the efficiency of any electrical apparatus is

$$\eta = \frac{\text{output power}}{\text{input power}} = \left|\frac{\text{output power}}{\text{output power} + \text{losses}}\right| \quad .....(1)$$

where η is the symbol used to denote efficiency. When equation (1) is multiplied by the factor 100, the efficiency will be in percent.

The efficiency of a transformer is high and in the range 95 to 98%. This implies that the transformer losses are as low as 2 to 5% of the input power.

While calculating the efficiency, it is generally much better to determine the transformer losses rather than measured the input and output powers directly.

In transformer, the open circuit test yields the core losses and the short circuit test provides the copper losses. Thus the efficiency can be determined from these data with reasonable accuracy.

The transformer ratings are based on output KVA (MVA). Therefore, the equation for efficiency may be written as

$$\eta = \left|\frac{KVA_{out} \times PF}{(KVA_{out} \times PF) + \text{Copper loss} + \text{core loss}}\right|$$

Condition for maximum efficiency:

The efficiency of a transformer is at a maximum when the fixed losses are equal to the variable losses. In other words, when the copper losses is equal to the iron losses, the efficiency is maximum.

Example: A transformer with a rating of 10 KVA 2200/220V 50 Hz was tested with the following results.

Short circuit test power input = 340 W

Open circuit test power input = 168 W

Determine

(i) the efficiency of this transformer at full load

(ii) the load at which maximum efficiency occurs.

The load power factor is 0.80 lagging.

Solution

(i) Efficiency at full load, η_{FL}

$$\eta = \frac{P_{out}}{P_{in}} = \frac{(10 \times 10^3 \times 0.8)\ 100}{(10 \times 10^3 \times 0.8) + \text{Cu loss} + \text{Iron loss}}$$

$$= \frac{(10000 \times 0.8)\ 100}{(10000 \times 0.8) + 340 + 168}$$

= 94.0%.

(ii) The maximum efficiency occurs at a load when the copper loss = core loss.

Thus the copper loss = core loss = 168 W.

Let the current at full load = I.

The current at maximum efficiency = I'.

Then, the copper loss at full load = $I^2 R_{eq}$ = 340 W

the copper loss at h_{max} = $(I')^2 R_{eq}$ = 168 W.

Therefore, $\frac{I^2 R_{eq}}{I'^2 R_{eq}} = \frac{340}{168}$

or $I' = I\sqrt{\frac{168}{340}}$

This is the factor by which the power decreases,

Therefore, $P_{atmax\eta} = \sqrt{\frac{168}{340}} \times (10000 \text{x} 0.8)$

= 5623 W

$P_{atmax\eta}$ = 5623 W

= 70.26% of 8000 W

= 0.7026 of full load.

or

Therefore, $\eta_{max} = \frac{5623}{5623 + 168 + 168} \times 100$

= 94.36%.

All day efficiency

Lighting transformers and most distribution transformers will not have full load for all the 24 hours in a day. To keep the operational efficiency of such distribution transformers are designed to have their maximum efficiency at a lower value than full load.

Allday efficiency

$$\frac{\text{Output in 24 houea}}{\text{Output in 24 hours losses in 24 hours}}$$

Aallday

$$= \frac{\text{Output KWh 24 houea}}{\text{Output KWh (24 hours) + losses KWh (24 hours)}}$$

Here, the iron loss is considered through out the period where as copper loss depends up on the period for which transformer is loaded and percentage load.

Example: A 100 KVA distribution transformer has a full load loss of 3 KW. At full load the losses are equally divided between iron and copper loss. During a certain day the transformer connected to the lighting load operated with loads as given below.

a On full load, unity PF 3 hours.

b On half full load, unity PF 4 hours.

c Negligible and during the remaining part of the day.
Calculate the all day efficiency.

Solution

As the load is primarily lighting, the PF = 1.0.

(a) Output energy at FL in 3 hours

= 100 KVA x 1 x 3 = 300 KWh

(b) Output energy at 1/2 FL in 4 hours

= 100 x 1/2 x 1 x 4 = 200 KWh.

Energy wasted in kWh during full load

= 3 KW x 3h = 9 KWh.

At full load

Iron loss = copper loss = 3.0¸2 = 1.5 KW.

Copper loss at 1/2 full load

= 1.5 x $(1/2)^2$ = 1.5/4 KW.

Total energy loss during half full load

= iron loss for 4 hours + copper loss for 4 hours

= (1.5 x 4) + (1.5/4 x 4)

= 6 + 1.5 = 7.5 KWh.

The transformer has no load for

= (24 - 7) hours = 17 hours.

Constant loss for 17 hours

= 1.5 x 17 = 25.5 KWh.

The total loss for 24 hours= (9 + 7.5 + 25.5) KWh = 42

$$\eta_{\text{all day}} = \frac{\text{Output KWh 24 hours}}{\text{Output KWh(24 hours) + losses (24 hours)}}$$

$$\text{KWh} = \frac{(300 + 200)}{(300 + 200) + 42} = 0.922$$

$$\eta_{\text{allday}} = 92.2\%$$

Voltage regulation of transformers

Objectives: At the end of this lesson you shall be able to
- **define the voltage regulation of a transformer**
- **calculate the voltage regulation of a transformer.**

Voltage regulation:

The voltage regulation of a transformer is the difference between the no-load and full load secondary voltage expressed as a percentage of the full load voltage. The primary or applied voltage must remain constant.

This is an additional condition that must be fulfilled in the case of transformers.

Also, the power factor of the load must be stated since the voltage regulation does depend on the load power factor .

In general,

Voltage regulation =

$$\frac{V_{noload} - V_{load}}{V_{load}} \times 100\%$$

Let V_0 = Secondary terminal voltage at no-load

V_S = Secondary terminal voltage at load.

$$\text{Then \% regulation} = \frac{V_o - V_S}{V_S} \times 100$$

The numerical values employed in the calculations depend on which winding is used as a reference for the equivalent circuit. Similar results are obtained whether all impedance values are transferred to the primary or to the secondary side of the transformer.

Example:

The secondary voltage of 11KV/440V, 100KVA transformer is 426 V at no-load. Under the full load condition, the same is 410V at 0.92 Power factor. Calculate the percentage voltage regulation of the transformer.

solution:

$$\text{\% of Voltage regulation} = \frac{V_o - V_S}{V_S} \times 100$$

$$\text{\% of Voltage regulation} = \frac{426 - 410}{410} \times 100$$

$$= \frac{16}{10} \times 100$$

$$= 3.9\%$$

Parallel operation of two single phase transformers

Objectives: At the end of this lesson you shall be able to
- **state the necessity of parallel operation of transformers**
- **state the conditions to be full filled for the parallel operation of transformers**
- **explain how to determine the polarity terminals of transformer.**

Necessity of parallel operation of transformers

1 When the power demand of the load increases, two or more transformer may be operated in parallel.

2 When the power demand decreases, only required numbers of transformer may be operated with their full load capacity. Where as the remaining transformers may be switched "OFF" and taken for general maintenance/service.

3 Thus the efficiencies and life of the transformers increases and the losses are reduced.

4 It provides more reliability of power i.e., even one transformer fails or become out of service, other transformers will supply to the certain amount of load.

5 It is not economical to manufacture a single very large capacity transformer. Thus operationg two or more numbers of optimal capacity transformers in parallel is more economical.

6 It is easy to plan the maintenance schedule of the transforemers, hence the cost of maintenance and spares are reduced.

Conditions

1 the same voltage ratio

2 Input voltage must be same

3 the same per unit (or percentage) impedance

4 the same polarity

5 the same phase sequence and zero relative phase displacement, for 3 phase transformers.

Of these (4) and (5) are absolutely essential (1) and (2) must be satisfied to a close degree.

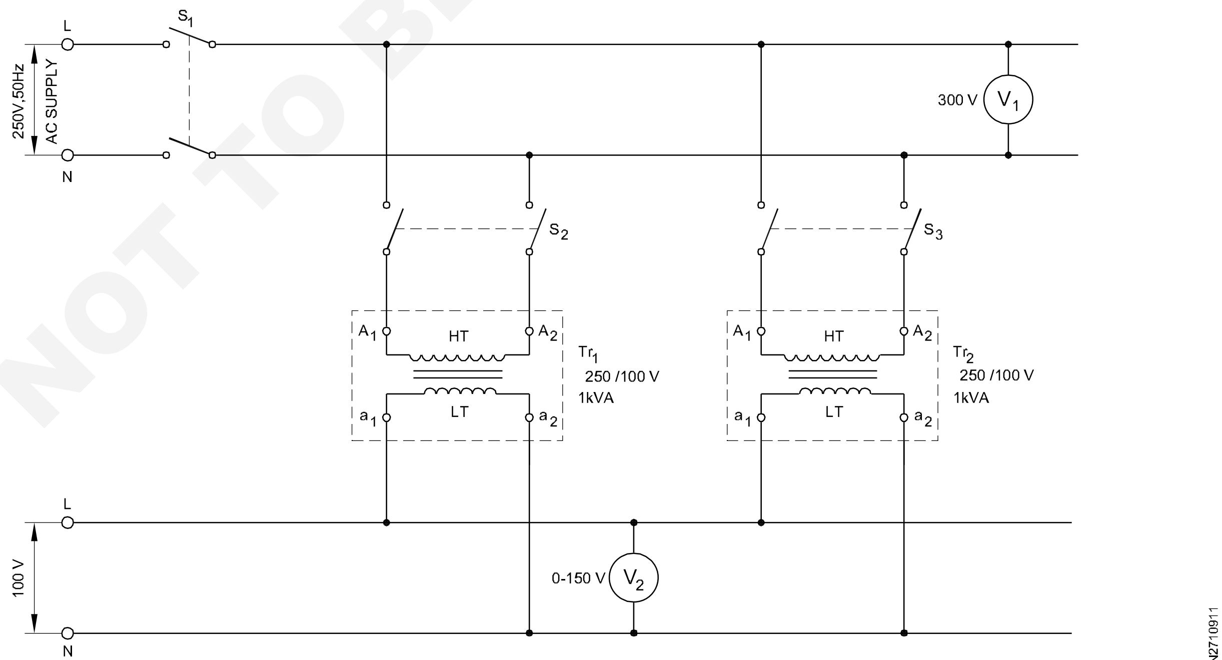
There is more allowance for a wide extent with (3), but the more nearly it is true, the better will be the load division between several transformers.

Parallel operation

Fig 1 shows two single phase transformers connected in parallel with their primary windings connected to the same supply and their secondary windings supplying a common load.

When operating two or more transformers in parallel, to have satisfactory performance the following conditions should be met

Fig 1



TWO SINGLE PHASE TRANSFORMERS CONNECTED IN PARALLEL

Voltage ratio: If voltage readings on the open secondaries of various transformers, to be run in parallel, do not show identical values, there will be circulating currents between the secondaries (and therefore between primaries also) when the secondary terminals are connected in parallel. The impedances of transformers is small, so that a small percentage voltage difference may be sufficient to circulate considerable current and cause additional I^2R loss.

When secondaries are loaded, the circulating current will tend to produce unequal loading conditions. Thus it may be impossible to take the full load output from the parallel connected group without one of the transformers becoming excessively heated.

Impedance: The currents carried by the two transformers are proportional to their ratings:

- if their numerical or ohmic impedances are inversely proportional to those ratings, and
- their per unit impedances are identical.

A difference in the quality factor (i.e the ratio of reactance to resistance) of the per unit impedance results in a divergence of the phase angle of the currents, so that one transformer will be working with a higher and the other with a lower power factor than that of the combined output.

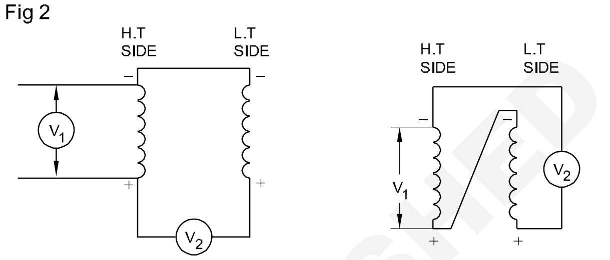
Verification of terminals or Polarity: When two or more transformers are to be connected in parallel on their primary and secondary sides, the terminals of the same polarity only can be connected together, otherwise a heavy circulating current will be produced between the windings.

Standard procedure to determine the polarity is explained below:-

- connect one end of the high voltage winding to one end of the low voltage winding as shown in Fig 2a.
- Connect a voltmeter between the two open ends.
- Apply a voltage not greater than the rated voltage of the winding to either high or low voltage winding.

If V_2 reads less than V_1 (Fig 2a) the primary and secondary emfs are in opposition. The marking on primary will be A_1 for +ve side and A_2 for –ve side and a_1 for +ve side of secondary and a_2 for –ve side. If the connections are made (Fig 2b) the voltmeter V_2 will read more than V_1. Thereby it is ascertained opposite ends are connected.

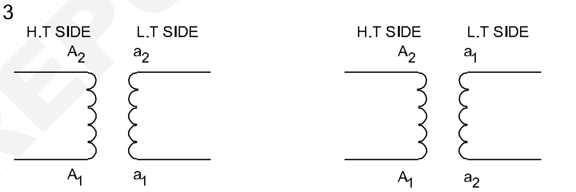
Fig 2



a) V_2 IS LESS THAN V_1 (V_P-V_S)VOLTS b) V_2 IS MORE THAN V_1 (V_P+V_S)VOLTS

If in transformer has similar ends in one side (Fig 3a) the polarity marking is said to be subtractive polarity marking on the other hand if the opposite ends are in one side (Fig 3b) the polarity marking is called as additive polarity marking.

Fig 3



a) SUBTRACTIVE POLARITY MARKING b) ADDITIVE POLARITY MARKING

Series (Secondary only) operation of transformers

Objectives: At the end of this lesson you shall be able to
- **state the necessity of series operations**
- **state the conditions to be fulfilled for series operation**

Series operation:

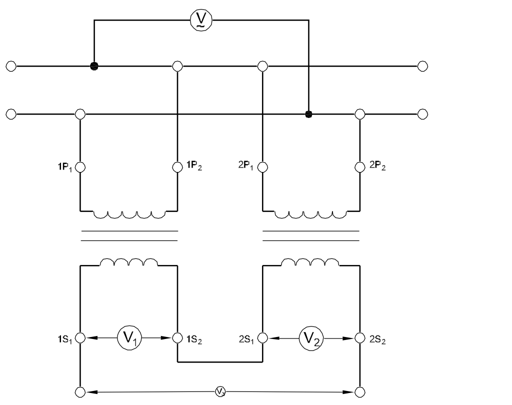
The connection diagram for series operation (secondary only) of two identical transformers is given below (Fig 1)

Necessity for series operations:

In general, the transformers are available with some standard input (primary) and output (secondary) voltages. In order to get some intermediate voltage for example , 36V, 48 V for special purpose, the series operation of transformers (secondary only) are necessary.

In series operation, individual secondary voltages of both transformers are added if they are connected with proper polarity, but the current ratings are remains same.

Fig 1



SERIES OPERATION OF TRANSFORMERS (SECONDARY ONLY)

Condition for series operation:

Both transformers should be identical i.e,

a) Voltage ratio/turns ratio must be same

b) Polarities must be same

c) Type of core of both transformers (core or shell type) must be same.

d) Input voltages of both transformers must be same.

e) KVA ratings of both transformers must be same.

f) Percentage impedance or per unit impedance of both the transfers must be same.

Precautions:

- **The polarities of secondary of both transformers should be connected in proper way, same as series connection, to get the voltage added, otherwise the output voltage will be zero.**
- **As the output voltage is double that the individual secondary voltages, care to be given to ascertain the insulation level of the secondary windings.**

Three Phase transformer - Connections

Objectives: At the end of this lesson you shall be able to
- **state the transformer connections, angular divergence of the 3 phase transformers**
- **explain the scott connection of transformer and its uses.**

Transformer Bank

Transformers, like other electrical devices, may be connected into series, parallel, two-phase or three-phase arrangements. When they are grouped together in any of these arrangements the group is called a transformer bank.

The high voltage and low voltage winding terminals of a three-phase transformer are connected either in star or in delta for connections to a three-phase system.

When the primary high voltage winding terminals are connected in, say, star and the secondary low voltage winding terminals are connected in, say, delta, it is said that the transformer windings are connected in star-delta (U - D or U - d). Similarly

star-star (Uy)

delta-delta (Dd)

and, delta-star (Dy) connections can be used.

Type of connection	High voltage side	Low voltage side
Delta	D	d
Star	U	y
Zigzag	Z	z

Angular displacement (divergence)**:** There is a definite time phase relationship between the terminal voltages of the high voltage side and low voltage side for these connections. The time phase relationship between the voltages of high voltage side and low voltage sides will depend upon the manner in which the windings are connected.

If the high voltage side and low voltage side windings are connected in star-star (as in Fig 1a and 1b). The phase displacement will be zero. If, however, the low voltage winding connections are reversed, as shown in Figs 2(a) and (b), the time phase displacement in induced voltages between the high voltage and low voltage windings will be 180 degrees.

If the primary high voltage and secondary low voltage side windings are connected in Yd or Dy as shown in Figs 3(a) and (b), the phase displacement will be - 30 degrees.

The displacement in the clockwise direction is negative. Anti clockwise is positive.

Fig 1

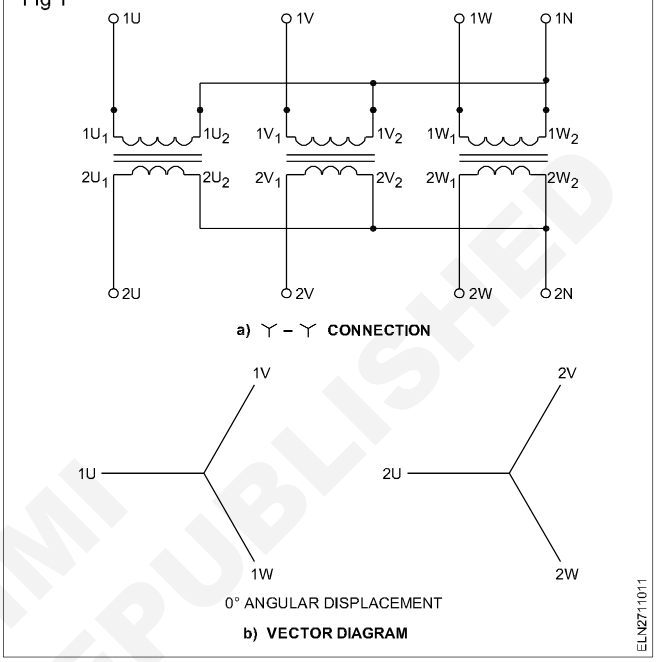
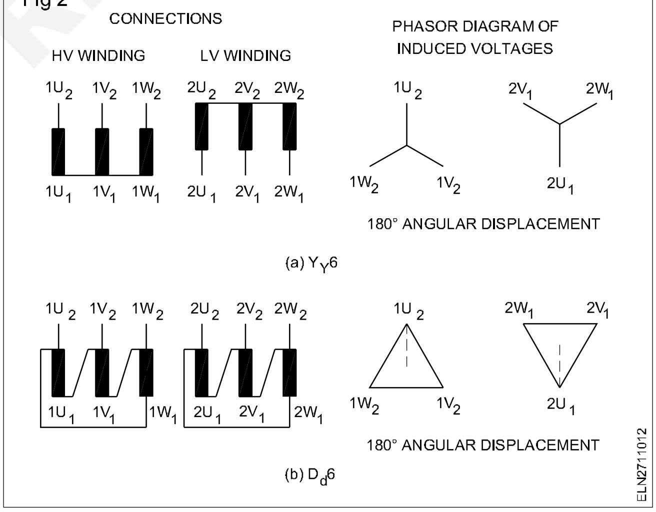
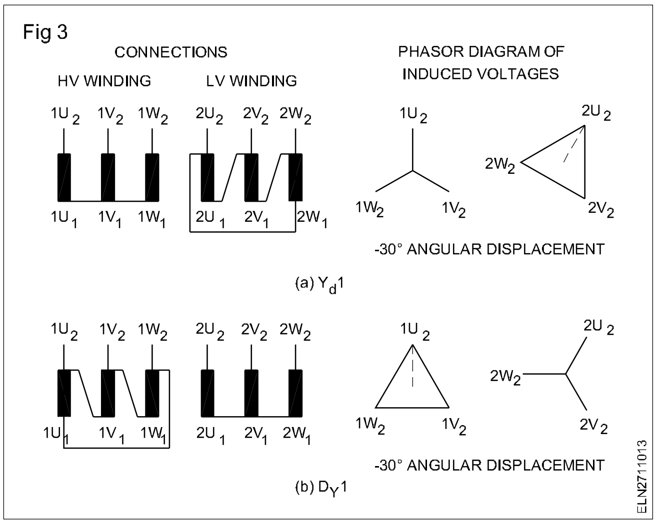


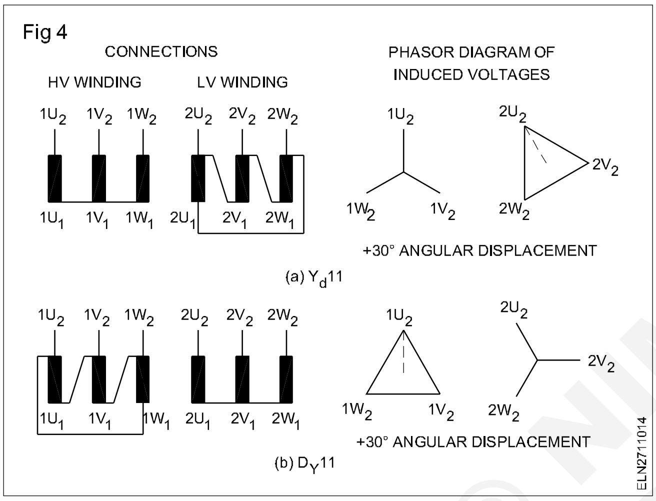
Fig 2



If the windings are connected in Yd or Dy as Figs 4 (a) & (b), the displacement of the terminal voltage will be + 30°.

Observe the change in connections made at the low voltage side in Figs 3(a) and Fig 4(a). Similarly the change in the high voltage side winding connections Figs 3(b) and Fig 4(b) causes the difference in displacement angle.





Scott connection or T.T. connection: In certain special equipment the line voltage required for its 3-phase connection may not be of standard rating as available in the system. Further, the power consumption in these equipment may also be high. To meet this requirement Scott connected transformers are used. These Scott connected transformers enable transformation of 3-phase to 3-phase more economically.

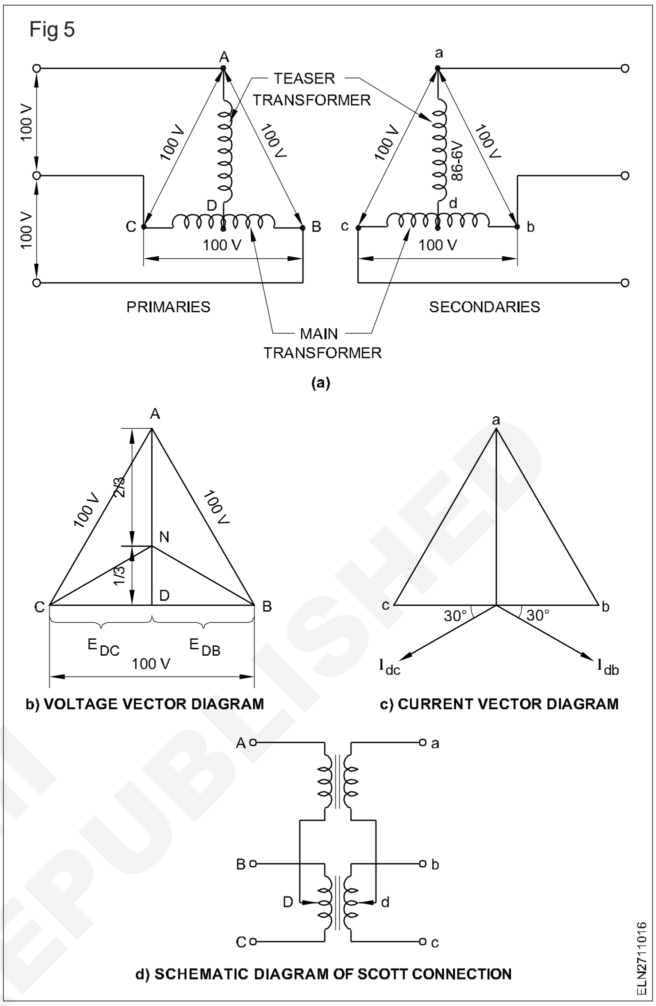
This Scott connection can also be used for 3-phase to 2-phase transformation as explained subsequently.

The main transformer has centre tapped primary and secondary windings Fig 5. The primary and secondary windings are indicated by CB and cb respectively in the Fig 5. Another transformer called teaser transformer has a 0.866 tap and one end of both the primary and secondary windings of the teaser transformer (say D and d) is joined to the centre tap of both primary and secondary of the main transformer.

The other end A of the teaser transformer and the two ends B and C of the main transformer primary are connected the 3-phase supply.

3-phase supply is taken out from one end 'a' of the teaser transformer secondary and the two ends b and c of the secondary of the main transformer.

For convenience unity transformation ratio is choosen and the supply line voltage is assumed as 100V (Fig 5).



By analysing the vector diagram Fig 5b, it is found that voltage E_{DC} and E_{DB} are each 50V and differ in phase by 180^0 because both the coils DB and DC are in the same magnetic circuit and are connected in opposition. Fig 5d shows the schematic connection diagram.

Each side of the equilateral triangle represents 100V. The voltage E_{DA} being the altitude of the equilateral triangle is equal to $\sqrt{3}/2 \times 100 = 86.6V$ and legs behind the voltage across the main by 90^0. The same relation holds good for the secondary voltages. The transformer rating is restricted to 86.6% of its KVA rating. By suitable turn ratio the trnsformer rating can be improved to 92.8%.

3-phase to 2-phase conversion and vice versa: In industrial application of electric power supply certain equipment like electric furnaces and welding transformers require two phase supply.

At present, the available electrical supply is in variably three phase it is necessary to convert the 3 phase supply to 2 phase supply. This is accomplished by Scott connection.

Three single phase transformers for three phase operation

Objectives: At the end of this lesson you shall be able to
- **list and interpret the four types of connections of primary and secondary windings**
- **state the phase and line values of current and voltage.**

There are various methods available for transforming 3-phase voltages, that is for handling a considerable amount of power. There are four possible ways in which the primary and secondary windings of a group of three transformers may be connected together to transfer energy from one 3-phase circuit to another. They are:

Primaries in Y, Secondaries in Y

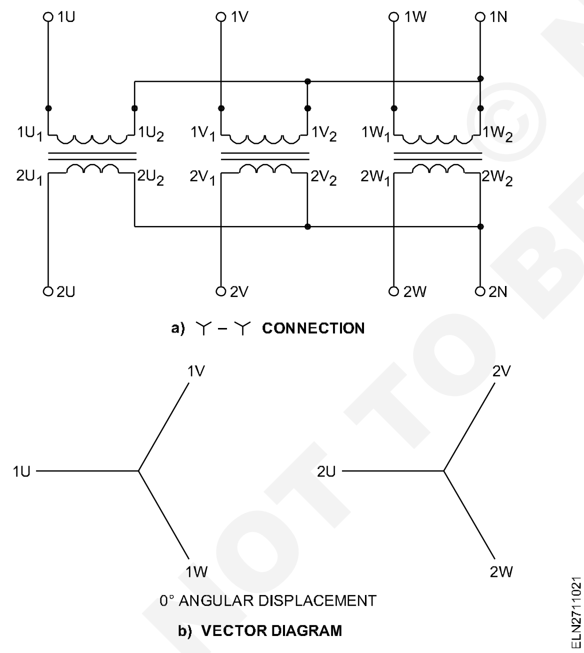
Primaries in Y, Secondaries in Δ

Primaries in Δ, Secondaries in Δ

Primaries in Δ, Secondaries in Y.

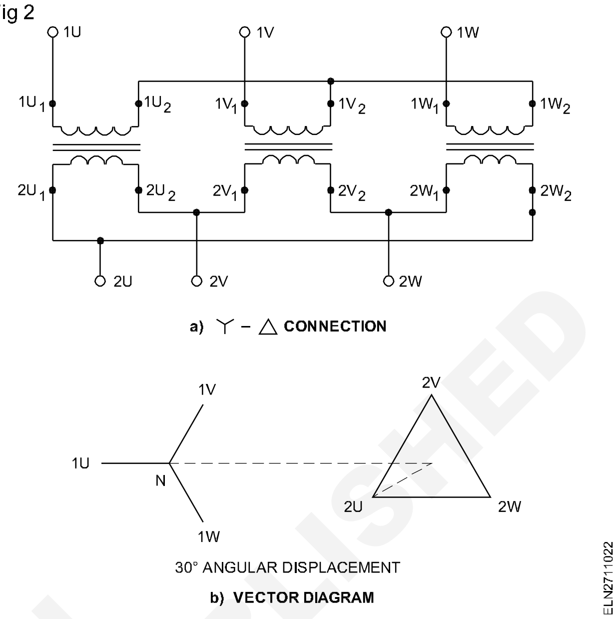
Star/Star or Y/Y connection: Fig 1 shows the connection of a bank of 3 trans-formers in a star-star. This connection is most economical for small, high voltage transformers because the number of turns per phase and the amount of insulation required is minimum. This connection works satisfactorily only if the load is balanced. For a given voltage V between lines, the voltage across the terminals of a Y connected transformer is $V/\sqrt{3}$; the coil current is equal to the line current I.

Fig 1



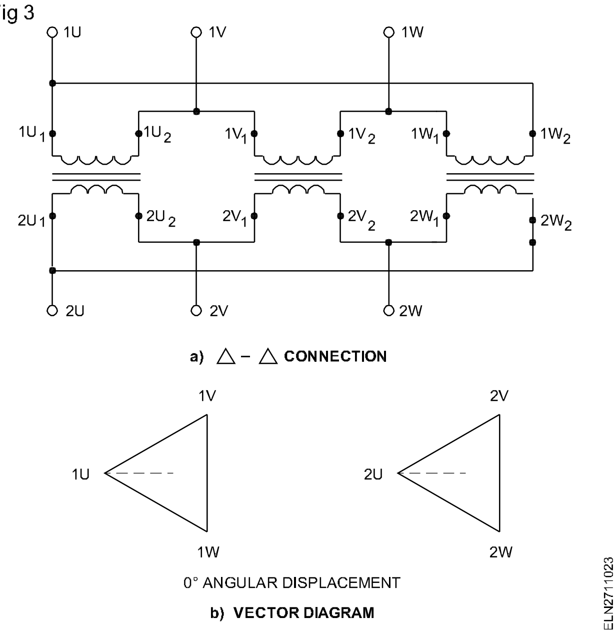
Star - Delta or Y/Δ connection: In primary side 3 transformers are connected in star and the secondary consist of their secondary connected in delta as shown in Fig 2. The ratio between the secondary and primary line voltage is $1/\sqrt{3}$ times the transformation ratio of each transformer. There is a 30° shift between the primary and secondary line voltages. The main use of this connection is at the substation end of the transmission line.

Fig 2



Delta - Delta or Δ/Δ connection: Fig 3 shows three transformers, connected in Δ on both primary and secondary sides. There is no angular displacement between the primary and secondary line voltages. An added advantage of this connection is that if one transformer becomes disabled, the system can continue to operate in open-delta or in V-V. In V-V it can be operated with a reduced capacity of 58% and not 66.6% of the normal value.

Fig 3



Delta - Star or Δ/Y connection: (Fig 4) This connection is generally employed where it is necessary to step up the voltage, as for example, at the beginning of high tension transmission system.

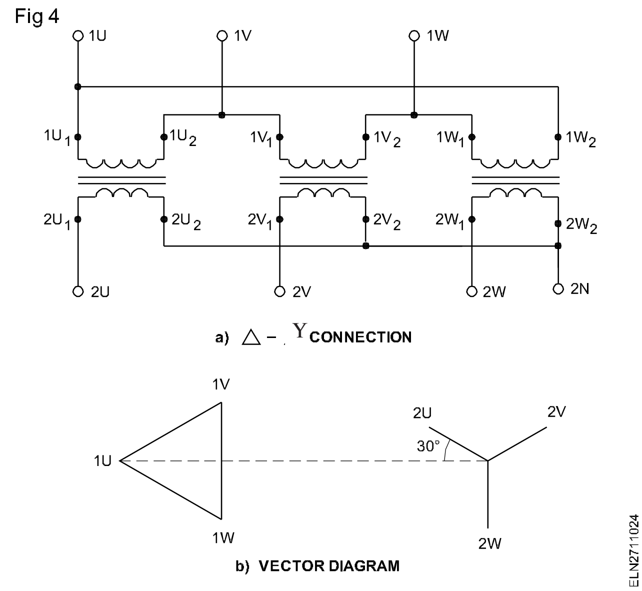


Fig 4

The primary and secondary line voltages and line currents are out of phase with each other by 30°. The ratio of secondary to primary voltage is $\sqrt{3}$ times the transformation ratio of each transformer.

Parallel operation of 3-phase transformer

Objectives: At the end of this lesson you shall be able to
- **explain parallel opration**
- **states the conditions for parallel operation of 3 phase transformer**
- **sates the necessity of parallel opertion.**

Parallel operation

Operating two or more transformers by connecting their primaries in parallel to a common supply line and connecting their respective secondaries in parallel with a common load-busbars is called as parallel operaion of transformers.

Conditions for pararllel opertion of transformers:

When operating two or more transformer in parallel, the following conditions have to be satisfied for the best performance of the transformer.

1 The voltage ratio must be same.

2 The per unit impedance or percentage impedance should be same i.e., the ratio between the equivalent leakage reactance and the equivalent resistance(X/R)should be same.

3 The polarities must be same.

4 For three phase transformers

  i The phase sequence must be same

  ii The vector group must be same (i.e., The relative phase displacement between the secondary line voltages must be zero)

Parallel operation of 3-phase transformer:

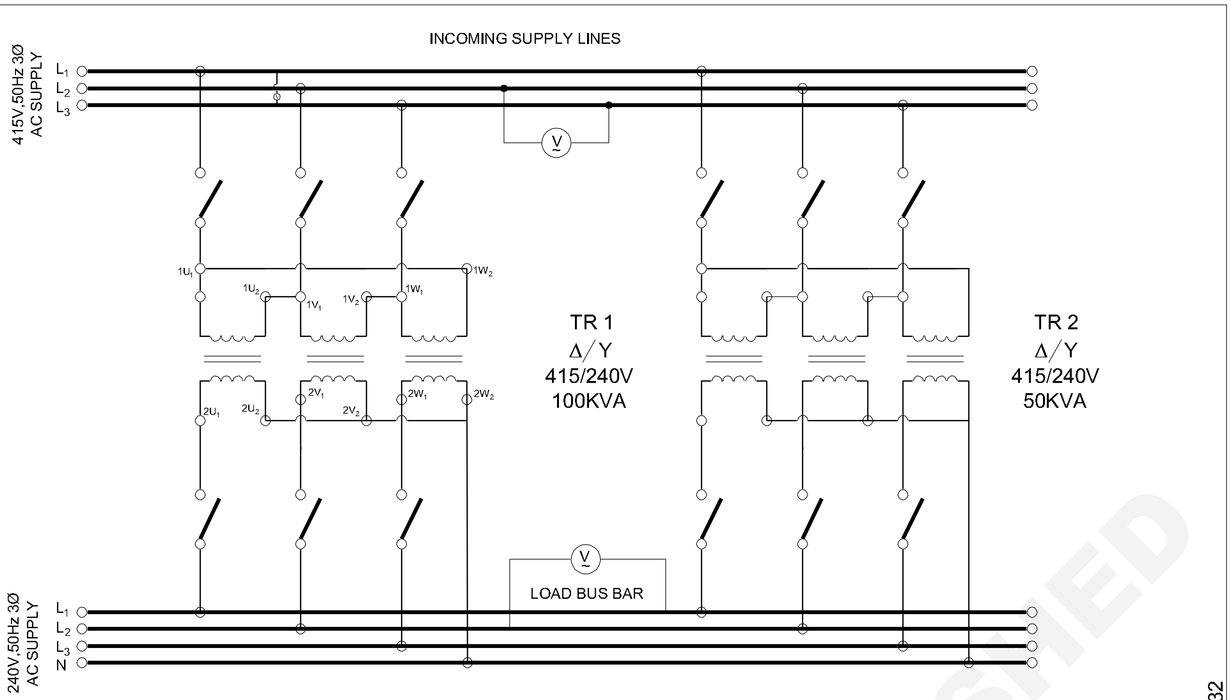
Fig 1 shows the connection diagram for parallel operation of two numbers of 3-phase transformers. In this case, the connection of both of transformer 1 and 2 are (delta - star)same.

However to operate the 2 transformers of having Y/Δ and connection, their primary and secondary line voltage Δ/Y must be same. In this case,the turns ratio may not be equal, but the voltage ratio between the terminal voltage of primary and secondary must be same.

If two transformers having different ratings, are connected in parallel the their percentage impedance must be same, where as the numerical impedance of transformer 1 will have half the impedance of transformer 2. In this case both the transformers will share the common load in propertional to their KVA ratings.(Fig 1)

For best performance of the parallel operation, the regulation of both the transformers must be same . If the percentage impedance of both the transformers are different. Than one transformer will be operating at a higer power factor and other will be operating at a lower power factor.

Fig 1



PARALLEL OPERATION - 3 PHASE TRANSFORMER - CONNECTION DIAGRAM

Cooling of transformer - Transformer oil and testing

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of cooling**
- **state the methods of cooling.**

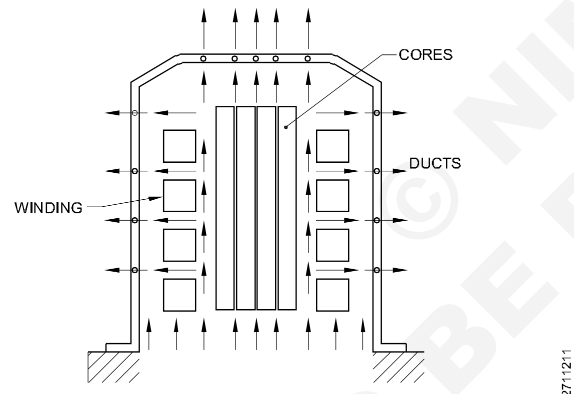
Necessity of cooling

Transformer is heated up when current flows through its, winding. This causes the liberation of heat. In large size transformer, where power rating is high, large amount of heat is liberated. This will affect the insulation of the windings as well as reduction of transformer efficiency. This heat should be transformed from transformer winding and dissipated in the atmosphere .

Methods for cooling transformers: Following are the methods of cooling employed in transformers. Any one or more methods could be adopted depending upon the size, application and location of the transformer.

- Natural air method
- Air blast method (Fig 1)

Fig 1

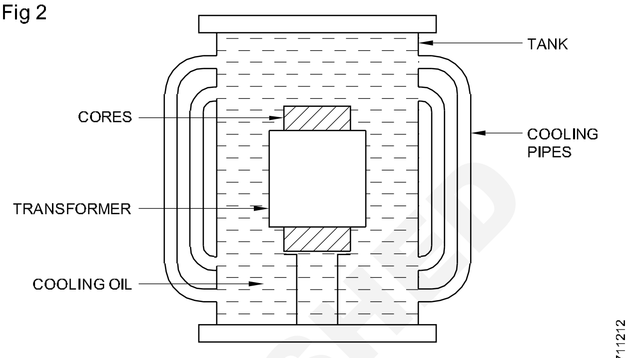


AIR BLOWER FAN

- Natural oil cooled method (Fig 2)
- Oil blast method
- Forced circulation of oil
- Oil and water cooled (Fig 3) and
- Forced oil and water cooled

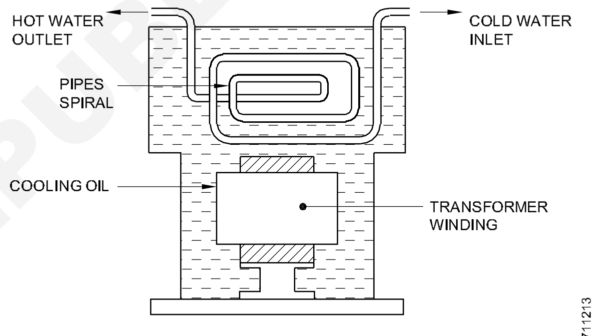
Natural air cooling method is generally adopted for low capacity distribution transformer upto 100KVA. The natural circulation of the surrounding air is used to carry away the heat from the transformer winding.

Fig 2



OIL - COOLED TRANSFORMER

Fig 3



OIL AND WATER COOLED TRANSFORMER

In air blast method, the fans are used to blow the air on the surface of the transformer thereby the heat generated is carried away by the air blast.

Transformer of 200KVA above capacity are cooled by using an insulating oil. The winding and core are immersed in oil. The area of the tank is increased by using cooling tubes. (Radiator tubes)

In oil and water cooled system, the low pressure water tubes through the heated oil used to remove the heat from the transformer.

Testing of transformer oil

Objectives: At the end of this lesson you shall be able to
- **explain the transformer oil**
- **name three insulating oils used in transformer**
- **list the important properties of a transformers oil**
- **state the necessity of transformer oil**
- **state the causes for deterioration of oil**
- **explain the methods of testings the oil for its parameter.**

Transformer oil

It is an insulating liquid, used to cool and insulate the transformer windigs and core.A cooling liquid is also considered as a part of the transformer.

Three kinds of cooling oils/liquids are used in transformers today.

- Mineral oil (inflammable)
- Silicon liquids(low flammable) and
- Hydrocarbon liquids (non-flammable)

The common transformer oil is a mineral oil obtained by refining crude petroleum. Clean and dry mineral oil is an excellent insulator. Its loss by evaporation is small. But it is an inflammable liquid and readily absorbs moisture from the air. Great care should be taken to keep the oil away from flame and moisture.

Synthetic liquids do not catch fire easily. Synthetic liquids are therefore replace mineral transformer oils of those transformers used in

- underground mines
- refineries and hazardous location
- tunnels
- workshop and plants of metal processing theatres and cinemas etc.

Transformer oil consists of organic compounds, namely paraffin, naphthalene and aromatics. All these are hydro carbons, hence insulating oil/transformer oil/ synthetic transformer oil known as ASKARELS and PYROCLORE are also in use.

Properties of transformer oil

A good transformer oil should have the following properties.

1 High specific resistance so that high insulation resistance

2 Better heat conductivity, (i.e) higher specific heat.

3 High firing point, so that not to catch fire at low temperature.

4 Do not absorb moisture easily, when exposed to air.

5 Low viscosity

Necessity of transformer oil: Large capacity distribution transformers produces more heat due to losses like core losses and copper losses, on load. It is necessary to stablize the heat within temperature class by providing suitable insulating materials.

Transformer oil acts as a good electrical insulating material. Thus it reduces electrical break down. Transformer oil will also act as cooling agent. Thus it brings thermal stability to all the internal parts of transformer.

Causes for deterioration of transformer oil: When the oil cooled transformers are in use, the oils of the transformers are subjected to normal deterioration due to the conditions of the use.

For example

1 The oil may come in contact with the air, there by presence of moisture and dust in the oil. The presence of moisture is harmful and affects the electrical characteristics of oil and will accelerate deterioration of insulating materials.

2 Sediment and precipitable sludge may be formed on the winding and core surfaces. It will reduce the cooling rate and hence it may lead to deterioration of the insulating materials.

3 The presence of certain solid iron, copper and dissolved metallic compounds will increase the acidity. In such cases, the resistivity decreases, and electrical strength also decreases, and it is also the causes for deterioration of transformer oil.

Testing of transformer oil: For reliable use and maintenance of oil cooled transformer, the transformer oil shall be tested before initial filling of the oil as well as during service of the transformers. As per the test result it may be required to filter the transformer oil or in some cases, new oil may be recommended for safe and better maintenance of oil cooled transformers.

The following tests are conducted periodically to decide the performance of the transformer oil.

1 Field test of insulation oil

2 Crackle test of insulating oil

3 Dielectric test of insulating oil

4 Acidity test.

1 Field test of insulating oil

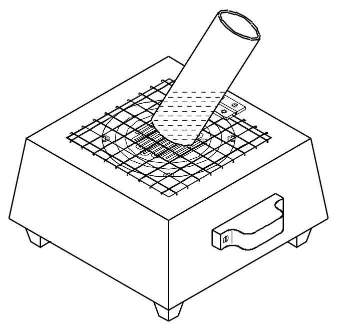
A drop of transformer oil, when placed slowly from a pipette on the still surface of a distilled water contained in heater should retain its shape when the oil is new.

In the case of used cyclo-octane oils (or) paraffin oils (even though unused) the drop usually flattened. If this flattened drop occupies an area of diameter less than 15 to 18 mm, the oil may be used. Otherwise, it has to be reconditioned. Oils with the longer spreads are unsuitable.

2 Crackle test of transformer oil (Fig1)

A rough test may be made, by closing one end of steel tube, and heating the closed end to just dull red hot. (Fig 1) When the oil sample is plunging into the tube, a sharp Crackle sound will be heard, if the oil contains much moisture. Dry oil will only sizzle.

Fig 1

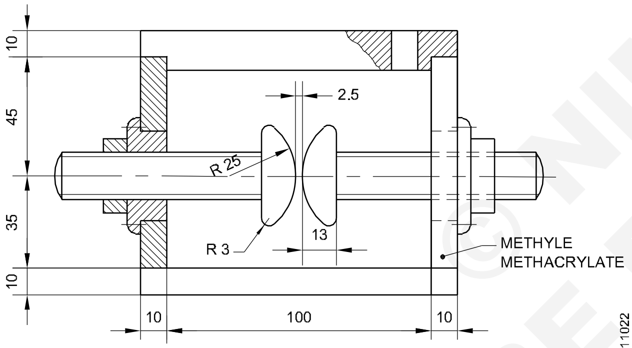


CRACKLE TEST

3 Dielectric test of transformer oil

This test is preferably conducted using standard oil test set. The oil test set consists of a container/cell made up of glass or plastic.(Fig 2)

Fig 2

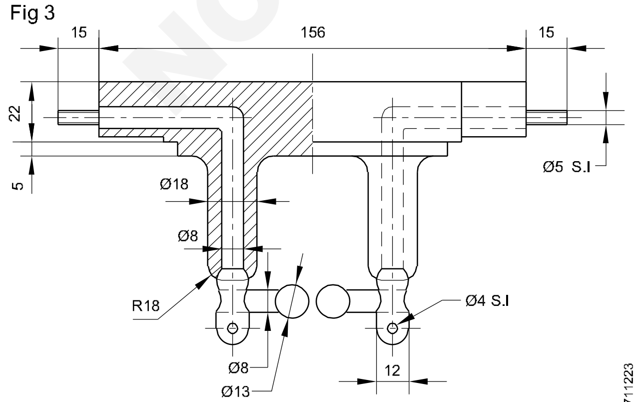


OIL TEST CONTAINER/CELL

The cell shall have an effective volume between 300 to 500 ml. It should be preferably closed. Section view of container. (Fig 3)

Two numbers of the copper, brass, bronze or stainless steel in the shape of sphere of diameter 12.5 to 13 mm elliptical are mounted on a horizontal axis at 2.5 mm apart, is used as electrodes, for oil test of 11KV transformer.

Fig 3



DIELECTRIC TEST

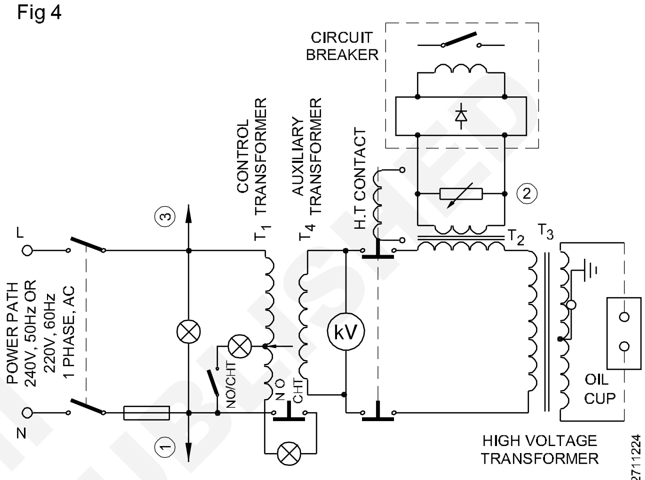
The cell is mounted on a test set. HT connection to the electrodes, is made by the point contact arrangements.

The test set is also provided into step up transformer where the voltage can be varied from zero to 60KV. In some designs, the voltage is varied by electric motor, with the operation of push button switch.

Electrical circuit diagram of dielectric test unit (Fig 4)

For conducting dielectric test on transformer oil, the oil is to be gently agitated and turned over several times so that homogeneous distribution of the impurities contained in the oil is spread all over.

Fig 4



CIRCUIT DIAGRAM OF DIELECTRIC TEST

Immediately after this, the oil is poured down into the test cell slowly in order to avoid air bubbles. The operation is carried out in a dry place free from dust. The oil temperature at the time of test shall be same as that of ambient.

After fulfilling the above conditions the cover of the cell is placed in position. The cell is placed in the test unit and power is switched "ON".

The AC voltage across the electrode of frequency 40 to 60Hz is increased uniformly at the rate of 2KV RMS starting from 'O' up to the value of producing break down. The break down voltage is the voltage reached during the test at the time the first spark occurs between electrodes.

The circuit is opened automatically if an arc is established between electrodes. The break down voltage is recorded and the reading is interpreted according to the standard ratings. The requirements as per IS-335-1983 is: Electrical Strength (break down voltage)

1 New unfiltered transformer oil - 30KV (RMS)

2 After filtration transformer oil - 50KV (RMS)

It is recommended to filter the transformer oil if the break down voltage does not attain 30KV (RMS).

The test shall be carried out 6 times on the same cell filling. The electric strength shall be the arithmetic mean of the 6 results which have been obtained.

4 Acidity test

The acid products are formed by the oxidation of the oil. This oxidation will deteriorate the insulating materials like insulating paper and press boards used in transformer windings. It is therefore essential to detect and monitor the acidity formation.

To conduct this test portable test kit is available consisting of:

1 Two polythene bottles containing 100ml each of ethyl alcohol and sodium carbonate solution of 0.0085N concentration.

2 An indicator bottle containing universal indicator.

3 Four clean glass test tube.

4 Three graduated droppers, which serves as pipettes.

5 Colour chart with acidity range.

6 Instruction booklet.

PROCEDURE

The test is conducted by taking 1.1 ml of insulating oil (to be tested) in test tube, 8 ml oil 1 ml of rectified spirit is added and mixture is to be gently shakened. Further 1 ml of solution of 0.008 5 N sodium carbonate added. After shaking the test tube once again 5 drops of universal indicator is added. The resulting mixture develops a colour depending on the acidity value of the mixture.

The approximate colour range will be as follows:

Total acidity value in No.	Colour
0.00	Black
0.2	Green
0.5	Yellow
1.0	Orange

Any how the colour chart will be provided with the test kit to indicate exact value.

Winding a small transformer

Objectives: At the end of this lesson you shall be able to
- **state the important data to be taken for rewinding the transformer**
- **explain the rewinding procedure for small transformers**
- **calculate the number of turns per volt using the formula and determine primary and secondary turns**
- **determine the dimensions of the transformer, size of bobbin and size of winding wire**
- **explain the tests to be carried out after winding the transformer.**

Scan the QR Code to view the video for this exercise

Rewinding of small transformer

It is necessary to rewind a transformer when the winding is burnt out or badly damaged.

While dismantling transformers, care should be taken to record the necessary particulars (data) by which the rewinding process becomes easy and the original performance of the transformer is assured.

Recording the data : The following data have to be taken from the transformer before and during disassembling.

1 Number of windings/turns/ layers.
2 Size of wires and insulation.
3 Input/output voltages & currents.
4 KVA ratings.
5 Conncetion diagrams.
6 Terminal marking / lead position
7 Types of cores / number of stampings
8 Physical condition of bobin / core.
9 Insulation schemes like size and specification of bindings, layer,interlayer,inter windings, bobin,lead wires, sleeves etc.

If the old bobbin is reused for winding, it shall be cleaned well and shall be free from any break or crack. If a new bobbin is used it shall be checked with the stamping (core) for proper assembly to avoid too much air gap or too tight a fitting.

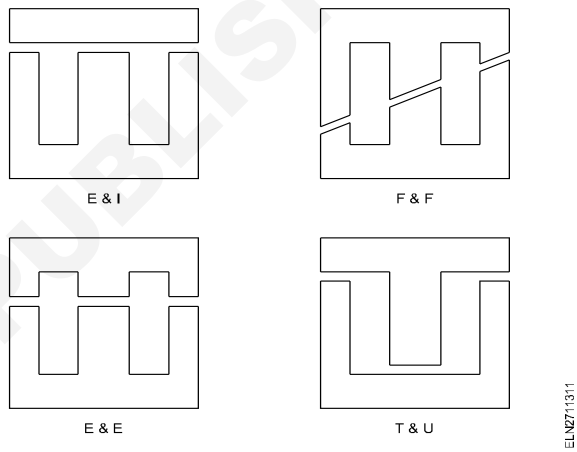
For winding, a suitable size of wire shall be selected from the data and the size of wire shall be measured as per I.S. 4800 (Part - I) 1968.

The size of the wire can be measured with insulation but it shall be within the limit of tolerance. The insulation scheme shall be followed as per the data taken. Where proper material is not available an equivalent type and size may be selected. Turns and tapping of the winding shall be made as in the original.

Method of stacking : Before stacking the core, stampings shall be checked for dents, bends and core insulation. Dents on the core shall be removed, and any mangled core shall be set right. Stacking shall be done as in the original sequence and pattern.

All the stampings available for the transformer shall be stacked without leaving out any. Fig 1 shows the different shapes of cores used for a shell type transformer. Leads shall be properly sleeved and terminated.

Fig 1



Procedure of rewinding a transformer: As stated above, if all the necessary winding details are obtained while disassembling the burnt out transformer, the rewinding procedure is more or less easy. However, if you have to prepare a new transformer the following information will be of great help.

Designing a transformer : Small transformers are generally of 'SHELL TYPE'. In shell type, both the primary and secondary windings are mounted on the centre limb of the core. For designing of a small power transformer proceed as stated below.

STEP NO.1

Find the total output power from the load voltage and current of the transformer.

$P_2 = E_2 \times I_2$ ....Formula 1.

The following example is given for your guidance.

Primary voltage - 240 V

Secondary voltage - 6V

Secondary total current - 2A

From the example the output power is calculated as 6 x 2 = 12VA.

STEP NO.2

Find the input watts.

$$P_1 = \frac{P_2}{\%\,\text{Efficiency}} \qquad \text{....... Formula 2}$$

Normally the efficiency of a transformer will be 80 to 90. As in the example

$$P_1 = \frac{6 \times 2 \times 100}{80} = 15 \text{ VA.}$$

STEP NO.3

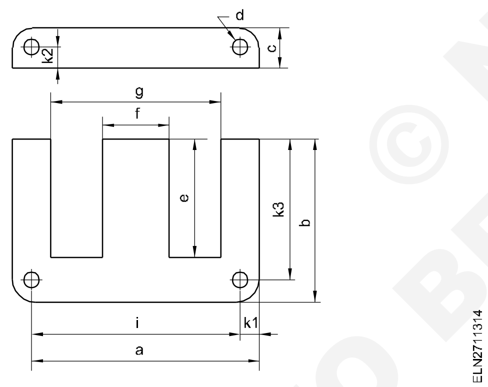
Determine the required cross-sectional area of the core of the transformer.

For finding the cross-sectional area, certain parameters like the flux density of the metal used for laminations, frequency of supply, allowable current density in the winding wire and power input to the transformer need to be known.

Cross section = 20 x 21=420 sq.mm or 4.2 sq. cm

Table 1 gives the standard size of stampings having E and I type laminations as available in the market which is given for your guidance. Fig 2 gives the dimensions of the stampings.

Fig 2



For the core area 4.248 sq.cm we can use the core of dimension having 20 mm as width and core thickness of 21mm.

The nearest size sheet should be selected from the standard size of the stamping table. Here we assume the centre limb width to be 20 mm, and hence, the core E.I. 60 is selected. However, you may select any other type to suit the cross-section. But the other details like the number of stampings and the bobbin dimensions may change accordingly.

STEP NO.4

The next step is to calculate the voltage per turn using Formula 4.

$e = 4.44 \times B \times A \times f \times 10^{-4}$ ....Formula 4.

where e - voltage per turn

B - flux density in tesla

A - area of iron core in cm^2

f - frequency in Hertz

Example

$e = 4.44 \times 0.8 \times 4.24 \times 50 \times 10^{-4} = 0.0753$ volts.

STEP NO.5

Calculate the primary coil turns.

$$N_1 = \frac{240}{0.0753} = 3187 \text{ turns (approx.)}$$

Calculate the secondary coil turns.

$$N_2 = \frac{6}{0.0753} = 80 \text{ turns (approx.)}$$

Add 10% to compensate the voltage drop (internal) in the secondary winding i.e. N_2 = 88 turns.

STEP NO.6

Calculate the size of wire with respect to the input power.

P = E x I ; I = P/E and according to the example,

Primary current = I_1 = 15/240 = 0.0625A

Secondary current = I_2 = 15/6 = 2.5A.

Cross-section of primary conductor considering 3A/mm^2 as current density will be

A = 0.0625/3 = 0.020833 mm^2

Diameter = 0.1628 mm

Say i.e. = 0.160 mm dia. or 37 SWG approximately

Cross-section of secondary conductor considering 3A/mm^2 as current density will be

A = 2.5/3A = 0.8333 mm^2

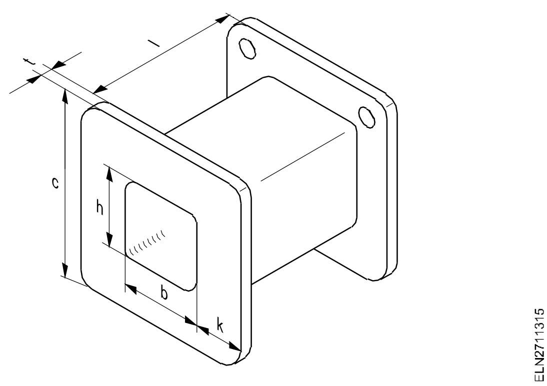
Diameter = 1.029 mm

Say = 1.00 mm dia. Hence 19 SWG.

STEP NO.7

Fig 3 gives the general dimensions of a bobbin. Here the bobbin selected is EI 60/21 which suits the core thickness of the centre limb taken earlier as 21 mm and core width as 20 mm.

Fig 3



STEP NO.8 : Check the feasibility of accommodating the number of turns of primary and secondary within the winding space.

Though the number of turns in the primary is to be 3187 of 37 SWG and the secondary to be 88 turns of 19 SWG super enamelled copper wire, it is atmost important to check whether these windings along with the respective insulation could be accommodated within the winding space of the core. This has to be determined before taking up the winding.

CONCLUSION : For the transformer as in the example, the derived winding data is as follows.

Transformer rating

Primary - 240V

Secondary - 6V

Frequency - 50 Hz

Volt ampere input - 15 VA

Core : Core area 20 x 21 mm as decided in Step 3.

Bobbin: Breadth 20.6 mm, height 21 mm, length 26.7 mm and the total height of the flange 42.7 mm as decided in step 7.

Wire sizes and turns

Primary - 3187 turns of size 0.16 mm or 37 SWG

Secondary - 88 turns of size 1.00 mm or 19 SWG

Stampings: Considering the thickness of each stamping as 0.35 mm, for the total thickness of 21 mm we may require 60 stampings. Considering the space between stampings and the stacking we may require 55 stampings only. Hence EI 60/21 type 55 numbers of stampings having 0.35 mm thickness are to be procured.

Testing of transformer after rewinding: After rewinding the core assembly, the transformer is to be inspected for proper tightness of the core and coil as well as proper termination of the end leads.

Insulation resistance test : Insulation resistance is measured between windings and core with a 500 volts Megger. The reading so obtained shall be infinity and in no case below one megohm.

Transformation ratio test: Keeping the transformer secondary open, the primary shall be connected to the rated AC voltage. With the help of suitable voltmeters both the primary and secondary voltage shall be measured.

Load test : The transformer shall be connected with a suitable load, so that the full load secondary current flows through the secondary of the transformer winding. The raise in the winding temperature shall be observed by a suitable industrial thermometer, on the load.

The transformer temperature will raise initially and after some time the temperature will come to a standstill. This raise in temperature shall be noted and it shall be within the limit of class of insulation of the transformer designed.

Short circuit test : Where it is not possible to load the transformer directly, the secondary winding of the transformer shall be short circuited and the low voltage on the primary shall be adjusted through a dimmerstat so that full load secondary current flows through the secondary winding of the transformer. The transformer so switched on shall be tested for raise in temperature to ascertain the class of insulation.

Generally oil-cooled transformers are of class-A where-as air-cooled transformers may be class 'A' or 'E'.

Table 1
Standard size of stampings

Specification of stampings	a	b	c	d	e	f	g	i	k1	k2	k3
EI42	42	28	7	3.5	21	14	28	35	3.5	—	24.5
EI48	48	52	8	3.5	24	16	32	40	4	—	28
EI54	54	36	9	3.5	27	18	36	45	4.5	—	31.5
EI60	60	40	10	3.5	30	20	40	50	5	—	35
EI66	66	44	11	4.5	33	22	44	55	5.5	—	38.5
EI78	78	52	13	4.5	39	26	52	65	6.5	—	45.5
EI84	84	56	14	4.5	42	28	56	70	7	—	49
EI92	92	62.3	11.3	4.5	51	23	69	82	5	6.5	57.5
EI106	106	70.5	14.5	5.5	56	29	77	94	6	8.5	64.5
EI130	130	87.5	17.5	6.8	70	35	95	115	7.5	10	80
EI150	150	100	20	7.8	80	40	110	135	7.5	12.5	92.5
EI170	170	117.5	22.5	8	95	45	125	150	10	12.5	107.5
EI195	195	134.5	25.5	9.5	109	51	144	171	12	13.5	122.5
EI231	231	166	29	10	137	58	173	204	13.5	15.5	152.5

Nominal thickness of stampings:0.35 mm and 0.5 mm.

General maintenance of three-phase transformers

Objectives: At the end of this lesson you shall be able to
- **explain the need and advantages of maintenance of transformer**
- **state the factors affecting the life of transformers**
- **state the various periodical maintenance to be carried out in a transformer.**

Necessity of maintenance

Power transformer is required to give a long and trouble free service, It should be under constant attention and maintenance as it is a costly device.

A rigid system of inspection and preventive maintenance will ensure long life, trouble free service and low maintenance cost. Maintenance shall consists of regular inspection, testing and reconditioning wherever necessary.

Principal object of maintenance: The principal object of maintenance is to maintain the insulation in good condition. Moisture, dirt and excessive heat in contact with oxygen are the main causes of insulation deterioration and avoidance of these will keep the insulation in good condition.

There will be a decline in the quality of insulation during the ageing process due to chemical and physical effects. The decay of the insulation follows the chemical reaction rate and if the sustained operating temperature exceeds the normal operating temperature of 75^0C by about 10^0C the life of the transformer will get shortened.

FACTORS AFFECTING THE LIFE OF TRANSFORMERS

1 Effect of moisture

Transformer oil readily absorbs moisture from air. The effect of water in the oil is to decrease the dielectric strength of the oil. Therefore preventive steps should be taken to guard against moisture penetration to the inside of transformers. This will include blocking of all openings for free access of air and frequent reactivation of breathers in service.

2 Effect of oxygen

Oxygen present inside the transformer due to air in oil, reacts on the cellulose of insulation. Due to decomposition of the cellulose product, an organic acid soluble in oil is formed which will lead to a thick sludge. This sludge blocks the free circulation of the oil and deposited in bottom there by causing damage to coils/cores.

3 Effect of solid impurities

The dielectric strength of oil is diminished by minute quantities of solid impurities present in the oil. It is therefore a good practice to filter the oil after it has been in service for a short time.

4 Effect of varnishes

Some varnishes particularly of oxidizing type reacts with transformer oil and precipitate sludge on the windings. This should be kept in mind by the maintenance engineer when rewinding and replacing the coils during repairs.

5 Effect of slackness of windings

Slackness of windings may cause a failure due to repeated movement of coils which may wear the conductor insulation at some places and lead to an inter turn failure, momentary short circuit which may cause electric and magnetic unbalance. It is a good practice to lift the core and windings of a transformer and take up any slackness which may have developed by tightening the tie rods.

MAINTENANCE PROCEDURE

1 Safety precautions

i Before starting any maintenance work the transformers should be isolated from the supply and the terminals are earthed.

ii The oil level should be noted before unsealing the tank.

iii No fire should be kept near the transformer while maintenance work is going on.

2 Breather

Generally two types of breathers are used namely

a) Silicagel breather

b) Oil filled silicagel breather

a Silica gel breather

The colour of the crystals changes from blue to pink as the crystals absorbs moisture. When the crystals gets saturated with moisture they become predominantly pink and it should be reactivated / reconditioned.

b Oil filled silicagel breather

Oil available in the oil chamber attached with silicagel breather should be replaced, if it is gel condeminated.

External connections: All terminal connections should be tight. If they appear blackened or corroded, remove the connection and clean down to bright metal with emery paper. Remake the connection and give it a heavy coating of grease.

Earth connections: All earth connections should be properly maintained. A small copper loop to bridge the top cover of the transformer and the tank may be provided to avoid earth fault current passing through the bolts when there is a lightening surge, high voltage surge or failure of bushings.

Bushings: Clean the bushing projection and examine them for cracks and chips. It is recommended to have a spare in stock. In transformers located in control areas to avoid salt formation, a thin coating of grease pasted on the bushings.

Recommended maintenance schedules for transformers of rating less than 1000 KVA is given in Table 1.

Table 1

Maintenance schedule for transformers of capacities less than 1000 KVA

Sl.No.	Inspection Frequency	Items to be inspected	Inspection Notes	Action required during inspection if defects are noticed
1	Hourly	Load (Amperes)	Check against rated figures	Regulated with the values
2	Hourly	Voltage	- do -	- do -
3	Daily	De-hydrating breather	Check that air passages are clear. Check the colour of silica gel.	If silicagel is pink colour re place it or reactivate it.
4	Monthly	Oil level in transformer	Check transformer oil level	If low top-up with dry oil. Examine for oil leakage.
5	Quarterly	Bushings	Examine for cracks and dirt deposits	Clean or replace.
6	Half-yearly	Non-conservator transformer	Check for moisture under cover	Improve ventilation. Check oil
7	Yearly	Oil in transformer	Check dielectric strength acidity and sludge	Restore the quality of oil
8	Yearly	Earth resistance	Check the connection - nuts & bolts	Take suitable action if earth resistance is high.
9	1 year	Relay, alarms their circuits etc.	Examine relay and alarm contacts, their operation fuses etc.,check relay accuracy.	Clean the components, replace contacts change the setting if required
10	2 year	Non-conservator transformers	Internal Inspection	Filter oil regardless of condition
11	3 year	All parts	Overall inspection by lifting of core and coils	Wash by Flushing down with clean dry oil.

Project Work

Objectives: At the end of this lesson you shall be able to
- **define project work**
- **state the purpose of project work**
- **state the steps involving in project works.**

Project work

It is a type of activities which allow the trainees/ students to study, investigate, research, develop a model or find a conclusion/ solution and submit the report for a particular issues/ assignments towards the interest of public, nation and resources etc by applying their skill, ability, knowledge and experience.

Purpose of project work: The general purpose of any project should fulfill anyone or more of the following:

- Overcome the problems/ risks available in existing activities or technology etc.
- Simplifying the existing procedure/ activities of any operation or works.
- Reducing the cost of production or maintenence and increasing the productivity.
- Increasing the safety towards human lives/ machineries.
- Conserve the natural resources.
- Use of renewable energy sources such as wind, tide and solar etc.
- Using of new technology/ concept which is not available in market.
- Broadcasting or predicting any dangers/ risk involves in human lives/ machineries etc.

Steps involved in project works

- Deciding the objectives - purpose
- Deciding what to do - investigating and planning
- Find out the cost - costing
- Arranging the requirements - organising
- Selecting the right people - staffing
- Giving the instructions - directing
- Participating in works - involving
- Arranging the sequence - assembling or compiling
- Executing the project - testing or surveying
- Submitting the result conclusion - reporting

List of projector works may be assigned to the group of trainees as per syallabus

1 Overload protection of electrical equipments.

2 Automatic control of street light/ night lamp.

3 Fuse and power failure indicator using relays.

4 Door alarm/ indicator.

5 Decorative light with electrical flasher.

Scan the QR Code to view the video for this exercise