MECHANIC ELECTRIC VEHICLE

NSQF LEVEL - 4

1st Year

TRADE THEORY

SECTOR: AUTOMOTIVE

(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 : **Automotive**

Duration : **2 Years**

Trade : **Mechanic Electric Vehicle - 1st Year - Trade Theory - NSQF Level - 4 (Revised 2022)**

Developed & Published by

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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 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 Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Mechanic Electric Vehicle - 1st Year - Trade Theory - NSQF Level - 4 (Revised 2022) in Automotive 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 Instructional Media Packages (IMPs) and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

Atul Kumar Tiwari, I.A.S
Secretary
Ministry of Skill Development & Entrepreneur-ship,
Government of India.

October 2023
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 Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabus 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 practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. 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.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

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 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 instructional 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 organisation to bring out this IMP **(Trade Theory)** for the trade of **Mechanic Electric Vehicle 1st Year - NSQF Level - 4 (Revised 2022)** under the **Automotive** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. A. Thangavelu	-	Asst. Training Officer (Retd.,), Govt. I.T.I, Chennai.
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NIMI COORDINATORS

Shri. Nirmalya Nath	-	Deputy Director, NIMI, Chennai - 32.
Shri. S. GopalaKrishnan	-	Assistant Manager NIMI, Chennai - 32.

NIMI records its appreciation of 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 staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the two years course of the **Mechanic Electric Vehicle - Trade Theory - 1st Year** in **Automotive** Trade. The contents are sequenced according to the practical exercise contained in the manual on Trade Theory. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This co-relation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

This manual is divided into Ten modules. The Ten modules are given below

Module 1	Workshop safety practice
Module 2	History of Automobiles
Module 3	Basic electrical and electronics
Module 4	Electric Vehicle Technology
Module 5	Hand and power tools
Module 6	Basic of AC & DC and Electrical cables
Module 7	Maintenance of automobile electrical components
Module 8	Automotive wiring and Electrical accessories
Module 9	Electric vehicle safety systems
Module 10	Automotive basic electricity

TRADE PRACTICAL

The trade practical manual is intented to be used in workshop . It consists of a series of practical exercises to be completed by the trainees during the two years course of the **Mechanic Electric Vehicle - Trade Theory - 1st Year** in **Automotive** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 4 (Revised 2022)

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No.	Learning Outcome	Exercise No
1	Identify and handle different types of tools and workshop equipment in the Auto workshop following safety precautions. (NOS: ASC/N1435)	1.1.01 - 1.1.10
2	Check, identify and interpret different types of vehicles and their specifications. (NOS: ASC/N1435)	1.2.11 - 1.2.15
3	Identify the electrical circuits and test their parameters by using electrical measuring instruments, and the basic electronic circuits and analyse their circuit functioning. (NOS: ASC/N1435)	1.2.16 - 1.3.29
4	Identify and study of Electric vehicle components and Performance comparison of EV and IC engine vehicles. (Components of Electric Vehicle such as Motor, Motor Controller, Battery Pack, Battery Management System, Charging System etc.) (NOS: ASC/N1435)	1.4.30 - 1.4.44
5	Check the automobile systems and sub-systems such as power train, chassis, transmission system, different suspension systems, tyres & wheels (Functions, tyre marking, Tyre Designs), body engineering systems, Safety System etc. and operate garage equipment. (NOS: ASC/N1435, ASC/N1436)	1.4.45 - 1.5.58
6	Trace and Test all Electrical, Electronic components & circuits and assemble circuit to ensure functionality of system. (NOS: ASC/N1435)	1.6.59 - 1.6.69
7	Diagnose, repair and perform maintenance of automobile electrical components & general vehicle architecture. (NOS: ASC/N1435, ASC/N1437)	1.7.70 - 1.7.78
8	Perform checking and troubleshooting of wiring circuits - HV and LV and the electrical components in the electric vehicle. (NOS: ASC/N1435, ASC/N1437)	1.8.79 - 1.8.84
9	Dismantle, diagnose & rectify the defects in vehicle and assemble the vehicle components to ensure functionality of vehicle. (NOS: ASC/N1435, ASC/N1437)	1.9.85 - 1.9.90
10	Read and apply engineering drawing for different application in the field of work (NOS: ASC/N9420)	1.9.91 - 1.10.99

SYLLABUS - MECHANIC ELECTRIC VEHICLE

FIRST YEAR

Duration	Reference Learning Outcomes	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 50 Hrs.; Professional Knowledge 10 Hrs.;	Identify and handle different types of tools and workshop equipment in the Auto workshop following safety precautions. (NOS: ASC/N1435)	1. Importance of trade training, List of tools & Machinery used in the trade. (05 hrs) 2 Safety attitude development of the trainee by educating them to use Personal Protective Equipment (PPE). (05 hrs) 3 First Aid Method and basic training. (05 hrs) 4 Safe disposal of waste materials like cotton waste, metal chips/ burrs etc. (05 hrs) 5 Hazard identification and avoidance. (05 hrs) 6 Safety signs for Danger, Warning, caution & personal safety message. (05 hrs) 7 Preventive measures for electrical accidents & steps to be taken in such accidents. (05 hrs) 8 Use of Fire extinguishers. (07 hrs) 9 Practice and understand precautions to be followed while working in fitting jobs. (05 hrs) 10 Safe use of tools and equipment used in the trade. (03 hrs)	All necessary guidance to be provided to the newcomers to become familiar with the working of Industrial Training Institute system including stores procedures. Soft Skills, its importance and Job area after completion of training. Importance of safety and general precautions observed in the in the industry/ shop floor. Introduction of First aid. Operation of electrical mains and electrical safety. Introduction of PPEs. Response to emergencies e.g.; power failure, fire, and system failure. Importance of housekeeping & good shop floor practices. Introduction to 5S concept & its application. Occupational Safety & Health: Health, Safety and Environment guidelines, legislations & regulations as applicable. Basic understanding on Hot work, confined space work and material handling equipment. (10 Hrs)
Professional Skill 50 Hrs.; Professional Knowledge 10 Hrs.	Check, identify and interpret different types of vehicles and their specifications. (NOS: ASC/N1435)	11 Demonstrate the Comparison among commercialand passenger vehicle such as decision making in finding the driving wheels in both cases. (05 hrs) 12 Demonstration and Classification of vehicles based on various categories such as Body Type, Load, Fuel used, Power source used, no. of wheels, transmission used, Placement & position of engine, transmission & Steering system, no. of axles, braking system used, differential & final reduction etc. (10 hrs) 13 Demonstration on identifying the car body styles and the reason behind. (15 hrs)	Study of automobiles, History of Automobile, Evolution and growth of the Industry, Key Automobile Companies and their Products. Brief description of components and their locations. Study the Classification of Automobiles based on various aspects and determining the reason (Commercial, Passenger), Product Segments (Criteria for Vehicle Types, Variants and Versions, Markets: India, EU and US). Introduction and uses of Vehicle hoists – brief introduction Two post and four post hoist, Engine hoists, mechanical Jacks, Hydraulic jacks, Stands etc. (10 Hrs)

		14 Demonstration of vehicle specification. Identification of vehicle information Number. (10hrs) 15 Study two different vehicles and prepare a report to show differences between these two vehicles. (10 hrs)	
Professional Skill 75 Hrs; Professional Knowledge 15 Hrs	Identify the electrical circuits and test their parameters by using electrical measuring instruments, and the basic electronic circuits and analyse their circuit functioning. (NOS: ASC/N1435)	16 Practice in joining wires using soldering Iron, Construction of Simple electrical circuits, Crimping of connectors. (10 hrs) 17 Measuring of current, voltage and resistance using digital multimeter, practice. (10 hrs) 18 Continuity test for fuses, jumper wires, fusible links, circuit breakers. (05 hrs) 19 Identify and Diagnose series, parallel, series- parallel circuits using Ohm's law, Check electrical (05 hrs) 20 Prepare circuit with a test lamp, perform voltage drop test in circuits using multimeter. (05 hrs) 21 Measure current flow using multimeter /ammeter, use of service manual wiring diagram for troubleshooting. (10 hrs) 22 Testing of relay and solenoids and its circuit. (05 hrs) 23 Identify and test power and signal connectors for continuity. (03 hrs) 24 Identify and test different type of Diodes. (04 hrs) 25 NPN & PNP Transistors for its functionality. (03 hrs) 26 Difference between MOSFET and IGBT. (03 hrs) 27 Construct and test simple logic circuits OR, AND & NOT and Logic gates using switches. (04 hrs) 28 Construct circuit to read temperature and pressure sensor. (04 hrs) 29 Construct PWM generator. (04 hrs)	Basic electricity: Electricity principles, Ground connections, Ohm's law, Voltage, Current, Resistance, Power, Energy. Voltmeter, ammeter, Ohmmeter Mulitmeter, Conductors & insulators, Wires, Shielding, Length vs. resistance, Resistor ratings. Capacitors and Coils Fuses & circuit breakers, Ballast resistor, Stripping wire insulation, cable colour codes and sizes, Resistors in Series circuits, Parallel circuits and Series-parallel circuits, Electrostatic effects, Capacitors and its applications, Capacitors in series and parallel Cells in series and parallel Magnetic effects, Heating effects, Thermo-electric energy, Thermistors, Thermo couples, Electrochemical energy, Photovoltaic energy, Piezoelectric energy, Electromagnetic induction, Relays, Solenoids, Primary & Secondary windings, Transformers, stator and rotor coils. Basic electronics: Electrical and Electronic Components: - Switches Description of Normally open, Normally closed, single pole single throw switch (SPST), ganged, and mercury switches used in Automobile circuit. Description of Relay, ISO Relays, Solenoids, Buzzers. Resistors- Description of different type of resistors and their colourcodes. - Fixed, stepped, and variable resistors Rheostat, Potentiometer. Description of Diodes, Diode identification and ratings, zener diodes, Avalanche diodes, Light emitting diodes, photo diodes and clamping diodes. Transistors- Description of NPN, PNP, field-effect, transistor (FET), IGBT, phototransistors. Description of Integrated circuits.

			Circuit protection Devices- Description of fuses, different type of fuses- glass or ceramic, blade and bullet or cartridge fuses. Fusible links, maxi fuses, circuit breaker, Positive Temperature coefficient (PTC) resistor device Logic gates-OR, AND & NOT and Logic gates using switches. Input and Output Interfacing. PWM Generation. (15 Hrs)
Professional Skill 140 Hrs.; Professional Knowledge 25 Hrs.	Identify and study of Electric vehicle components and Performance comparison of EV and IC engine vehicles. (Components of ElectricVehicle such as Motor, Motor Controller, Battery Pack,Battery Management System, Charging System etc.) (NOS: ASC/ N1435)	30 Identify and test different types of diodes. (05 hrs) 31 Practice using digital meters such as power analyzer AC DC clamp meters, Lux meters. (10 hrs) 32 Test and identify different types of transistors. (10 hrs) 33 Study report on current adoption status of BEV, HEV, PHEV, FCEV type vehicles. (15 hrs) 34 Identify and study performance of Electric vehicles, in comparison to IC engine vehicles. (05 hrs) 35 Identification and study of basic components of EV (05 hrs) 36 Identify various gauges/ instrument on dashboard of an electric vehicle and identify differences in instrumentation panel with IC engine vehicle. (10 hrs) 37 Basic motor power calculation. (10 hrs) 38 Selection,sizing and haracteristic of motor. (10 hrs) 39 Study and hands on of electric transmission. (10hrs) 40 Identification of components specific to EV and how they are in comparison to IC engine-based vehicle. (10 hrs) 41 Calculation of motor effort. (10 hrs) 42 Check the proper voltage, various practical work related to chopper circuit. (10 hrs) 43 Testing of amplifier, output torque, efficiency testing at different condition. (10 hrs) 44 Practice and hands on Bearing replacement,greasing, replacing the copper windings on stator. (10 hrs)	Introduction to Electric Vehicle Technology, EV Terminology Comparison of Electric Vehicle with IC engine vehicle based on emissions, range, fuel type. Types of electric vehicle, BEV, HEV, PHEV and FCEV. Architecture of Electric Vehicle, working principle of fully electric vehicle, Major component, performance parameter, Basics of Motors, Selection, sizing and characteristic of Motor, calculation for motor effort, electric transmission. Principle, working and operation of propulsion system, DC Motor - Drives Armature Voltage, chopper circuit, step up, Step down chopper, control strategy, chopper amplifier. Brushless DC Motor – principle working, features, speed control system of brushless DC motor, efficiency, calculation. (25 Hrs)

Professional Skill 150 Hrs.; Professional Knowledge 30 Hrs.	Check the automobile systems and sub-systems such as powertrain, chassis, transmission system, different suspension systems, tyres & wheels (Functions, tyre marking, tyre Designs), body engineering systems, safety system etc. and operate garage equipment. (NOS: ASC/N1435, ASC/N1436)	45 Demonstration on Identification of Various Automobile systems and subsystems. (12 hrs) 46 Comparative analysis on body over chassis & Monocoque body. (09 hrs) 47 Practical to identify the External and Internal Body Components and their Functions. (09 hrs) 48 Draw suitable sketches to show functions of various components. (10 hrs) 49 Demonstration on Identification of powertrain & its type. (10 hrs) 50 Demonstration on Identification of transmission & driveline components. (14 hrs) 51 Demonstration on Identification of Steering systems. (10 hrs) 52 Demonstration on Identification of suspension systems. (14 hrs) 53 Demonstration on Identification of disc and drum brakes, warning & safety devices. (12 hrs) 54 Practice to measure a wheelbase of a vehicle with measuring tape. (10 hrs) 55 Practice to remove wheel lug nuts with use of an air impact wrench. (10 hrs) 56 Practice on General workshop tools & power tools. (10 hrs) 57 Practice to check the air pressure inside the vehicle tires is maintained at the recommended setting. (10 hrs) 58 Practice on loosening and tightening of various screws, nuts and bolts using tools. (10 hrs)	Functional Introduction to various automotive systems and sub systems. Power Train: Introduction to engines and its types, transmission and driveline systems. Chassis System: Chassis and Monocoque body, Steering Systems, Suspension System(Its functions & different components, different types like Double Wishbone, trailing twist axle suspension, Macpherson Srut suspension, etc), Brakes etc. Functions of Tyres and Wheels, Introduction to JATMA/ ATMA/ ETRTO standards, Tyres and Wheels markings. Tyre selection considerations for automobile, Tyre Designs- Diagonal vs Radial Ply, Tubed vs Tubeless, Wheel Alignment. Body Engineering: Styling, Exterior, Interior, trims etc. Vehicle Integration: DMU, Ergonomics, Layout and Packaging studies. Marking scheme, Marking material-chalk, Prussian blue. Cleaning tools- Scraper, wire brush, Emery paper, Description, care and use of Surface plates, steel rule, measuring tape, try square vacuum gauge, tire pressure gauge. Details of various types of marking and cutting tools- punch, scriber, hammer and mallets, hack saw frame and blade, chisels Threads-thread categorization- types of threads- types of screwed joints-types of nuts- property classes of bolts- screw locking arrangements-types and description of screwing tools. (30 Hrs)
Professional Skill 100 Hrs.; Professional Knowledge 20 Hrs.	Trace and Test all Electrical, Electronic components & circuits and assemble circuit to ensure functionality of system. (NOS: ASC/N1435)	59 Identify the Phase, Neutral and Earth on power socket, use a tester to monitor AC power. (09 hrs) 60 Construct a test lamp and use it to check the health of mains. (09 hrs) 61 Measure the voltage between phase and ground and rectify earthing. (05 hrs) 62 Identify and test different AC mains cables. (05 hrs)	Basics of AC & DC. Various terms such as +ve cycle, -ve cycle, Frequency, Time period, RMS, Peak, Instantaneous value. Single phase and Three phase supply. Terms like Line and Phase voltage/ currents. Insulators, conductors and semiconductor properties. Different type of electrical cables and their Specifications. Types of wires & cables, standard wire gauge (SWG).

		63 Prepare terminations, skin the electrical wires /cables using wire stripper and cutter. (08 hrs) 64 Measure the gauge of the wire using SWG and outside micrometer. (09 hrs) 65 Refer table and find current carrying capacity of wires. (05hrs) 66 Crimp the lugs to wire end. (05 hrs) 67 Measure AC and DC voltages using multi meter (10 hrs) 68 Practice in joining wires using soldering Iron, Construction of simple electrical circuits, measuring of current, voltage and resistance using digital multimeter, practice continuity test for fuses, jumper wires, fusible links, and circuit breakers (16 hrs) 69 Diagnose series, parallel, series-parallel circuits using Ohm's law, check electrical circuit with a test lamp, perform voltage drop test in circuits using multimeter, measure current flow using multimeter /ammeter, use of service manual wiring diagram for troubleshooting. (19 hrs)	Classification of cables according to gauge (core size), number of conductors, material, insulation strength, flexibility etc. Basics of electricity, Electricity principles, Ground connections, Ohm's law, Voltage, Current, Resistance, Power, Energy. Voltmeter, ammeter, Ohmmeter, Multimeter, Conductors & insulators, Wires, Shielding, Length vs. resistance, Resistor ratings. Fuses & circuit breakers, Ballast resistor, Stripping wire insulation, cable color codes and sizes, Resistors in Series circuits, Parallel circuits and Series-parallel circuits, Electrostatic effects, Capacitors and its applications, Capacitors in series and parallel. (20 Hrs)
Professional Skill 125 Hrs.; Professional Knowledge 20 Hrs.	Diagnose, repair and perform maintenance of automobile electrical components & general vehicle architecture. (NOS: ASC/N1435, ASC/N1437)	70 Carry out study about new types of battery and suggest improvements to the main limiting factors to batteries, battery fault, battery testing. (10 hrs) 71 Familiarization of electrical and electronics components on vehicle (10 hrs) 72 Hands on removing and fitting basic mechanical, electrical and trim components. (15 hrs) 73 Instrumentation and signaling system Gauges & Meters: Mandatory & additional gauges, Engine/ Motor temperature gauge, Charging gauge,Speedometer, Tachometer diagnostics (15 hrs) 74 Perform fault diagnosis on electrical wiring harness. (20 hrs) 75 Familiarization and Types & Classification of Switches,	Introduction to automobile electrical architecture & power supply systems, Nomenclature of auto electrical systems, Typical layouts. General vehicle Architecture System Understand basic circuit diagrams and symbols Instrument Cluster: Different types, Tell-Tales. Electrical Distribution System: Wire, Fuse, Relay etc. selection process, Voltage, Drop Analysis, Grounding and Splicing Strategy Wiring Harness Design: Harness Topology. Familiarization and Types & Classification of Switches. Diagnostics, fault finding and Root cause analysis for electrical system. (20 Hrs)

		Steering lock cum ignition switch. (15 hrs) 76 Combi Switch, Fascia switches, Headlamp levelling switch, mirror adjustment switches, Front & Rear fog lamp switches. (20 hrs) 77 Hazard switch, Window winding switch, Heated rear window switch, HVAC Control panel switches, Steering wheel switches. (10 hrs) 78 Remove and install power door lock and tracing the circuit. (10 hrs)	
Professional Skill 50 Hrs.; Professional Knowledge 10 Hrs.	Perform checking and troubleshooting of wiring circuits - HV and LV and the electrical components in the electric vehicle. (NOS: ASC/N1435, ASC/N1437)	79 Identify Wire Gauge required based on Current Capacity. (04 hrs) 80 Select Fuse for circuit protection. (04 hrs) 81 Diagnose and carry out remedial action as per the OEM Manual - Horns, Wiper Motor, Power Windows. (04 hrs) 82 Discuss and demonstrate personal and shop safety procedures and use appropriate attire and protective equipment. (05 hrs) 83 Operate equipment according to safety protocols and identify tools, tests equipment and service procedures used in the servicing of EV and HEV's. (05 hrs) 84 Practice to identify components and their locations indicated on the wiring diagram. (04 hrs)	Wiring and circuit diagrams Automotive Wiring- difference between primary wiring and secondary wiring. Comparison between solid and stranded primary wire. Description of wire size- Metric and American wire gauge (AWG), Importance of ground straps used in automotive wiring. Description of different type of terminals and connectors Molded, multiple-wire hard shell, bulkhead, weather- pack, metri-pack, heat- shrink covered butt connectors. Importance of printed circuit boards, wiring harnesses, wiring diagrams and color codes and circuit numbering. Study of common electrical and electronic symbols used in wiring diagrams Accessories: Horn circuit, wiper circuit, power window components and circuit. Power door lock circuit, automatic door lock circuit, remote keyless entry system circuit, antitheft system, immobilizer system. Navigation system, Car infotainment system, car videos. (05 hrs)
		85 Practice to identify the power source, ground connection, and controls for electrical circuits using a wiring diagram. (04 hrs) 86 Explain vehicle safety systems' including disconnects; interlock loops etc. (04 hrs) 87 Identification of Wire Thickness using wire Gauge, Stripping & Crimping of wire. (04 hrs)	Description and function of Airbags, Seatbelt, Vehicle safety systems, Crash sensors, Seat belt pre- tensioners, Tire pressure monitoring systems, Integrated communications, Proximity sensors, Reflective displays, Global positioning satellites, Triangulation/ trilateration, Telematics.

		88 Diagnose, repair, and test DC/DC converters. (04 hrs) 89 Check Inverter Assembly. (04 hrs) 90 Use Scan Tool. (04 hrs) controls for electrical circuits using a wiring diagram. (04 hrs) 86 Explain vehicle safety systems' including disconnects; interlock loops etc. (04 hrs) 87 Identification of Wire Thickness using wire Gauge, Stripping & Crimping of wire. (04 hrs) 88 Diagnose, repair, and test DC/DC converters. (04 hrs) 89 Check Inverter Assembly. (04 hrs) 90 Use Scan Tool. (04 hrs)	Application of Automotive bus system- currently used in cars: CAN (Control Area Network), LIN (Local Interconnect Network), FlexRay™ and MOST (Media Oriented Systems Transport)., Importance of E/E Architecture. High Voltage Elements - PDU, Voltage Converters, Switching Devices, HV - Diagnostics and Troubleshooting, HV Cabling - Repair, Safety Certification, HVIL, Isolation Testing Power Electronics - Inverter and Voltage Converters, Introduction to Scan Tool and reading vehicle diagnostics. (05 Hrs)
Professional Skill 100 Hrs.; Professional Knowledge 20 Hrs.	Dismantle, diagnose & rectify the defects in vehicle and assemble the vehicle components to ensure functionality of vehicle. (NOS: ASC/N1435, ASC/N1437)	91 Hand on assemble and disassembly of several vehicle components as per vehicle manual. (20 hrs) 92 Study of various screws, nuts and bolts and hands on how to use both power tools and hand tools for disassembly. (10 hrs) 93 Check measuring of voltage drop. (05 hrs) 94 Identify and interpret electrical system concern. (15 hrs) 95 Perform measuring of circuit voltage, ampere and resistance. (05 hrs) 96 Practice on testing fuses and relays. (15 hrs) 97 Practice on Brazing wires. (10 hrs) 98 Practical on soldering wires. (10 hrs) 99 Check, Perform practical, identify and test power and signal connectors for continuity. (10 hrs)	Understanding Assembly and disassembly processes from vehicle manual. Thread categorization- types of threads- types of screwed joints- types of nuts- property classes of bolts- screw locking arrangements- types and description of screwing tools. General principles of electrical engineering- structure of atoms- voltage- current- fuses- electrical conduction- current direction- types of current- voltage drop- resistance- PTC and NTC resistors- types of resistors- ohm's law- resistor circuits- electro magnetism- electromagnetic induction solenoids - description of multimeter- function and types of relays- semiconductors. (20 Hrs)

Organisation structure of the industrial training institute

Objectives: At the end of this lesson you shall be able to
- **state the organizational structure of the I.T.I**
- **state the General discipline in the institute**
- **state the Scope of mechanic Electric Vehicle.**

Organisation structure of industrial training institute (ITI): The industrial training institute plays a vital role in economy of our country and in terms of providing skilled manpower for the global needs.

The directorate of training comes under ministry of skill development and entrepreneurship (MSME) it offer a range of vocational training trades in different sectors based on economy / labour market. The vocational training programmes are delivered under the aegis of national council of vocational training. They are given training in various trades including engineering and non engineering trades. The training duration is as 6 month, 1 year, 2 Year. The minimum eligibility for admission in I.T.I 8th, 10th, 12th and above with respect ot the trades and admission process will be held in every year in July.

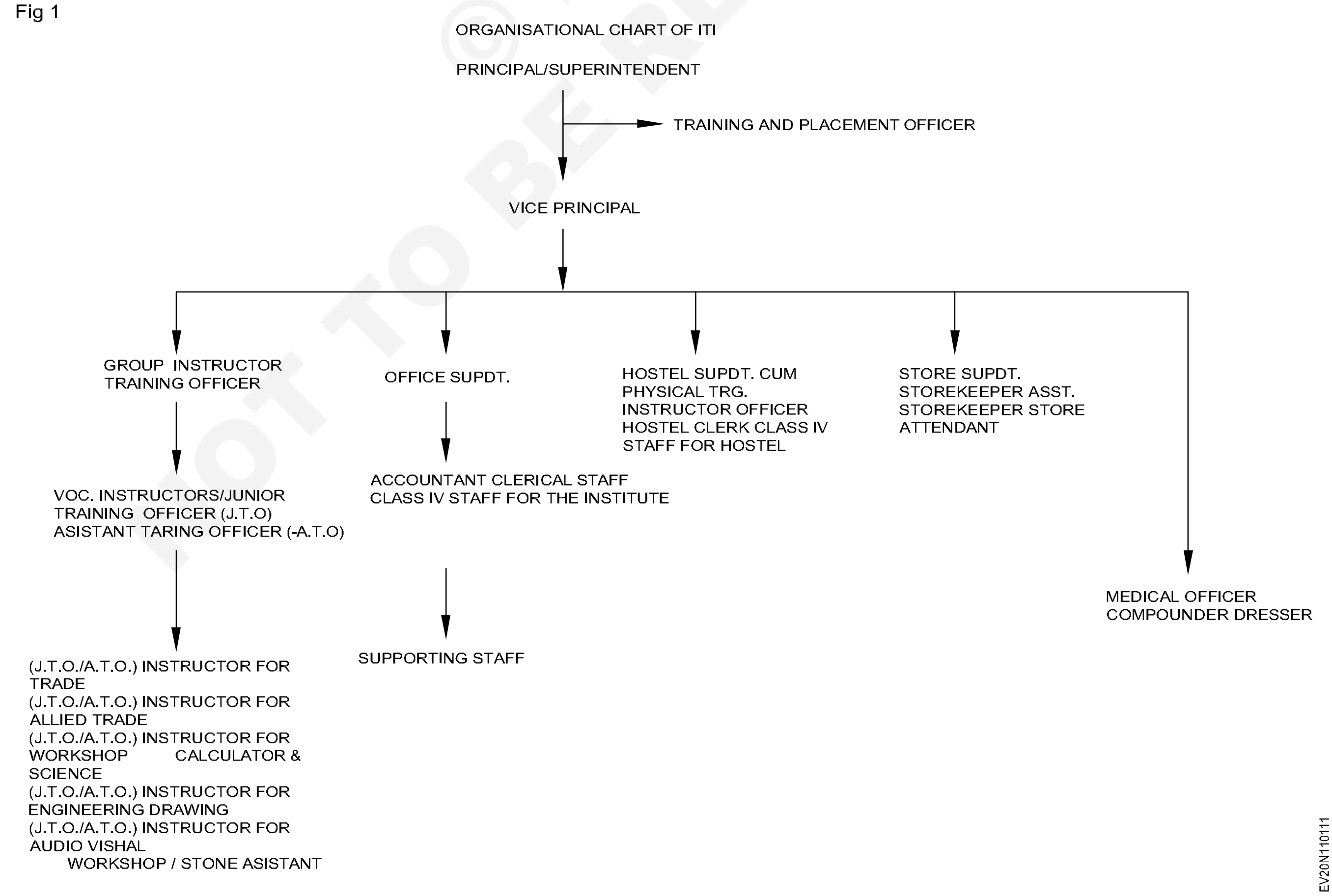
From 2018 annual pattern was introduced with implemented revised syllabus.

At the end of each year. All India Trade Test (AITT) will be conducted in every year July month with OMR answer sheet pattern, with multiple choice type of questions. After passing, National trade certificate (NTC), will be issued by DGT which is authorized and recognized by internationally.

After completion of industrial training with 'NTC' certificate, they have to undergo Apprenticeship training (ATS) for one or two year with respect to 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.

The head of the industrial training institute is the principal under whom there is one vice principle accounts officer and other technical and non technical staffs are working in the organisation. The structure of organisation is as follows. (Fig 1)

Fig 1



General Discipline in the Institute:

- Always be polite, courteous while in institute.
- Do not arguments with others, on matters of related to your training or with the office issues while seeking clarifications.
- Do not bring bad name to your institute by your improper habitude.
- Do not waste your precious time in gossips with your friends and on activities other than trainings.
- Do not be late to the theory practical and other classes.
- Do not interfere in other's activities.
- Atlentive and listen to the lecture carefully during the theory class and practical demonstration given by the instructor.
- Give respect to your trainer and all other staffs and co-trainees in your institute.
- Be interested in all the training activities.
- Do not make noise and play while undergoing training.
- Keep the institute premises neat and clean and avoid polluting the environment.
- Do not take away any material from the institute which does not belong to you.
- Always attend the institute well dressed and good physical appearance.
- Be regular to attend the training without fail and avoid absent from the theory or practical classes.
- Prepare well before writing a test/examination.
- Avoid any malpractice during the test/examination.
- Write your theory and practical records regularly and submit them on time for correction.
- Take care of your safety as well as other's safety while doing the practicals.

Time-Table

Practical and theory class hours are schedulated in advance and working hours as generally 8 hrs.

Facilities in I.T.I

Hostel, first aid provision, visiting doctor's and facility libraries and available in mandatory of the I.T.I'S

Course content in the syllabus

- Identify and handle different type of tools and workshop equipments.
- Check, identify and interpret different type of electric vehicle and their specification
- Identify and study of electric vehicle components
- Comparison of EV with IC engine vehicle
- Check the automobile systems
- Diagnose, repair and perform maintenance of automobile electrical components & general vehicle architecture
- Dismantle, diagnose & rectify the defects in vehicle and assemble the vehicle components.

Learning activities of trainee's

- Read & interpret technical parameters/documentation, plan and organize work processes, identify necessary materials and tools.
- Perform task with due consideration to safety rules, accident prevention regulations and environmental protection stipulations.
- Apply professional knowledge, core skills & employability skills while performing the job and machining work.
- Check the job/components as per drawing for functioning identify and rectify errors in job/ components.
- Document the technical parameters related to the task undertaken.

Scope of mechanic Electric Vehicle Trainee's: Mechanic Electric Vehicle trade under CTS is delivered nationwide through a network of ITI's. The course duration is two years.

Progression Pathways of Mechanic Electric Vehicle

- Can join industry as EV Technician and will progress further as Senior Technician, Supervisor and can rise up to the level of Manager.
- Can become Entrepreneur in the related field.
- Can appear in 10+2 examination through National Institute of Open Schooling (NIOS) for acquiring higher secondary certificate and can go further General/ Technical education.
- Can take admission in diploma course in notified branches of Engineering by later entry.
- Can join Apprenticeship programme in different types of industries leading to National Apprenticeship certificate (NAC).
- Can join Crafts Instructor Training Scheme (CITS) in the trade for becoming instructor in ITI's.
- Can join Advanced Diploma (Vocational) courses under DGT as applicable.

Job opportunity after completion of training.

- Electric Vehicle technician in EV dealer point
- Can join in Central and State Government establishment
- Can join EV manufacturing industry
- Can start Electric Vehicle service centre
- Can start Electric Vehicle charging station
- Can start own Electric Vehicle repair workshop

Store procedure is I.T : The instructor has to be responsible for providing the materials for training practical for week days. He has to be demand the material in store according to practical of the week and collect the material from store and take charge on ledger and issue to the trainee's for do the practical work.

on complation of practical, instructor has to be collect the old material and deposit it in to the store. There after reduce the charge quantity in his ledger. The trainee's can collect the special tools from the store for their practical work by entry in the store tools registor. The trainee's are responsible for tools draw and deposit in store.

Soft skill: The modern vehicle are occupid with electrical and electronic devices. That devices are operated by specified software. so that trainee's need to upgrade their skill in modern vehicle software to shine in auto mobile field The electrical and electronic circuit components and software may be differ from vehicle to vehicle refer the paricular vehicle's manual for correct specifications.

Importance of health and safety

Objectives: At the end of this lesson you shall be able to
- **Define safety**
- **State the goal of health and safety**
- **Explain need of health and safety**
- **List the types of hazards.**

Safety

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

Employees health and safety.

- Employees 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 impacted by the workplace environment.
- It involves interactions among many related areas, including occupational medicine, occupational (or industrial) hygiene, public health, and safety engineering, chemistry, and health physics.

Need of employees health and safety.

- Health and safety of the employees is an important aspect of a company's smooth and successful functioning.
- It is a decisive factor in organizational effectiveness. It ensures an accident-free industrial environment.
- Proper attention to the safety and welfare of the employees can yield valuable returns.
- Improving employees morale
- Reducing absenteeism.
- Enhancing productivity
- Minimizing potential of work-related injuries and illnesses
- Increasing the quality of manufactured products and or rendered services.

Work place (Industrial) Hygiene

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

Anticipation (Identification): Methods of identification of possible hazards and their effects on health.

Recognition (Acceptance) : Acceptance of ill-effects of the identified hazards

Evaluation (Measurement & Assessment): Measuring or calculating the hazard by instruments, Air sampling and Analysis, comparison with standards and taking judgment 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

Work Place Hazards:

"Source or situation with potential for harm in terms of injury or ill health, damage to property, damage to the workplace environment, or a combination of these"

Types of workplace health hazards of employees

1 Physical Hazards	2 Chemical Hazards
3 Biological Hazards	4 Physiological Hazards
5 Psychological Hazards	6 Mechanical Hazards
7 Electrical Hazards	8 Ergonomic Hazards.

1 Physical Hazards

- Noise
- Heat and cold stress
- Vibration
- Radiation (ionising & Nonionising)
- Illumination etc.,

2 Chemical Hazards

- Inflammable
- Explosive
- Toxic
- Corrosive
- Radioactive

3 Biological Hazards

- Bacteria
- Virus
- Fungi
- Plant pest
- Infection

4 **Physiological**

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

5 **Psychological**

- Wrong attitude
- Smoking
- Alcoholism
- Unskilled
- Poor discipline
  - absertecism
  - disobedience
  - aggressive behaviours
- Accident proneness etc,
- Emotional disturbances
  - violence
  - bullying
  - sexual harassment

6 **Mechanical**

- Unguarded machinery
- No fencingt
- No safety device
- No control device etc.

7 **Electrical**

- No earthing
- Short circuit
- Current leakage
- Open wire
- No fuse or cut off device etc,

8 **Ergonomic**

- Poor manual handling technique
- Wrong layout of machinery
- Wrong design
- Poor housekeeping
- Awkward position
- Wrong tools etc,

Safety Slogan

A Safety rule breaker, is an accident maker

Safety practice

Objectives: At the end of this lesson you shall be able to
- **state the causes for accidents in general terms**
- **state the safe attitudes**
- **list out the four basic categories of safety signs.**

Causes for accidents: Normally accidents do not just happen. They are caused.

Causes for accidents are many. Some of the important causes are listed below.

- Unawareness of danger
- Disregard for safety
- Negligence
- Lack of understanding of proper safety procedures
- Untidy condition of workplace
- Inadequate light and ventilation
- Improper use of tools
- Unsafe conditions

Safe attitudes: People's attitudes govern what they have to do or fail to do. In most cases where someone is working with unsafe equipment or in an unsafe situation, somebody has allowed that state of affairs to come about by something they have done or failed to do.

Most accidents don't just happen; they are caused by people who (for example) damage equipment or see it is faulty but don't report it, or leave tools and equipment lying about for other people to trip over.

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 planning and organising work, by training the people, and engaging the 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, in the working conditions, which employees are asked to do, and the training given to them.

Employee's responsibilities: You will be responsible for use the equipment, with safety precaution and the experience of your training, and your general attitude to safety work and follow the organisation standing orders.

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 procedures 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
- Mandatory signs
- Warning signs
- Information signs

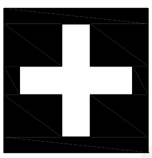
Prohibition signs (Fig 1)

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

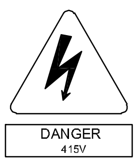
Shape	Circular.
Colour	White symbol on blue background.
Meaning	Shows what must be done.
Example	Wear hand protection.

Warning signs



Shape	Triangular.
Colour	Yellow background with black border and symbol.
Meaning	Warns of hazard or danger.
Example	Caution, risk of electric shock.

Information signs



Shape	Square or oblong.
Colour	White symbols on green background.
Meaning	Indicates or gives information of safety provision.
Example	First aid point.

Prohibition signs (Fig 2)

Fig 2

Mandatory signs (Fig 3)

Fig 3

MANDATORY SIGNS

Warning signs (Fig 4)

Fig 4

WARNING SIGNS

Questions about your safety

Do you know the general safety rules that cover your place of work?

Are you familiar with the safety laws that cover your particular job?

Do you know how to do your work without causing danger to yourself, your workmates and the general public?

Are the plant, machinery and tools that you use really safe? Do you know how to use them safely and keep them in a safe condition?

Do you wear all the right protective clothing, and have you been issued with all the necessary safety equipment?

Have you been given all the necessary safety information about the materials used?

Have you been given training and instruction to enable you to do your job safely?

Do you know who is responsible for safety at your place of work?

Do you know who are the appointed `Safety Representatives'?

- Stop the machine before changing the speed.
- Disengage the automatic feeds before switching off.
- Check the oil level before starting the machine.
- Before starting the machine, move the ram by hand to ensure that the ram or tool-handler does not strike the workpiece or table.
- Never start a machine unless all the safety guards are in position.
- Take measurements only after stopping the machine.
- Use wooden planks over the bed while loading and unloading heavy jobs.
- Do not stop the machine before the finish of the cutting stroke.

Safety is a concept, understand it.

Safety is a habit, cultivate it.

Knowledge of personal safety and general precautions observed in the shop

Objectives: At the end of this lesson you shall be able to
- **state the personal protective equipment and its purpose**
- **name the two categories of personal protective equipment**
- **list the most common type of personal protective equipment**
- **list the conditions for selection of personal protective equipment**
- **state the safety precaution in handling diesel machines.**

Personal Protective Equipment (PPE)

Devices, equipment, clothing are used by the employees, as a last report, 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). Engineering methods could include design change, substitution, ventilation, mechanical handling, automation, etc.

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

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 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 consistent will help to avoid some common kinds of industrial accidents.
- Personal protective gear 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.

They are to meet the applicable BIS (Bureau of Indian Standards) standards for different types of PPE.

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

Fig 1

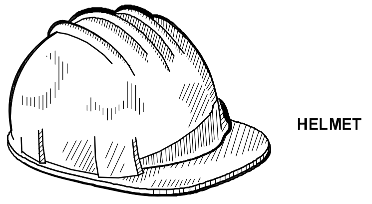


Fig 2

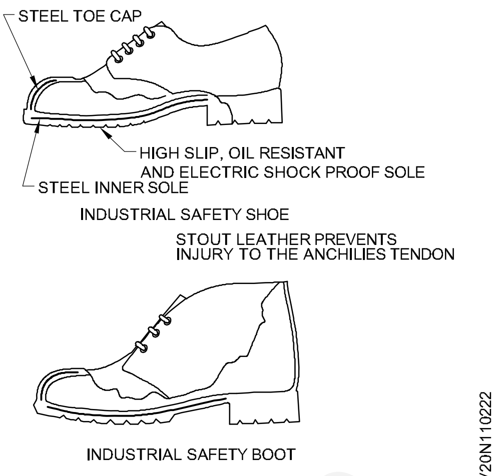
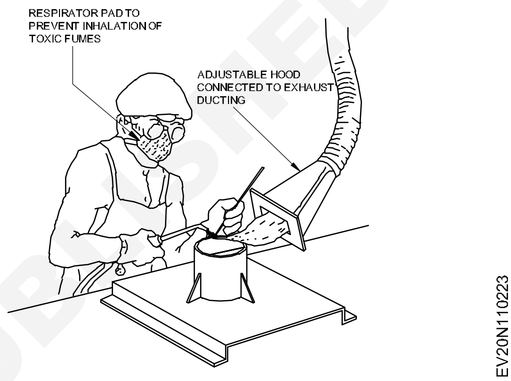


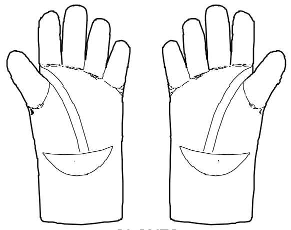
Fig 3



Common type of personal protective equipments and their uses and hazards are as follows

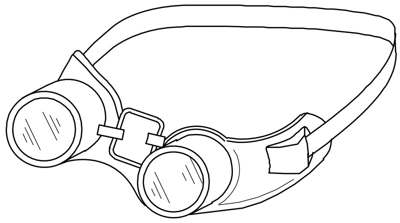
Types of Protection	Hazards	PPE to be used
Head protection (Fig 1)	1 Falling objects Helmets 2 Striking against objects 3 Spatter	Helmets
Foot protection (Fig 2)	1 Hot spatter 2 Falling objects 3 Working wet area	Leather leg guards Safety shoes Gum boots
Nose (Fig 3)	1 Dust particles 2 Fumes/ gases/ vapours	Nose mask
Hand protection (Fig 4)	1 Heat burn due to direct contact 2 Blows sparks moderate heat 3 Electric shock	Hand gloves
Eye protection (Fig 5, Fig 6)	1 Flying dust particles 2 UV rays, IR rays heat and High amount of visible radiation	Goggles Face shield Hand shield Head shield
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 welders screen for welders
Ear protection (Fig 7)	1 High noise level	Ear plug Ear muff
Body protection (Fig 8, Fig 9)	1 Hot Particles	Leather aprons

Fig 4



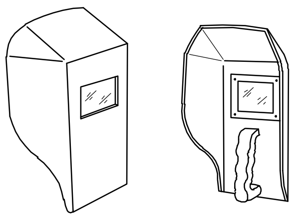
GLOVES

Fig 5



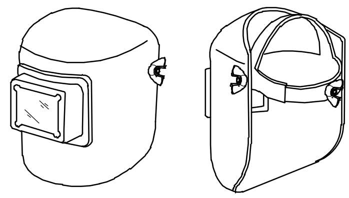
GOGGLES

Fig 6



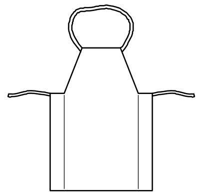
HAND SCREEN

Fig 7



WELDING HELMET

Fig 8



APRON

Fig 9

LEG GUARDS

Elementary first-aid

Objectives: At the end of this lesson you shall be able to
- **define first aid**
- **list out the first aid key points**
- **describe the ABC of first aid**
- **determine the responsiveness.**

Introduction to First aid:

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life.

First aid procedure often consists of simple and basic life saving techniques that individual performs with proper training and knowledge.

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 place them in the recovery position, with the patient learnt over on their side, which also has the effect of clearing the tongue from the pharynx. The first aider will be taught to deal with this through a combination of 'back slaps' and 'abdominal thrusts'. Once the airway has been opened, the first aider would assess to see if the patient is breathing.
- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.
- **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.

ABC of first aid

ABC stands for airway, breathing and circulation.

- **Airways:** 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.

When providing first aid one needs to follow some rule. There are certain basic norms in teaching and training students in the approach and administration of first aid to sick and injured.

Important guideline for first aiders

Evaluate the situation

Are the things that might put the first aider at risk. When faced with accidents like fire, toxic smoke, gasses, an unstable buildings, 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.

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 hishead.

First aid procedure

- 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. If breathing or pulse stops at any time, roll the person on to his back and begin CPR.
- 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 your 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.

- If fainting is likely due to low blood sugar, give the person something sweet to eat or drink when they become conscious.

Do not

- Do not give an unconscious person any food or drin.
- Do not leave the person alone.
- Do not place a pillow under the head of an unconscious person.
- Do not slap an unconscious person's face or splash water on the face to try to revive him.

Electrical safety tips

Objectives: At the end of this lesson you shall be able to
- **rescue a person who is in contact with a live wire**
- **treat a person for electric shock/injury.**

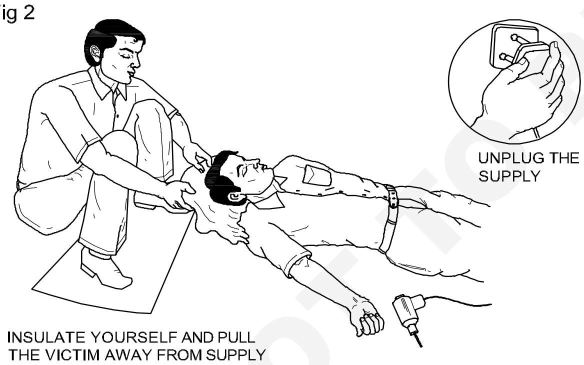
The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that the electric current has been disconnected.

If the casualty is still in contact with the supply - break the contact either by switching off the power, removing the plug or wrenching the cable free. If not, stand on some insulating material such as dry wood, rubber or plastic, or using whatever is at hand to insulate yourself and break the contact by pushing or pulling the person free. (Figs 1 & 2)

Fig 1

EV20N110311

Fig 2



EV20N110312

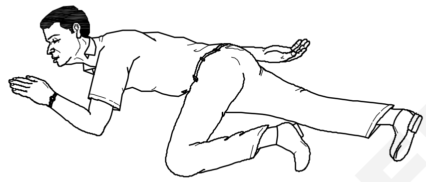
In bare foot, do not touch the victim with your bare hands until the circuit is made dead or moved away from the equipment.

If the victim is aloft, measures must be taken to prevent him from falling or atleast 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 victim is unconscious but is breathing, loosen the clothing about the neck, chest and waist and place the casualty in the recovery position.(Fig 3)

Fig 3



KEEP THE VICTIM AT EASE

EV20N110313

Keep a constant check on the breathing and pulse rate.

Keep the casualty warm and comfortable. (Fig 4)

Send for help.

Fig 4

EV20N110314

Do not give an unconscious person anything by mouth.

Do not leave an unconscious person unattended

If the casualty is not breathing - Act at once - don't wate time!

Safety practice frist - aid

Electric shock: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of the contact.

Other factors that contribute to the severity of shock are:

- Age of the person
- Not wearing insulating footware or wearing wet foot wear
- Weather condition
- Floor is wet or dry
- Mains voltage etc.

Effects of electric shock: The effect of current at very low levels may only be an unpleasant tingling sensation, but this in itself may be sufficient to cause one to lose his balance and fall.

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

At an excessive level of current flow, the muscles may contract and the person unable to release his grip on the conductor. He becomes conscious and the muscles of the heart may contract spasmodically (fibrillation). This may be fatal.

Electric shock can also cause burning of the skin at the point of contact.

Treatment of electric shock

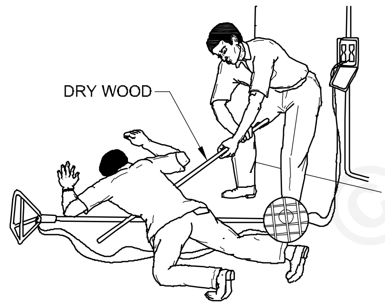
Prompt treatment is essential.

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 current, 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 5)

Fig 5



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

Electrical burns: A person receiving an electric shock may also sustain burns when the current passes through his body. Do not waste time by applying first aid to the burns until breathing has been restored and the patient can breathe normally - unaided.

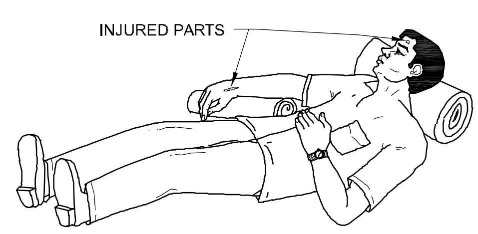
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air, eg.by covering with water, clean paper, or a clean shirt. This relieves the pain.

Severe bleeding: Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention. As an immediate first aid measure, pressure on the wound itself is the best means of stopping the bleeding and avoiding infection.

Immediate action: Always in cases of severe bleeding

- Make the patient lie down and rest
- If possible, raise the injured part above the level of the body (Fig 6)

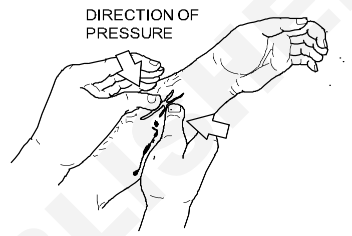
Fig 6



- Apply pressure to the wound
- Summon 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 7)

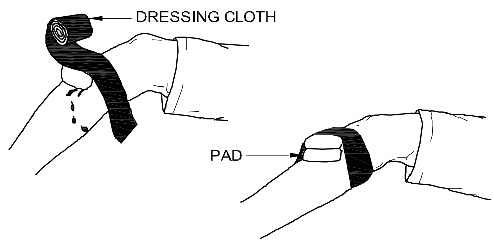
Fig 7



For an abdominal stab wound, such as 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 (preferably an individual dressing) and bandage firmly in place. If bleeding is very severe apply more than one dressing. (Fig 8)

Fig 8



Follow the right methods of artificial respiration.

Operation of Electrical Mains:

Modern electrical switch boards are a fairly simple affair they contain a set of miniature circuit breakers at least one safety switch and a main switch.

If the power appliances or lighting goes off, but the electricity is in other places, check your main circuit breaker has tripped, go to your main switch board box and open it and identify which switch has gone off and then switch it back ON the word of warning though, it may go OFF again in case you probably investicate the fault and rectify it before switch on again.

Electrical safety tips

Many injuries occur as the result of contact with electrical equipment or appliances. If the part of the body comes in contact with the electrical circuit, a shock will occur.

The current will enter the body at one point and leave at another and this passage of electricity can cause severe pain, burning of skin at the point of contact, and even death. So it is need safe and free from electrical hazards.

Electrical safety precautions

1 Use only properly grounded or double insulated items/ equipments.

2 Do not overload outlets.

3 Do not plug multi-outlet bars to other multi outlet bars.

4 Only use equipment that has been approved by national testing laboratory

5 Minimize the use of extension cards.

6 Do not cover power cords with rugs or mats.

7 Do not run electrical cord through pedestrian aisles.

8 Disconnect the power before servicing the equipment.

9 Do not ignore warning signs.

10 Replace the defective cords immediately.

11 Cover or guard any exposed electrical components or wire.

12 Don't use electrical equipment when your hands or equipments are wet and don't use it near wet surface/ water.

13 Don't pull cord from a distance.

Note: Always use PPE before start work with electrical components.

Concept of house keeping & 5 'S' method

Objectives: At the end of this lesson you shall be able to
- **elements of house keeping and cleanliness at work place**
- **state the concept of 5'S' techniques.**

Concept of house keeping: House keeping is the systematic process of making home/work place neat and clean. House keeper is responsible for systematic administration of activities that provide segregation, storage, transfer, processing treatment and disposal of solid waste (which is collected during cleaning)

Scope of house keeping maintenance: The scope of work hieghly depend on where the house keeping activity is performed in general, maintains cleanliness and orderliness, Furnishes the room, office, workplace, house keeping supervisor assisted by an assistant house keeper.

- Eye appeal
- Safety
- Maintenance

Elements of housekeeping and cleanliness at workplace: The major elements which are normally included in the housekeeping and cleanliness practices at the workplace are described below.

- **Dust and dirt removal:** Working in dusty and dirty area is unhygienic as well as unhealthy for the employees, regular sweeping the workplace for the removal of dust and dirt is an essential housekeeping and cleanliness practice. Further, compressed air is not to be used for removing dust or dirt off employees or equipment. Compressed air can caused dirt and dust paticles to be embedded under the skin or in the eye.

- **Employees facilities:** Adequate employees facilities such as drinking water, wash rooms, toilet blocks, and rest rooms are to be provided for the employees at the workplace so that employees can use them when there is a need. Cleanliness at the place of these facilities is an important aspect of the facilities.

- **Flooring:** Floors are to be cleaned regularly and immediately if liquids or other materials are spilled. Poor floor conditions are a leading cause of accidents in the workplace. It is also important to replace worn, ripped or damaged flooring that poses a trip hazard.

- **Lighting:** Adequate lighting reduces the potential for accidents. It is to be ensured that inoperative light fixtures are repaired and dirty light fixtures are cleaned regularly so that the light intensity levels are maintained at the workplace.

- **Aisles and stairways:** Aisles and stairways are to be kept clear and not to be used for storage. It is also important to maintain adequate lighting in stairways. Further stairways need to have railings preferably round railings for adequate grip.

- **Spill control:** The best method to control spills is to prevent them from happening. Regular cleaning and maintenance on machines and equipment is an essential practice. When cleaning a spill, it is required to use the proper cleaning agents or absorbent materials. It is also to be ensured that the waste products are disposed of properly.

- **Waste disposal:** The regular collection of the waste materials contribute to good housekeeping and cleanliness practices. Placing containers for wastes near the place where the waste is produced encourages orderly waste disposal and makes collection easier. All recyclable wastes after their collection are to be transferred to their designated places so that the waste materials can be dispatched to the point of use or sold.

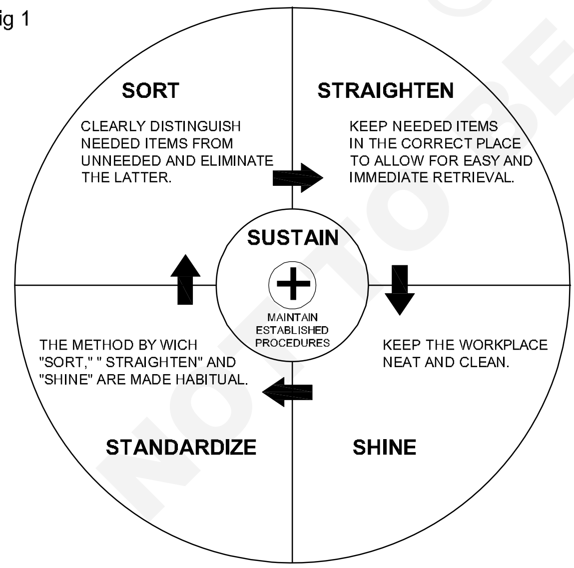
- **Tools and equipment:** Tools and equipment are required to be inspected prior to their use. Damaged or worn tools are to be taken out of service immediately. Tools are to be cleaned and returned to their storage place after use.

- **Maintenance:** One of the most important elements of good housekeeping and cleanliness practices is the maintenance of the equipment and the buildings housing them. This means keeping buildings, equipment and machinery in safe and efficient working condition. When a workplace looks neglected means there are broken windows, defective plumbing, broken floor surfaces and dirty walls etc. These conditions can cause accidents and affect work practices.
- **Storage:** Proper storage of materials is essential in a good housekeeping and cleanliness practice. All storage areas need to be clearly marked. Also it is important that all containers be labeled properly. If materials are being stored correctly, then the incidents of strain injuries, chemical exposures and fires get reduced drastically.
- **Clutter control:** Cluttered workplaces typically happen because of poor housekeeping practices. This type of workplace can lead to a number of issues which include ergonomic as well as injuries. It is important to develop practices where items like tools, chemicals, cords, and containers are returned to their appropriate storage location when not in use.
- **Individual workspace:** Individual workspace need to be kept neat, cleared of everything not needed for work. It is necessary to make a checklist which is to be used by the employees to evalute their workspace.

It can be said that a clean work area demonstrate the pride employees have with the job and the culture of safety at the workplace.

5 Steps (5s) - Concept (Fig 1)

Fig 1



5S CONCEPT WHEEL

EV20N110321

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 clear and better organised.
- Working in workplace 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.

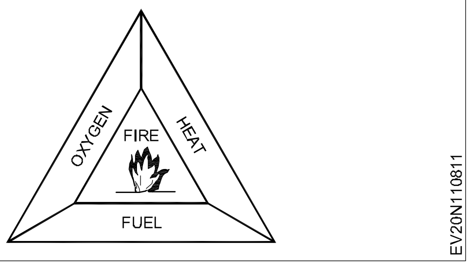
Safety practice - fire extinguishers

Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire break out**
- **state the causes for fire in a workshop**
- **state the conditions required for combustion relevant to fire prevention**
- **state the general precautionary measures to be taken for prevention of fire.**

Fire is the burning of combustible material. It might injure people, and sometimes cause loss of life as well. Hence, every effort must be made to prevent 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. Some liquids do not have to be heated as they give off vapour at normal room temperature say 15oC, eg. petrol.

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.

Remove any one of these factors to extinguish the fire.

Preventing fires: The majority of fires begin with small outbreaks which burn unnoticed until they have a secure hold. Most fires could be prevented with more care and by following some simple common sense rules.

Accumulation of combustible refuse (cotton waste soaked with oil, scrap wood, paper, etc.) in odd corners are a fire risk. Refuse should be removed to collection points.

The cause of fire in electrical equipment is misuse or neglect. Loose connections, wrongly rated fuses, over loaded circuits cause overheating which may in turn lead to a fire. Damage to insulation between conductors in cables causes fire.

Clothing and anything else which might catch fire should be kept well away from heaters. Make sure that the heater is shut off at the end of the working day.

Highly flammable liquids and petroleum mixtures (thinner, adhesive solutions, solvents, kerosene, spirit, LPG gas etc.) should be stored in the flammable material storage area.

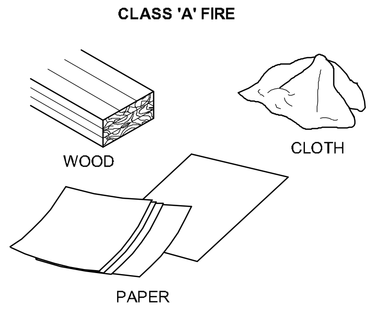
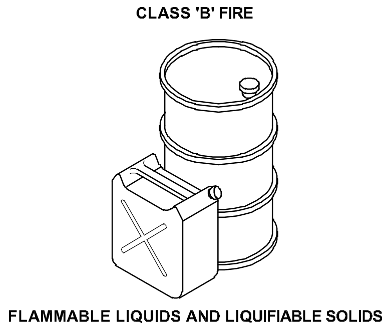
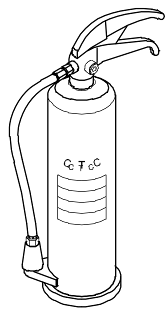
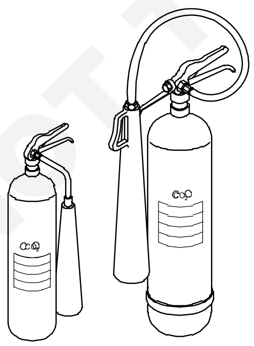
Blowlamps and torches must not be left burning when they are not in use.

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

Different types of fire have to be dealt with in different ways and with different extinguishing agents.

An extinguishing agent is the material or substance used to put out the fire, and is usually (but not always) contained in a fire extinguisher with a release mechanism for spraying into the fire.

It is important to know the right type of agent for extinguishing a particular type of fire; using a wrong agent can make things worse. There is no classification for 'electrical fires' as such, since these are only fires in materials where electricity is present.

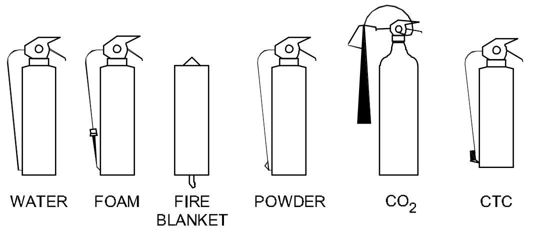
Fuel	Extinguishing
Fig 2 	Most effective ie. cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
Fig 3 	Should be smothered. The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire. Water should never be used on burning liquids. Foam, dry powder or CO2 may be used on this type of fire.
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. Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire.
Fig 5 	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 extinguishers

Objectives: At the end of this lesson you shall be able to
- **distinguish different types of fire extinguishers**
- **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 a fire.**

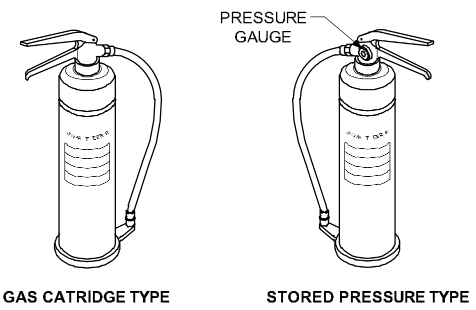
Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 1)

Fig 1



Water-filled extinguishers: There are two methods of operation. (Fig 2)

Fig 2

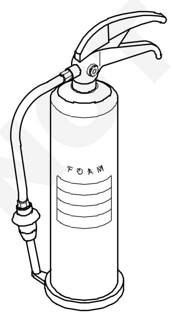


- Gas cartridge type
- Stored pressure type

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

Foam extinguishers (Fig 3) : These may be of stored pressure or gas cartridge types. Always check the operating instructions on the extinguisher before use.

Fig 3



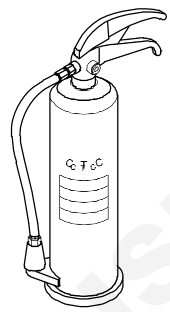
Most suitable for

- Flammable liquid fires
- Running liquid fires.

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

Dry powder extinguishers (Fig 4) : 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 4

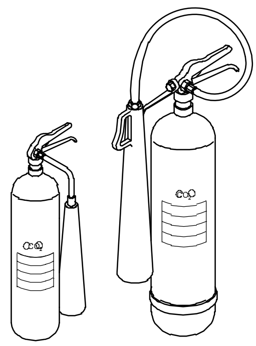


Carbon dioxide (CO_2): This type is easily distinguished by the distinctively shaped discharge horn. (Fig 5).

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.

Fig 5

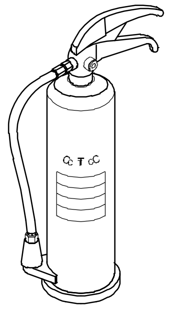


Halon extinguishers (Fig 6): These extinguishers may be filled with carbon-tetrachloride and Bromochlorodifluoro methane (BCF). They may be either gas cartridge or stored pressure type.

They are more effective in extinguishing small fires involving pouring liquids. These extinguishers are particularly suitable and safe to use on electrical equipment as the chemicals are electrically non-conductive.

The fumes given off by these extinguishers are dangerous, especially in confined space.

Fig 6



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. Failure to do this may mean that some person being unaccounted for and others may have to put themselves to the trouble of searching for him or her at risk to themselves.

Basic understanding on Hot Work

Objectives: At the end of this lesson you shall be able to
- **Basic understanding on hot works**
- **Select the confined space for work**
- **Proper handling of material and equipment.**

Introduction on hot work: Hot work has to potential to ignite combustible material that can quickly grow out of control and result in the injury of workers and loss of property. Automobile maintenance work involving riveting, welding, burning, grinding drilling, cutting, abrasive blasting and use of power tools or similar spark or electric fire producing operations are considered hot work that can result in fire or explosion.

Hot work injury happened due to adequate work planning, workers training and quick response in case hot work is danger situation. Hot work injury or damage prevention training or awareness requires for the workers.

Cause for fire in workplace: The following causes for fire accident happened in electric vehicle repair shop.

- Combustible materials adjacent to the opposite sides of bulkheads, paints, overheated, fire woods, rubbers, ply wood patrician and other any flammable chemicals stored near hot work place.
- Unprotected cables run near hot work on the vehicle
- Overload on traction motor without cooling effect on motor
- The vehicle manufacturers and dealers, distributors are responsible for given proper training and awareness to their workers about use of PPT before start the Hot Work.

Duties and responsibilities of the employers: The employers are responsible for protecting their worker from the hazard during electric vehicle repair.

- Developing and implementing a written hot work safety plan
- Reviewing the hot work safety plan with employees
- Display the sop of safety at work place
- Inform to all employee's about hot work place safety and emergency procedure on hot work injury or fire hazard in electric vehicle, fire protection at vehicle repair.
- Establishing designated and non designated areas for hot work.
- Maintaining safe conditions that are fire from hot work hazards
- Employer must also create and maintain a written hot work policy that specified the requirements for employees performing hot hazard emergency duties.

Employees Responsibilities: The Electric Vehicle technician should have the following qualification.

- Safety hot work training
- Fire watch duties responsibilities
- Equipment used for hot material transportation
- Equipment operation method for hot material transportation
- PPE using method according type of hot works in vehicle repair shop
- Method of hot work plan following step by step at work place.
- Hot work is only permitted in areas that are free of fire hazards, that have been controlled by physical isolation.

Before and during hot work: Before begin the hot work in electric vehicle, communication must be established between the employees performing hot work and all of their co worker.

Use the appropriate fire extinguishers and other firefighting equipment according the conditions of the fire. Be take care when breaks in hot work activities, in case of fire during hot work must be immediately alert employees in that area and contact the appropriate emergency response personal in your work shop.

Requirement of post hot work: After completion of hot work, must continue monitoring the hot work parts or area for at least 30 minutes after completion of the hot work to ensure nothing ignites.

Technician's rights : Electric vehicle technician have the right to

- Check the work place and job condition that do not pose a risk of serious harm
- Receive information and training about work place hazards method to prevent them
- Review records of work related injuries and illness.
- Use the PPE according to the nature of hot work.
- File a complaint to supervisor to inspect their workplace. If they believe there is a serious hazard or administration is not following safety rules.
- cliam their rights under the law without retaliation,

including reporting an injury or raising health and safety concerns with their employer

Prepare the work place for hot work: The workspace should have the following conditions for their safety.

- Hot work space and job should be inspect and certified by your supervisor
- Wire and hazard component should be removed or isolated or protected the hot work space.
- Ensure adequate ventilation is provided at hot work space
- Ensure the working heights permits as required for work with safety
- Ensure the fire fighting equipments, fire extinguishers, water, sand first aid kit also provided in work place.
- If no alarm present, determine the method that will be used to raise the alarm
- Incase fire employee's should known the escape route and fire fighting operation
- Remove the combustible materials, and chemicals, fuel and other from hot work place
- Remove paint coating of vehicle body in way of hot work, at least 4 inches in every direction
- Remove insulation from hot work area to prevent the spread of fire
- Before start hot work use the fire resistive covers and metal shields provided as needed
- Remove combustible materials, dust, lint and oily deposits and floor swept clean
- Technician should be wear proper PPE as nature of hot work (eye protection, respirator, face shield, head, ear, foot and body protection etc)

Hot work material handling process: The following procedure may be prevent fire hazard and injury during hot work on electric vehicle or any other automotive equipments.

- Isolating the work area
- Identifying fire hazards
- Ensuring the presence of appropriate fire fighting equipment
- Employees are trained in safe hot work practice
- Suitable PPE available for workers
- Ensure the proper ventilation in hot work place
- Identify the type of hot work like welding, soldering, brazing, grinding, cutting and use of open flames, blow lamp use of hot air blowers etc
- Selection of the Hot work
- Preparation of the hot work job
- Start hot work with personal and hot work safety
- After finishing hot work at least should have watch 30 minutes for fire safety.

History and developments of automobile industry

Objectives: At the end of the lesson you shall be able to
- **State the study of automobile**
- **State the history of auto industry**
- **State the leading manufacturers**
- **State the automobile industry, and their new products**

Study of automobile: The automobile engineering related to automobile manufacturing, in different types vehicle like two wheeler, three wheeler, four wheeler, like a passenger vehicle, commercial vehicle and special vehicles as per customer's need.

The vehicle manufacturers also change their vehicles in design for their vehicle brand identification. The vehicle manufacturers are change their vehicle's mechanical electrical mechanism's operation for improve the quality and economy of their vehicle.

The study of automobile involves understanding the knowledge about different types of vehicle and their components function, future, operating method and maintenance of the vehicle. The following system involves with automobile study

Automobile study involves the vehicle design, development, testing of the vehicle

– Automobile study the modern technologies used in vehicles

– Automobile design involves the aesthetic and functional aspects of vehicle design including exterior and interior designs, ergonomics and user experience.

– Automobile maintenance and trouble-shooting study involves the upkeep and repair of vehicles including routine maintenance and trouble shooting.

– Automobile study involves marketing and understanding consumer (it includes marketing brand advertise, sales and service.

Auto industry – History of leading manufacturers

In 1887 first car rolled out in the streets of Calcutta the next year there were four cars in the street of Bombay.

1940 Indian company like Hindustan motors and premier started to manufacture car of other firm, the same decade started Mahindra and Mahindra also started utility vehicle.

1980 Hindustan Motors ambassador and premier were challenged by a new entrant, Maruti Udyog limited.

The alliance between Maruti and Suzuki was first joint venture between an Indian company.

2000-2010, almost every major car company establishing manufacturing facilities across different parts of the country.

Chennai, Mumbai, Pune, North NCR are majority of Indian car Industry.

Top and major manufactures in Automobile industry.

•	Maruti Udyog	- Car,
•	General motors' India	- Car
•	Ford India	- Car,
•	Eicher motors	- LV, HV
•	Bajaj Auto	- Two wheeler
-	Honda motor	- Car
-	Volkswagen	- Car
-	TVS Motor	- Two wheeler, three wheeler
-	Vespa	- Two wheeler
-	Hero Honda	- three wheeler, Four wheeler, two wheeler
•	Daewoo motors India	- Car
•	Hero motors	- Two wheeler,
•	Hindustan motors	- Car,
•	Hyundai Motor India	- Car,
•	Royal Enfield motors	- Two wheeler,
•	Telco	- Commercial vehicle
•	Swaraj mazda	- Can,LV H/V, commercial,
•	BMW	- Car
-	Bharat Benz	- HV
-	Ape	- Two , Three wheeler
-	KIA	- Four wheeler
-	Nissan	- Car, LV,HV
-	Ford	- Car commercial Vehicle,
-	Toyota	- Car,

The pioneer Mr. J.R.D. Tata's role in setting up the Tata group (ERC).

In India Maruti 800, Car launched by SMT, Indira Gandhi – in 1983.

India is the largest three wheeler and two wheeler market in the world and second largest tractor manufacture in the world, fifth largest commercial vehicle manufacture in the world and second largest producer of motorcycle in the world after china.

In India some industries are importing the vehicle spare parts and assembling them in their industing.

Example: TATA , Hindustan Motor and Ashok Leyland etc

In India some industries are importing the vehicle spare parts and assembling them in their industry

Example :Ford, Hyundai, Audi etc.

Development in automobile industry

Due to the recent developments in electronics and computers lots of changes have come in the automobile also a mini computer named (ECM) electronic control module takes the control of Engine control, transmission, controls, Safety controls, and suspension control system etc.

More number of sensors and transducers are employed in all systems to send information to their corresponding electronic control units to achieve precise control on a activities.

Due to this precise controls we could achieve the Fuel efficiency, clean emission engine, Easy steering and anti locking brakes, keyless entry, Navigation and smart dash board etc.

Gasoline Direct Injection (GDI)

Fuel is injected directly into the cylinders, not mixed with air in the inlet manifold or inlet ports before being drawn into the cylinders. The advantages of direct injection systems are that the fuel can be placed in the combustion space in a more controlled manner than the conventional inlet injection system.

Hybrid vehicles

Hybrid vehicle that combines a conventional internal combustion engine with an electric propulsion system (hybrid vehicle drive train). The presence of the electric power train is intended to achieve either better fuel economy than a conventional vehicle or better performance.

Electric vehicle (EV)

India has plans to make a major shift to electric vehicles by 2030, E-commerce companies, Indian car manufacturers like Reva Electric Car Company (RECC), and Indian app based transportation network companies like Ola are working on making electric cars in the near future.

The electric cars available in India are:

Mahindra e2oplus

Mahindra e-Verito

Tata Tigor Electric

Mahindra e-KUV 100

Tata Tiago Electric

Fuel cells

The fuel cell is used in space-craft, reverses this reaction combining Hydrogen and Oxygen to release electrics energy with pure water as a byproduct.

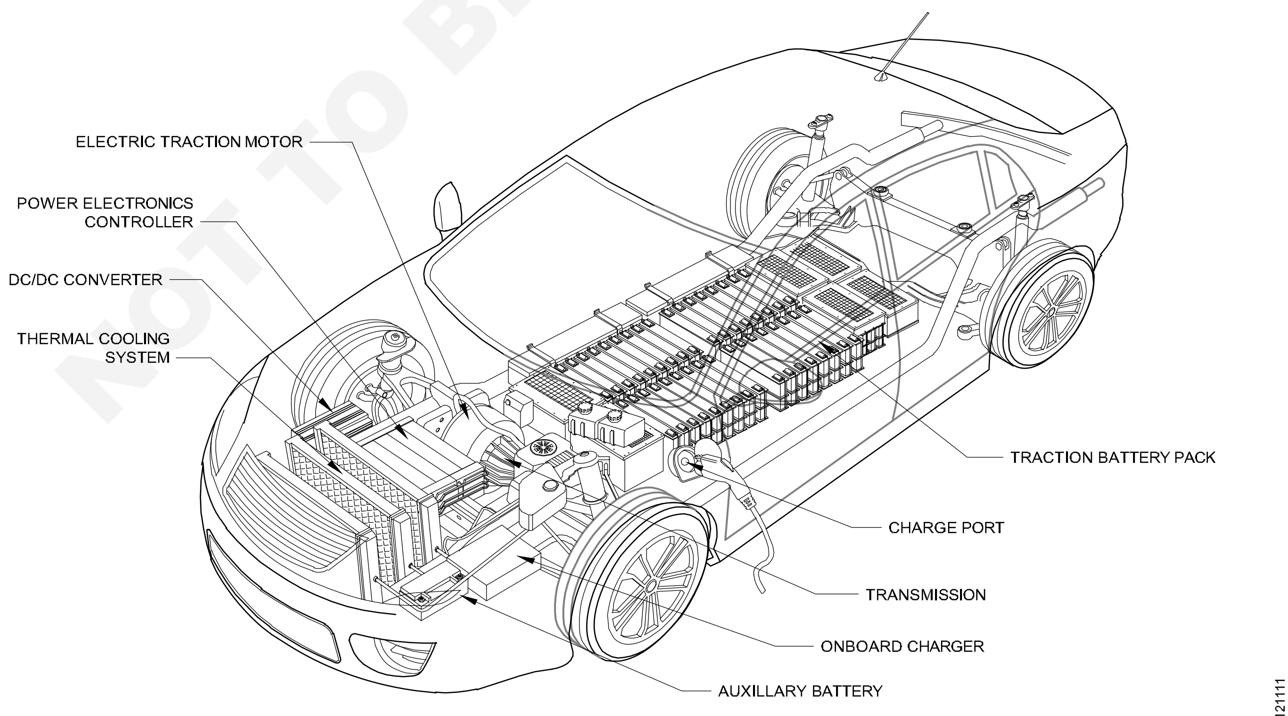
The attraction of using in an internal combustion engine, is part the fuel cell is very efficient indeed, achieving 45 to 60% Agency versus petrol engine 15 to 35%

Danger involved in fuel cell is the hydrogen is an explosive as that is difficult to store and handle.

Lean burn engine

This engine are designed for Lean-burning. They have higher compression ratios and thus provide better performance, efficient fuel usage and low exhaust hydrocarbon emissions compare with the conventional gasoline engines. Lean mixtures with very high air-fuel can only be achieved by direct injection engines.

Fig 1



BATTERY ELECTRIC VEHICLE (BEV)

Driverless Cars

This is a vehicle that is capable of sensing its environment navigating without human input.

Driverless cars combine a variety of techniques to perceive their surroundings, including radar, laser light, GPS and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage.

The potential benefits of driverless cars include reduced mobility costs and infrastructure costs, increased safety, increased mobility, increased customer satisfaction, and reduced crime. And also potentially significant reduction in traffic collisions, resulting injuries and related costs, including less need for insurance.

Alternate fuel

Bio fuels are also considered a renewable source. Although renewable energy is used mostly to generate electricity, it is often assumed that some form of renewable energy of a percentage is used to create alternative fuels. Research is going on the search of more suitable bio fuel crops and improving the oil yields of these crops, Using the current yields, Vast amount of land and fresh water in needed to produce enough oil to completely replace fossil fuel usage. Alternative fuels, known as non-conventional and advanced fuels, any materials or substances that can be used as fuels, other than conventional feels like; fossil fuels (Petroleum (oil|), coal, and natural gas.

Some well-known alternative fuels includes biodiesel, bio alcohol (Methanol, ethanol), vegetable oil, propane and other biomass sources.

Electric Vehicle components and their location: Electric vehicle also referred as battery electric vehicle (BEV). The electric vehicle have an electric motor instead of an internal combustion engine. EV uses traction battery pack to power the electric motor. EV runs on electricity and the vehicle emits no exhaust: Figure – 1 indicates the location of electric vehicle's functional parts and their location.

Key components of an All-Electric Car

Battery (all-electric auxiliary): in an electric drive vehicle, the auxiliary battery provides electricity to power vehicle accessories.

Charge port: The charge port allows the vehicle to connect to an external power supply in order to change the traction battery pack.

DC/DC converter: This device converts higher-voltage DC power from the traction battery pack to the lower voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.

Electric traction motor: Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.

Onboard charge: Takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery. It also communicates with the changing equipment and monitors battery characteristics such as voltage, current, temperature, and state of charge while charging the pack.

Power electronic controller : This unit manages the flow of electrical energy delivered by the traction battery, and it also controlling the speed of the electric traction motor and it produces the torque.

Thermal system (cooling): This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components.

Traction battery pack: Stores electricity for use by the electric traction motor.

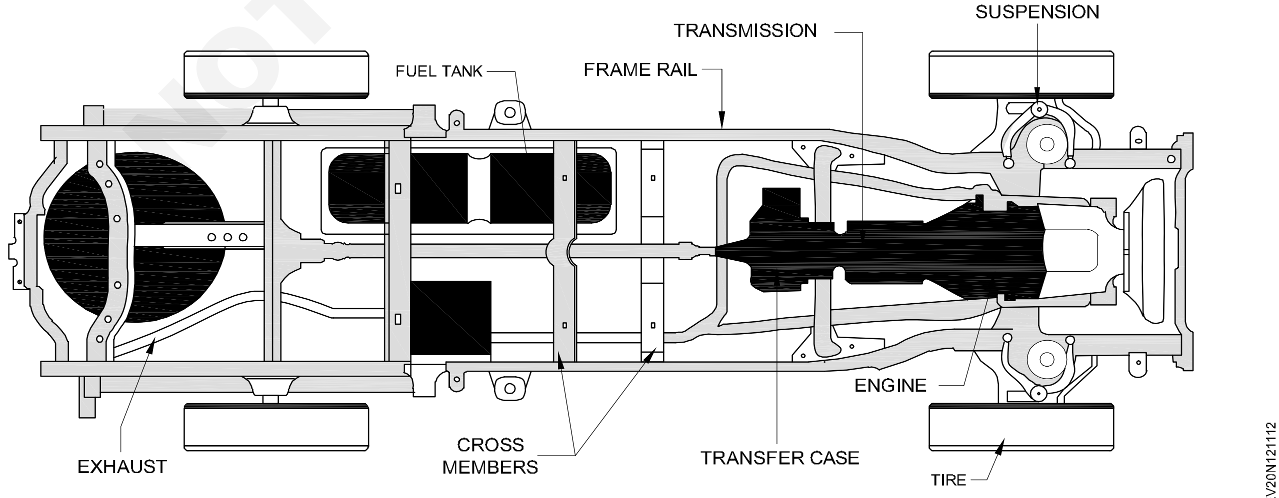
Transmission (electric): The transmission transfers mechanical power from the electric traction motor to drive the wheels.

Key components of IC Engine Vehicle (Fig 2)

Engine - It is used to generate machanical power

Transmission system - It is used to transfer the power from engine to wheel

Fig 2



Suspension system – it is used to observe the road shocks

Exhaust system – it is used to control the exhaust noise

Intake system – It is used to filter the intake air and supply fresh air to cylinder

Steering system – it is used to directional control of the vehicle

chassis & Frame – it is used for fulfill the fuel requirement of an engine

Fuel system – it is used for fulfill the fuel requirement of an engine

Brake system – it is used for control the vehicle speed and stop the vehicle

Lighting system – it is used for indicate the warming well view of road at might time.

Classification of vehicles

Objectives: At the end of this lesson you shall be able to
- **Classify the vehicles**

Classification of vehicles

Based on central motor vehicle act

- Motor cycle
- Invalid carriage
- Three wheelers
- Light motor vehicle
- Medium passenger motor vehicle
- Heavy passenger motor vehicle
- Heavy goods vehicle
- Any other motor vehicle of specified description

Based on wheel

Two wheeler

Three wheeler

Four wheeler

Six wheeler

Multi axles

Based on fuel used

Petrol vehicle

Diesel vehicle

Gas vehicle (CNG&LPG)

Electric vehicle

Hybrid vehicle

Based on body

Saloon (BMW, AUDI)

Sedan (Maruti ciaz, Ambassador etc)

Hatch back (Alto, i10, Santro, Tata Tiago)

Convertible (Jeep, Maruti gypsy)

Station wagon (Inova, Ertiga, etc)

Van (Omni, Tourister)

Special purpose (Ambulance, Milk van etc)

Based on drive

Front engine rear wheel drive(Sumo, Omni, Ambassador, etc) (Fig 1)

Rear engine rear wheel drive (Tata Nano, Bajaj Auro, Valvo bus etc.) (Fig 2)

Four wheel/ all wheel drive(Jeep, Scorpio, Gypsy etc) (Fig 3)

Fig 1

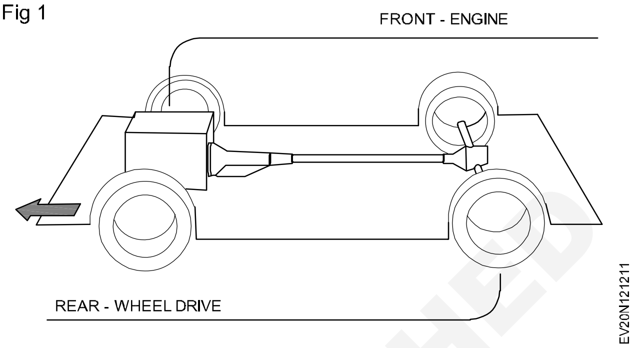


Fig 2

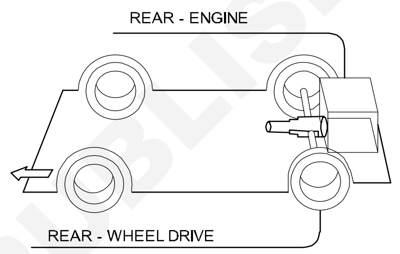
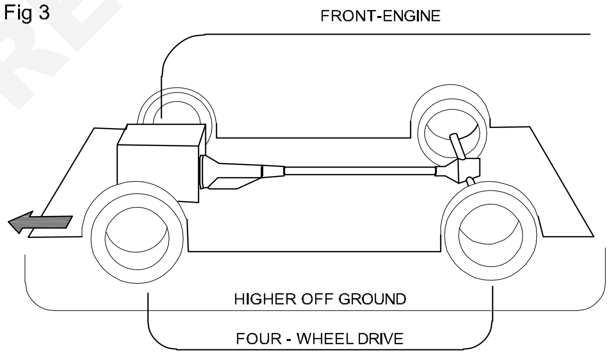
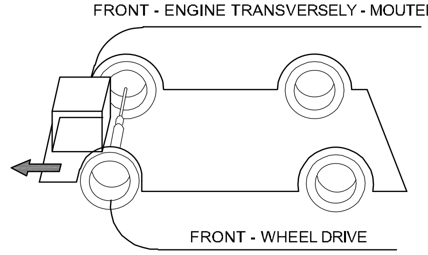


Fig 3



Front engine front wheel drive(Alto, Ertiga, Santro, Tiago etc) (Fig 4)

Fig 4



Based on position of engine

Front transverse engine(Example; Maruti 800)

Front longitudinal engine (Example; Maruti Omni)

Rear Transverse engine(Example Volvo bus)

Based on steering

Conventional manual steering

Power steering hydraulic

Power steering electric

Based on transmission

Manual transmission

Automatic transmission

This is a transmission that uses a torque converter, planetary gears set and clutches or bands to shift a vehicle's forward gears automatically.

Automated manual transmission (AMT)

This is an automated manual transmission it employs a mechanical clutch, but the action of the clutch is not controlled by the driver's clutch pedal. Gears shift done by using automated electronic, pneumatic or hydraulic controls.

Continuously Variable Transmission

This transmission has a continuously variable drive ratio and uses belts, pulleys, and sensors rather than gears to maintain a steady acceleration curve with no pauses for gear changes. Because of this, a CVT can keep the engine in its optimum power range, thereby increasing efficiency and mileage.

Classification of electric vehicle by propulsion system :- Electric Vehicles drives on electrical energy using at least one electric motor for propulsion. This type of system is used in two wheelers, four wheelers, Ships, and Aerospace Crafts.

BEV - Battery electric vehicle. This type of vehicle drives on electrical energy stored in the battery.

PEV - plug in electric vehicle. This type of vehicle has a socket and can be propelled by electric power.

HEV - Hybrid electric vehicle. It drives either with or without combustion engine and it does not have socket for recharging battery.

PHEV - Plug in hybrid electric vehicle. It drives on stored electrical energy or with combustion engine depending on user performance.

EREV - Extended range electric vehicle. It drives mostly on stored electrical energy. Range can be extended by onboard electric generator.

FCEV - Fuel cell electric vehicle. This type of vehicle drives on electrical energy generated by hydrogen fuel cells. It does not have a socket for recharging battery.

PFCV - Plug in fuel cell vehicle. Vehicle drives on electrical energy generated by fuel cell.

SEV - Solar electrical vehicle. This type of vehicle drives on solar energy.

NPV - Vehicle driven on energy generated by nuclear reaction. This type of vehicles not used for public use.

These above types of electric vehicle technology is used all over the world in automobile sectors.

Uses of hoists, jacks and stands

Objectives : At the end of this lesson you shall be able to
- **State the function of vehicle hoists**
- **State the function of engine hoists**
- **State the function of jacks**
- **State the function of axle stand.**

The modern automobile service stations are used in various types of equipments to lift the vehicles . They are as follows

Single post hydraulic car hoist

Two post car hoist

Four post car hoist

Engine hoist

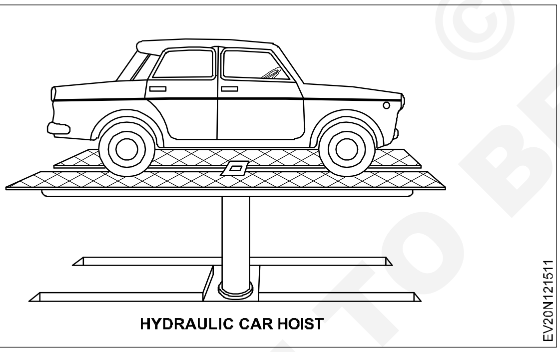
Jacks

Stands

Single post hydraulic car hoist (Fig 1)

It facilitates the servicing and repair works conveniently. It is constructed for dependable, trouble free performance and ensuring smooth and safe operation. The post is made of high grade steel. The car hoists are specially designed for resistant to wear and damage during water wash. Single post type is suitable for up to six tone of the vehicle weight.

Fig 1



HYDRAULIC CAR HOIST

Two post car hoist (Fig 2) : It is operated by electro-hydraulic system. It is easy to operate and maintain the double post hoist safety provision is also provided to hold the vehicle. Double post type suitable for vehicle up to 4 tones.

Four post car hoist (Fig 3): It operates by electro hydraulically and balancing and lifting the vehicle. It is easy to operate and maintain the moving parts. Four post hoist work as single and double post hoist it is suitable to lift the light vehicle or heavy vehicle.

Engine hoist (Fig 4)

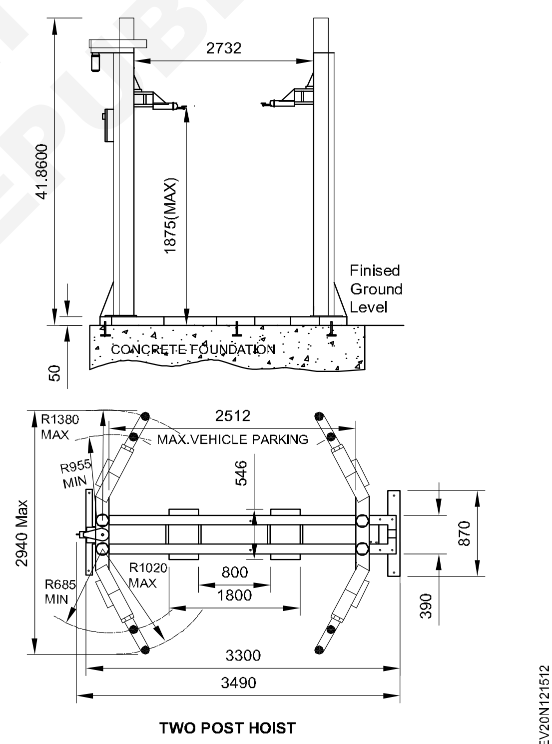
The engine hoist helps to lift an engine from a car/truck. The hydraulic pressure converts power to a mechanical advantage and lifts the engine from the car with less effort. When using a block and tackles for lifting an engine, use a lifting plate attached to the intake manifold or use a chain bolted at each end of the block.

Jacks: Jacks are operated by moving the handle up and down. The other type of portable floor jack is the pneumatic jack which uses compressed air to lift a car or truck. It is mostly used in production side.

Never work under a car without safety stands or jack stands.

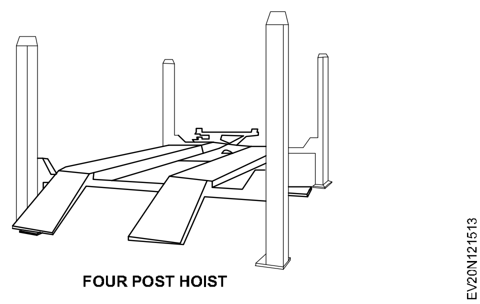
On roads mostly mechanical jacks are used to lift the car/vehicle for small jobs. These jacks work under the principle of screw and nut. Jacks are operated by mechanically and hydraulically, Jack is designed to lift the vehicle and hold the vehicle load during the repair works. Jack is a standard accessory with many vehicles

Fig 2



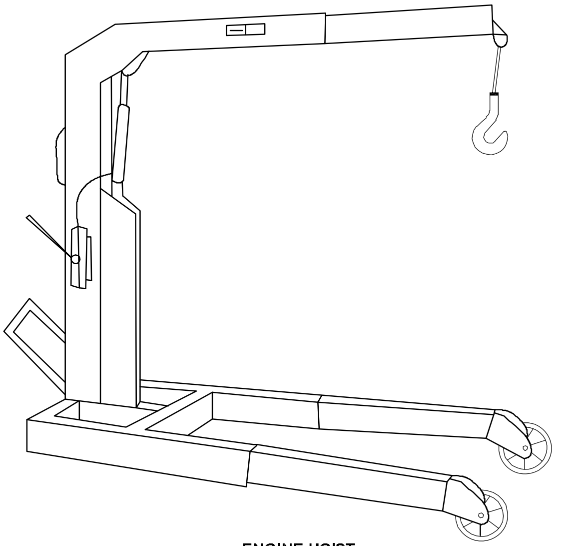
TWO POST HOIST

Fig 3



FOUR POST HOIST

Fig 4



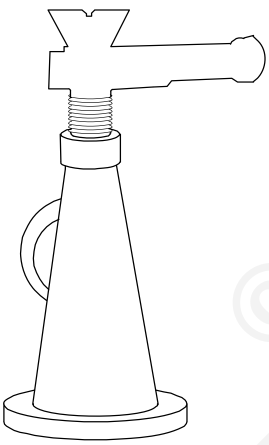
ENGINE HOIST

EV20N121514

Types of jacks

- Light weight screw jack (Fig 5)

Fig 5

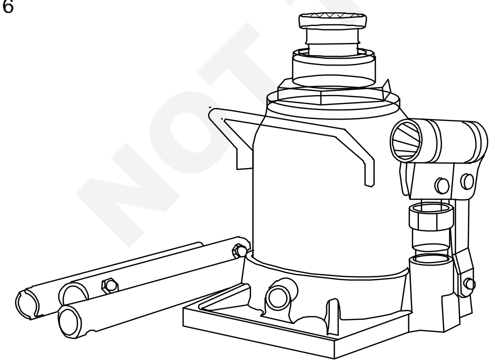


MANUAL TYPE LIFITING JACK

EV20N121515

- Heavy duty bottle type hydraulic jack (Fig 6)

Fig 6

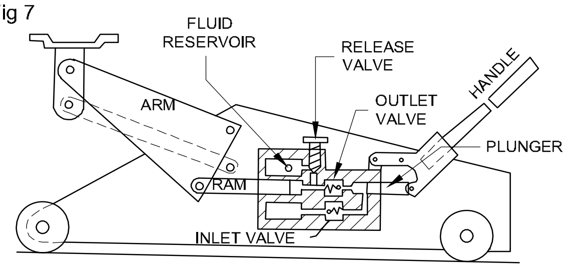


HEAVY DUTY BOTTEL TYPE LIFITING JACK

EV20N121516

- Trolley types hydraulic jack (Fig 7)

Fig 7



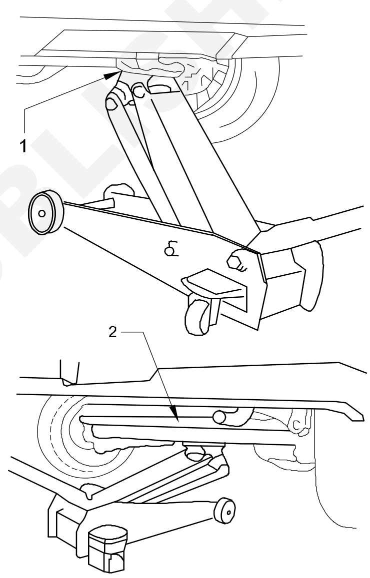
TROLLEY TYPE JACK

EV20N121517

In raising front vehicle end off the floor by jacking , be sure to apply jack against front jacking bracket(1) (Fig 8).

In raising rear vehicle end off the floor by jacking, be sure to apply jack against the center portion of rear axle (Fig 2) .

Fig 8



FLOOR JACK

EV20N121518

Caution: Never apply jack against suspension parts (i.e., stabilizer, etc.) front bumper or vehicle floor, Otherwise it may get deformed.

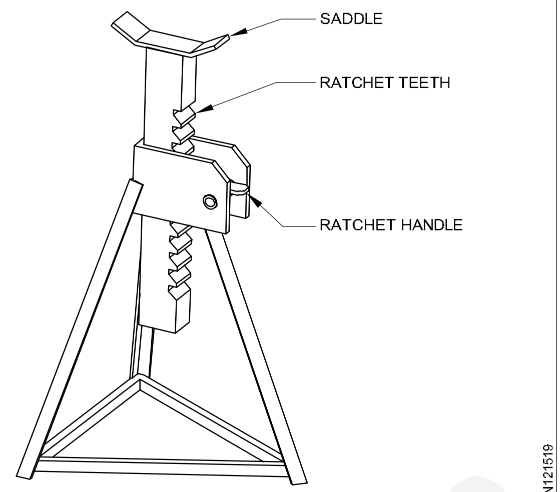
Warning: If the vehicle to be jacked up only at the front or rear end, be sure to block the wheels on ground in order to ensure safety.

After the vehicle is jacked up , be sure to support it on stands. It is extremely dangerous to do any work on the vehicle raised on jack alone.

Axle stand (Fig 9): It is always enjure the safety before starting the work under the lifted vehicle, Jack support is not enough, it could be dangerous. Always use axle stands for safety work. Different size of stands are used depend upon the vehicle load.

To perform service with either front or rear vehicle end jacked up, be sure to place safety stands (9) under body so that body is securely supported. And the check to ensure that body does not slide on safety stands and the vehicle is held stable for safety.

Fig 9



TYPICAL ADJUSTABLE JACK STAND

Introduction to electricity

Objectives: At the end of this lesson you shall be able to
- **describe electricity and structure of matter**
- **describe atomic structure**
- **describe the energy shell and electron distribution**
- **describe conductors, insulators and semi conductors.**

Introduction

Electricity is one of the most useful source of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

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

Examples of electric current

- Domestic electric supply, Industrial electric supply

Examples of static electricity

Shocks received from door knobs or carpeted room. Attraction of the paper to a comb.

Structure of matter

To understand electricity, One must understand the 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'.

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 part of the molecule is called atoms.

Atomic structure

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 of the nucleus, of an atom, and the electrons travel around the nucleus in orbits.

The nucleus

The nucleus is the central part of the atom. It contains the protons and neutrons of the atom as shown in the Fig 1

Protons

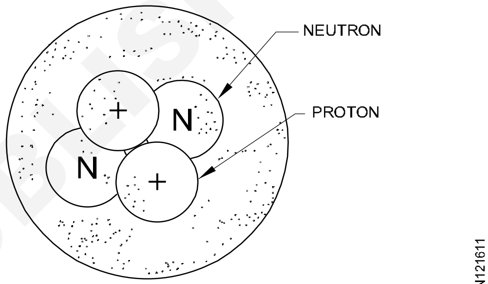
The protons have positive electric charge (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take active part in the flow or transfer of electrical energy.

Electron

It is a small particle revolving round the nucleus of an atom as shown in the Fig.2.It has negative electric charge.

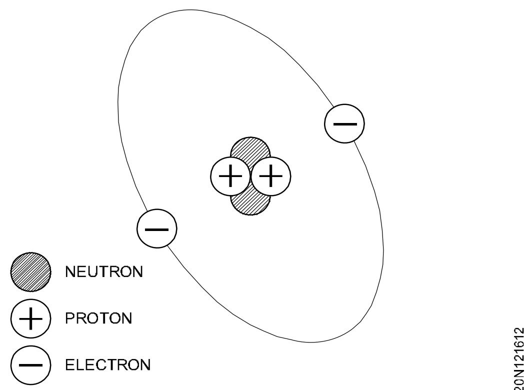
The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

Fig 1



NUCLEUS OF AN ATOM

Fig 2



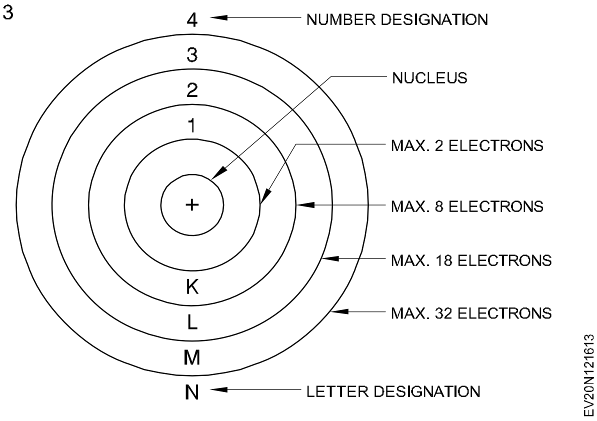
Neutron

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.

Energy shells

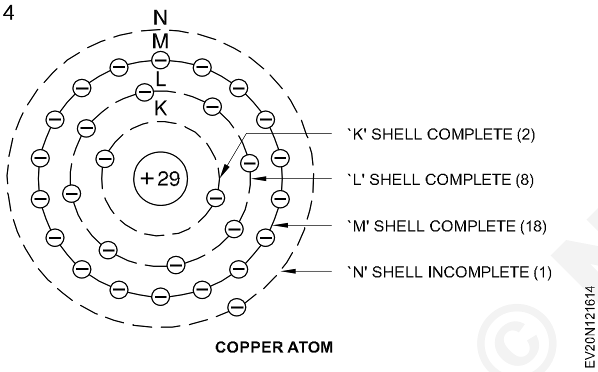
In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major steel layers are identified by numbers of by the letters starting with 'K' nearest the nucleus and continuing alphabetically out ward. There is a maximum number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

Fig 3



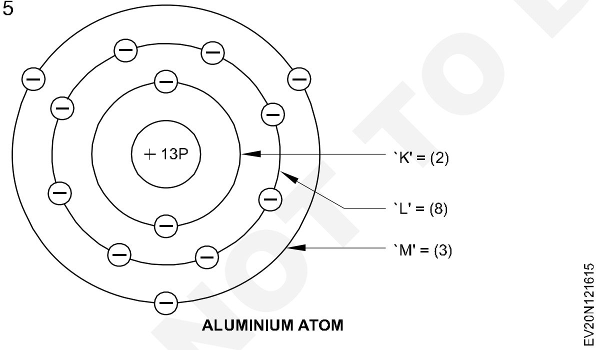
If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a copper atom which has 29 electrons would have four wheels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

Fig 4



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

Fig 5



Electron distribution

The chemical and electrical behavior of atoms depends on how completely the various shell and sub-shells are filled .

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

Metals possess the following characteristics.

- They are good electric conductors
- Electrons in the outer shell and sub- shells can move more easily from one atom to another.
- They carry charge through the material.

The outer shell of the atom is called the valence shell and the electrons are called valence electrons. Because of the their greater distance from the nucleus, and because of partial blocking of the electric field by electrons in the inner shells, the attracting force exerted by nucleus on the valence electrons is less. Therefore, valence electrons can be set free most easily. Whenever a valence electron is removed from its orbit it becomes a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor. Though electrons flow from negative terminal to positive terminal, the conventional current flow is assumed as from positive to negative.

Conductors Insulators and Semiconductors

Conductors

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

Some common good conductors are Copper. Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, Silver and Gold.

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, fiber, mica etc.

Semi conductors

A semi conductor is a material that has some of the characteristics of both the conductor and insulator . Semi conductor 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.

Cable

A length of insulated conductor. It may also be of two or more conductors inside a single covering. The conductors in a cable either be insulated or bare. Cables are available in different types. There are single core, twin core, three core, four core and multi core cables.

Properties of insulation 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

It is the electrical resistance of the insulation against the flow of current. Mega - Ohmmeter (Megger) is an instrument used to measure insulation resistance. It measures high resistance values in Megaohmms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Earthing and its importance

Objectives : At the end of this lesson you shall be able to
- **describe the necessity of earthing**
- **explain the reasons for system and equipment earthing**
- **describe the shielding**

Necessity of earthing

While working in electrical circuits, the most important consideration for an Electrician is the safety factor - safety not only for himself but also for the consumer who uses the electricity. Earthing is provided in a car to protect us from electrical shock due to any leakage of current

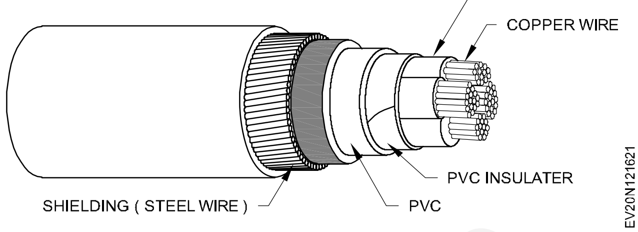
Reasons for earthing

An electric shock is dangerous only when the current through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered dangerous.

Shielding

Shielding is the (Fig 1) protective device layer over the insulated cable. Shielded cable or screened cable is an electrical cable one or more insulated conductors enclosed by a common conductive layer. The shield may be composed of braided strands of copper (or

Fig 1



other metal - braided spiral winding of copper tape, or a layer of conducting polymer.

Uses

- It act as earth / ground for the electrical appliances.
- It protect the cables from moisture entering as well as flexible.
- It also act as mechanical strength as well as flexible to the cables.
- It protect the cable from all weather condition like water, oil, gases and heat.

Ohm's Law

Objectives: At the end of this lesson you shall be able to
- **define EMF, PD, Current and resistance and state their units**
- **state the units of current**
- **state the power, energy.**
- **name the instruments used for measurement**
- **define ohm's law**
- **explain close circuit, open circuit and short circuit**
- **distinguish of AC and DC meters**
- **explain pire wheel.**

Electrical terms and definitions EMF and Pd

The force tending to make electrons to move along a conductor is called the potential difference (pd) in the conductor and is expressed in volts. This is also called the electric pressure or the voltage.

The voltage developed by a source such as a battery of a generator is called its electromotive force. (emf)

When one ampere current flows through one ohm resistance the p.d. across the resistance is said to be one "Volt". Voltmeter is used to measure the voltage of a supply and is connected in parallel to the supply. EMF/ Pd is denoted by letter "V".

Current

The flow of electrons is called current. Its unit is ampere. When one volt is applied across a resistance of one ohm the amount of current passess through the resistance is said to be one "Ampere". It is denoted by "A". Smaller units are milliampere and microampere. Ammeter should be connected in series with the load.

Power - Electric power is the rate of per unit time at which the electrical energy is transferred by an electric circuit. The SI unit of power is WATT, one Joule per second, thousands, millions, and billions of Watts are called Kilowatts, Megawatts, and Giga watts respectively.

Electrical Energy - Electrical energy is the power an atom charged particles to have to cause an action or move an object. This movement of electrons from one atom to another atom is called electrical energy. The electrical energy used to produce the heat energy, light and motion(motor).

Resistance

It is the property of a substance which opposes the flow of electricity. Its unit is ohm. The resistance of a conductor, in which a current of one ampere flows when potential difference of one volt is applied across its terminals, is said to be one ohm.

An ohmmeter is used to measure the resistance of an electric circuit. It is denoted by “W” Bigger units are Kilo ohms and Mega ohms.

1 K Ω = 10^3 ohms

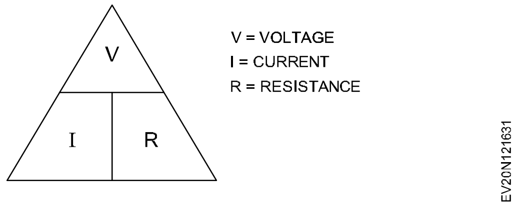
1 Mega Ω= 10^6 ohms

Ohm's Law states

`The current is directly proportional to the voltage and inversely proportional to the resistance' when the temperature remains constant.

An aid to remember the Ohm's law relationship is shown in the divided triangle. (Fig 1)

Fig 1



Written as a mathematical expression, Ohm's Law is -

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

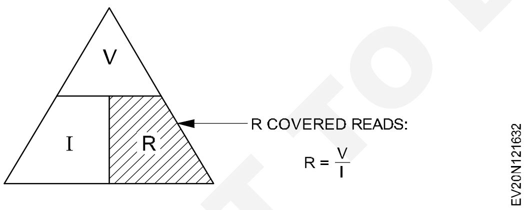
$$\text{or } I = \frac{V}{R}$$

Of course, the above equation can be rearranged as:

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$\text{or } R = \frac{V}{I} \quad \text{(Refer Fig 2)}$$

Fig 2



Example

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

Given:

Voltage(V) = 1.5 volts

Resistance(R) = 1 k ohm

= 1000 ohms.

Find:

Current(I)

Formula

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

Solution:

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

Answer:

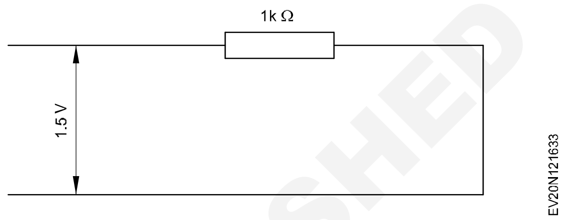
The current in the circuit is 0.0015 A

or

the current in the circuit is 1.5 milliampere (mA).

(1000 milliamps = 1 ampere)

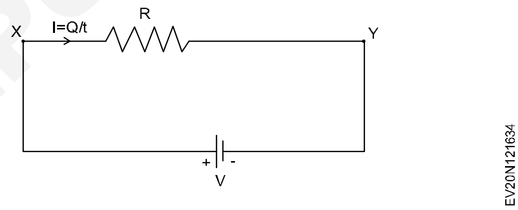
Fig 3



Electric Circuit (closed circuit, open circuit and short circuit)

An electric circuit is the path in which the electric current flows. Fig 4 shows a simple circut.

Fig 4



B is the source of electric energy (a cell) L is the lamp, the load or appliance to use the electric energy, S is the switch to control the circuit, i.e. to make the circuit on or off, F is the fuse to protect the circuit from faults, B, S and F have terminals marked 1, 2, 3, ... Connecting wires connect them systematically. Electric current starts from terminal 1, goes to terminal 2 through the connecting wire. When S ‘ON’ it passes to 3 and through F and L it returns to the terminal 8 of the source. Thus the current’s path is completed. A circuit like this is called a closed circuit. If the switch is off or the connecting wires are cut or disconnected, it becomes an open circuit. Current cannot pass in an open circuit. If an extra wire connects terminals 5 and 7, the current will find an easier path. This forms a short circuit. In this case, the current does not pass through the load. The current may be very high. The fuse protects the circuit in such cases.

Identification of A C and D C Meters

AC and DC meters can be identified as follows

1 By the symbol available on the dial / scale.

   a Direct current

   b Alternating current

2 By seeing the graduation on the dial / scale

a If the graduation of dial is uniform throughout, it is a D C meter.

b If the graduation of dial is cramped at the beginning and at the end, it is an A.C. meter

3 By seeing the terminals

a In the d C meter the terminals are marked with + and– The positive (+) terminal is Red in colour and the negative (–) terminal is Black in colour.

b In the A.C. meter there is no marking on the terminals and no difference in colour.

Pire wheel

(i) current:

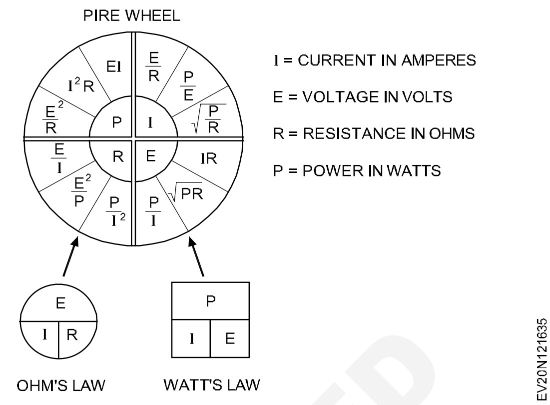
$I = V / R$

$= P / V$

$= \sqrt{P / R}$

The formulae (or equations) to solve for unknown voltage, current, resistance or power can be obtained by combining Ohm's law and Power law. This is shown in Fig 5.

Fig 5



Electrical measuring instruments and electrical circuits

Objectives: At the end of this lesson you shall be able to
- **Explain the connection of an ammeter in the circuit**
- **State the use of an ammeter**
- **Explain the use of voltmeter**
- **State the use of ohmmeter**

There are three basic types of meters used to test the electric circuit and accessories. The following meters are used in automobiles

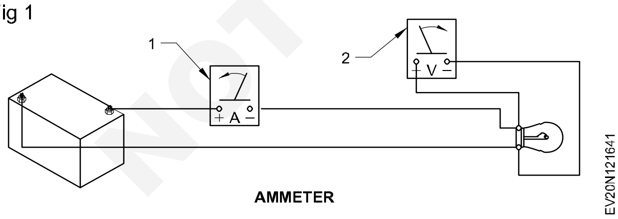
- Ammeter
- Voltmeter
- Ohmmeter

Ammeter (Fig 1)

The ammeter is(1) fitted on the vehicle panel board/ dash board.

It is connected in series in the circuit as shown in the Fig 1

Fig 1



Uses of ammeter

An ammeter is used to measure the amount of current flowing in the circuit

This is connected with series in the load.

It is used to indicate the rate at which the battery is being charged or discharged.

Care

Do not connect an ammeter in parallel in the circuit.

Take care of "+" and "-" mark on terminals.

Use DC meter for automobile charging system.

Select and use a ammeter as per the required range.

Voltmeter

A voltmeter (2) is used to measure electrical voltage. It is not fitted permnently on the vehicle but used separately whenever required. It is connected in parallel with the circuit. Use DC voltmeter for automobiles.

Uses of voltmeter

To measure the voltage at any point of circuit.

To measure the voltage drop in the circuit

To check the condition of the battery.

Care

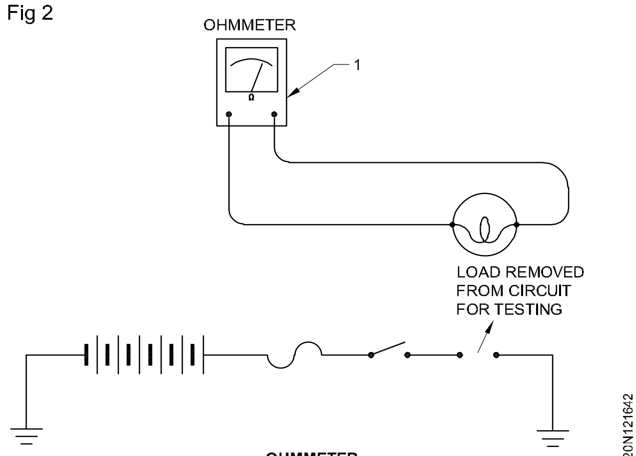
Select the voltmeter as per the required range.

Do not connect the voltmeter in series in the circuit.

Ohmmeter (Fig 2)

An ohmmeter (1) is also known as resistance meter.

Fig 2



OHMMETER

It is not fitted permanently on the vehicle but sis used separately whenever required.

It has its own built in power source. Hence device circuit being checked with the ohmmeter should be disconnected from the power supply as shown in the Fig 2 to prevent the damage to the ohmmeter

Uses of ohmmeter

An ohmmeter is used ;

- To measure the resistance of any conductor
- To measure the resistance of any load
- To check the continuity of the field cells.

Care

Do not connect the ohmmeter to any part of a live circuit.

Do not connect an ohmmeter across the terminals of a battery.

Maintenance of meters

Handle the meters with care

Keep the connections tight while the meters are in use.

Use the meters with specified loads.

After use, keep the meters in separate place.

Multimeter

Objectives : At the end of this lesson you shall be able to
- **state the function of multimeter controls**
- **explain about the dial (scale) of the multimeter**
- **explain about zero adjustment during ohmmeter function**
- **state the function of digital multimeter**
- **state the application of the multimeter**
- **state the precautions to be followed while using a multimeter.**

A multimeter is an instrument in which the functions of an ammeter, voltmeter and ohmmeter are incorporated for measurement of current, voltage and resistance respectively. Some manufacturers call this a VOM meter as this meter is used as volt, ohm and milli ammeter, Multimeters use the basic d' Arsonval (PMMC) movement for all these measurements. This meter has facilities through various switches to change the internal circuit to convert the meter as voltmeter, ammeter or ohmmeter.

There are two major types of multimeters

i Ordinary multimeters having passive components.

ii Electronic multimeters having active and passive components. An electronic multimeter may be of the analog type or digital type.

Most of the ordinary multimeters will have a sensitivity of 20k ohms per volt in the voltmeter mode whereas electronic multimeters have internal resistances to the tune of 5 to 10 megohms, irrespective of the selected voltage range.

There are several types of multimeters available in the market, manufactured by various manufactures. Each model differs from the others by the extra facilities available. It is a versatile tool for all automobile. With proper usage and care, it could give service for many years.

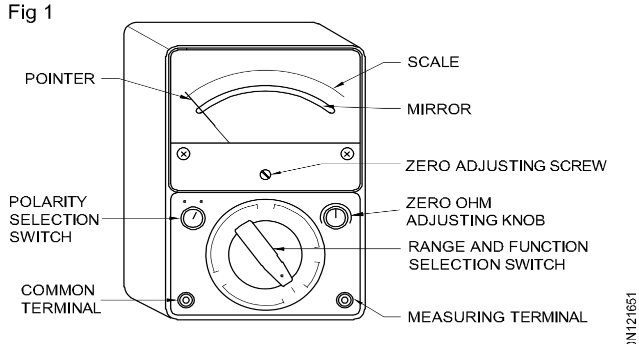
Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of these main parts and controls as shown in Fig 1.

Scale of multimeter

Fig 1



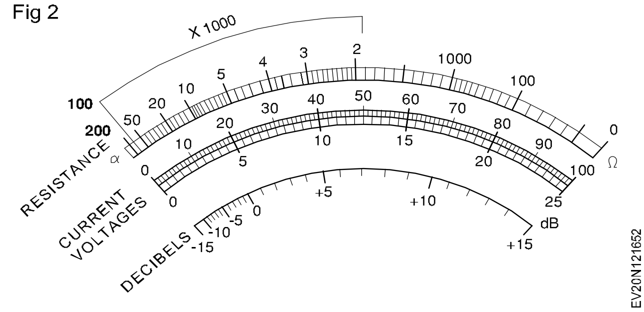
MULTIMETER

Separate scales are provided for:

- resistance
- voltage and current.

The scale of current and voltage are uniformly graduated (Fig 2)

Fig 2



The scale for resistance measurement is non-linear. That is, the divisions between zero and infinity (¥) are not equally spaced. As you move from zero to the left across the scale, the division become closer together.

The scale is usually ‘backward’, with zero at the right.

Zero adjustment

When the selector switch is in the resistance range and the leads are open, the pointer is at left side of scale, indicating infinite (a) resistance (open circuit). When the leads are shorted, the pointer is at right side of the scale,indicating zero resistance.

The purpose of the zero ohm adjusting knob is to vary the variable resistor and adjust the current so that the pointer is at exactly aero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

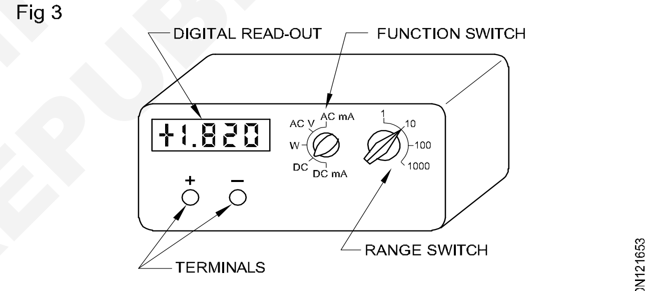
Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large values. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range. These range settings are interpreted differently from those of the ammeter or voltmeter. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

Digital multimeter (DMM)

In a digital multimeter the meter movements is replaced by a digital read - out. (Fig 3) this read-out 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 also a front panel switching arrangement. The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When the quantities are measured, the polarity is identified be the means of a + or - sign displayed to the left of the number.

Remember, When a multimeter is set for the ohmmeter function, the multimeter must not be connected to the circuit with the circuit's power is on

Fig 3



DIGITAL MULTIMETER

Electric and electronic accessories

Objectives; At the end of this lesson you should be able to
- **State the fuses, circuit breaker, ballast resistor, stripping wires.**
- **State the cable color codes and sizes.**

Fuses

Fuses are used to protecting the electrical equipment and circuit against the effect of excessive currents. Fuse has to protect a group of electrical items, it is used between the circuit, it is operative whether the ignition switch is ON or OFF position.

Circuit breakers

Circuit breakers are used in the automotive lightening circuit, the lamp will light and then go out. This giving an indication of a faulty circuit.

Ballast resistor

A ballast resistor is a resistor inserted into a circuit to compensate for different changes or a resistance as current decreases. This resistor is used in car engines produced with breaker points type ignition primary circuit between battery and ignition coil. the useage of this device reduces the chance of failure electrical devices

Types of ballast resistor

There are two types of ballest resistor

- Fixed ballest resistors
- self variable ballest resistors

A ballest resistor is an electrical and electronic component that controls the flow of current in a circuit when the flow of current through it increases and, when the flow of current reduces the resistance also decreases, the ballest resistor keep the current speedly through out the circuit

Uses

- It act as earth/ ground for the electrical appliances.
- It protect the cables from the moisture entering as well as a flexible.
- It also act as mechanical strength as well as a flexible to the cables.
- A ballest resistor serves to control current and voltage
- it protects equipment against over current and over voltage probloms
- ballest resistors are mostly used in lighting and auto motive applications
- This resistor assist to keep battery draining and overloads at bay by controlling the flow of electricity in an EV electrical system
- LED circuits, fluorescent lights and automobile apllications all employ these resistors

Stripping wire insulation:- A wire stripper is used for removing the protective coating of an electric wire in order to replace or repair wire. It is also capable of stripping the end portions of an electronic wire in order to connect them to other wires or terminals. A wire stripper is often considered an important tool for professional electricians and other related personnel.

Cable color codes and sizes:- Automobiles have a number of electric circuits and large number of cables are connected in to a singe wire harness assembly

The automobile manufacturers uses different color wires. It consists of basic colors and combination of colors to identify individual circuits.

The distinction between wires in a group is done by the use of colored bracer on the main colors of insulators of each wire. Wire harness consists by following lucas color code system in India.

The color code system helps to locate the defects easily in a particular wire circuits.

The size of the cables depends upon the current rating of the accessories connections in that circuit. A thick cable can carry more current and thin cable carries less current.

The specification of the cable refers to the number of strands and diameter if each strand eg. 25/012 indicates the cable consists of 25 strands of 0.012 " gauge diameter of each strand.

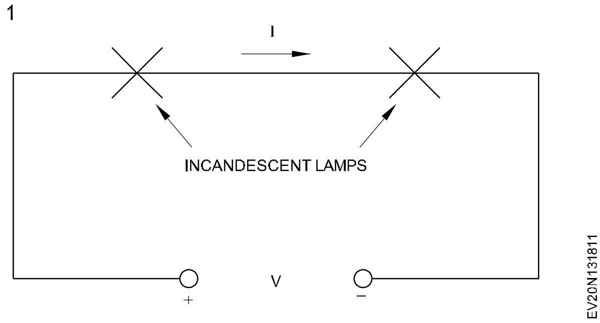
Resistors in DC series

Objectives : A t the end of the lesson you shall be able to
- **Identify the series connection and determine the current in the series circuit**
- **State the causes of a series connection break.**

The series circuit

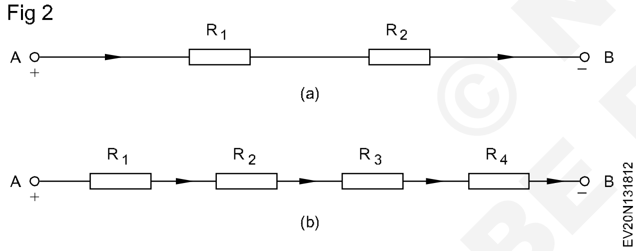
It is possible to connect two incandescent lamps in the way shown in (Fig 1). This connection is called a series connection, in which the same current flows in the two lamps.

Fig 1



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



Identifying series connections

In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, (Fig 3(a), 3(b), 3(c) & 3(d)) shows series resistors drawn in different ways. In all the above circuits we find there is only one path for the current to flow.

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 (Fig 4 (a) and 4(b)). The ammeters will show the same reading.

The current relationship in a series circuit is

I = IR1 = IR2 = IR3. (Refer Fig 4)

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.

An open circuit results whenever a circuit is broken or is incomplate, and there is no continutiy in the circuit.

Fig 3

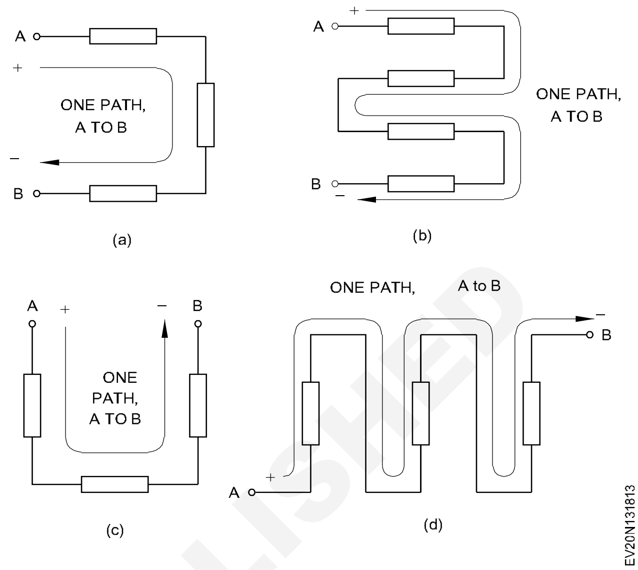
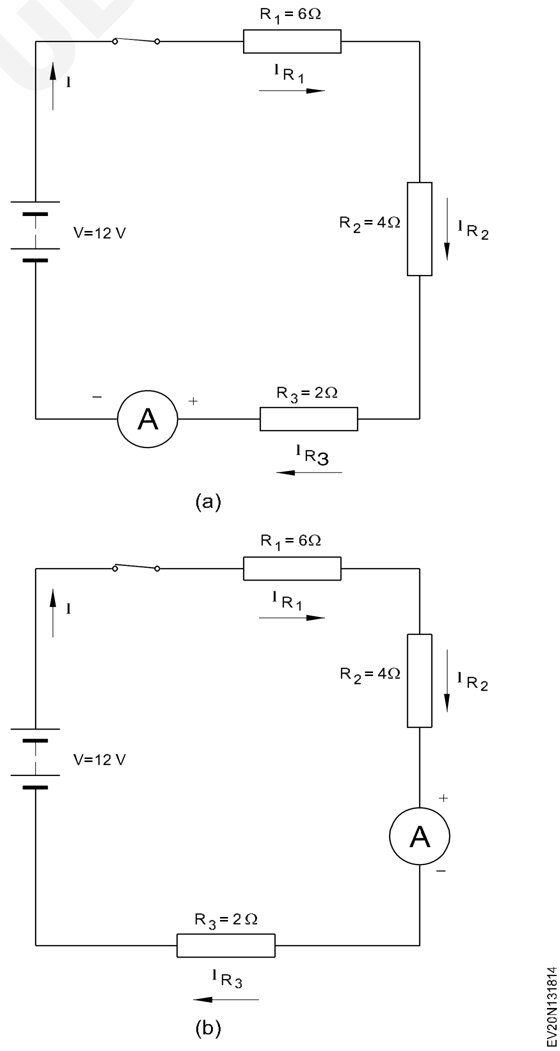


Fig 4



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.

c Total supply voltage/ source voltage appear across the open

How can we determine where a 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 resistor in turn. if one of the wire is open as shown in (Fig 4), the full supply voltage is indicated on the volmeter. in the absence of a current, therefore, the voltmeter must be reading full supply voltage across the open. that is

voltmeter reading

$= 18\ V - V_{R1} - V_{R2} - VR3$

$= 18\ V - OV - OV - OV = 18V.$

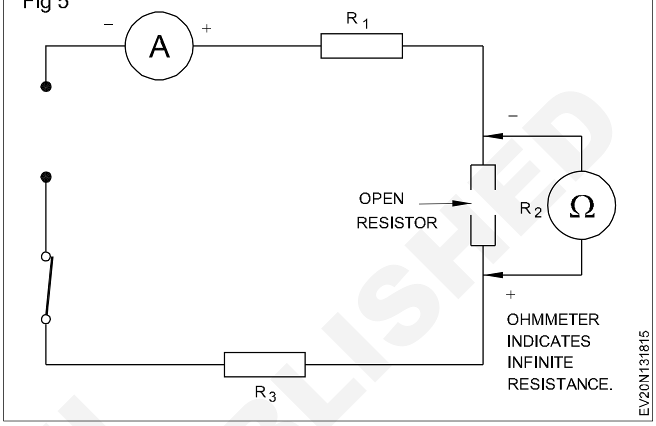
If the circuit was open due to a defective resistor, as shown in (Fig 6) (resistors usually open when they burn out), the volmeter would indicate 18V when connected across this resistor,R_2

Alternatively, the open circuit may be found using an ohmmeter. with the voltage removed, the ohmmeter will show no continuty (infinite resistance), When connected across the broken wire or open resistor, (Fig 5)

Practical application

With the knowledge gained from this lesson

Fig 5



Resistors in DC parallel circuit

Objectives: **At the end of this lesson you shall be able to**

- **explain a parallel connection**
- **determine the voltage in a parallel circuit**
- **determine the current in a parallel circuit**
- **determine the total resistance in a parallel circuit**
- **state the application of a parallel circuit.**

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.

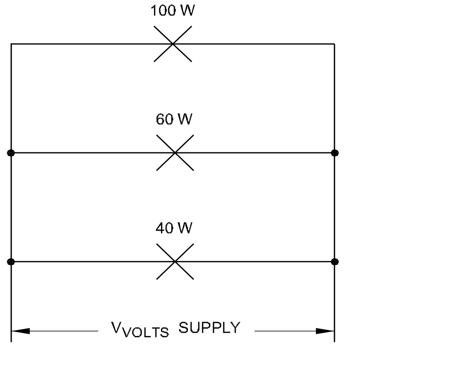
Voltage in parallel circuit

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.

(Fig 2) could also be drawn as shown in (Fig 3).

Fig 1



Mathematically it could be expressed as V = V1 = V2 = V3.

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 R1 = I1 = =

Current in resistor R2 = I2 = =

Current in resistor R3 = I3 = =

as V1 = V2 = V3.

Refer to (Fig 4) in which the branch currents I1, I2 and I3 are shown to flow into resistance branches R1, R2 and R3 respectively.

The total current I in the parallel circuit is the sum of the individual branch currents.

Mathematically it could be expressed as I = I1 + I2 +I3 + ... In.

Fig 2

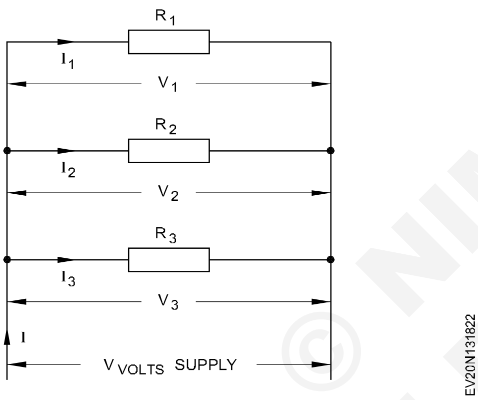
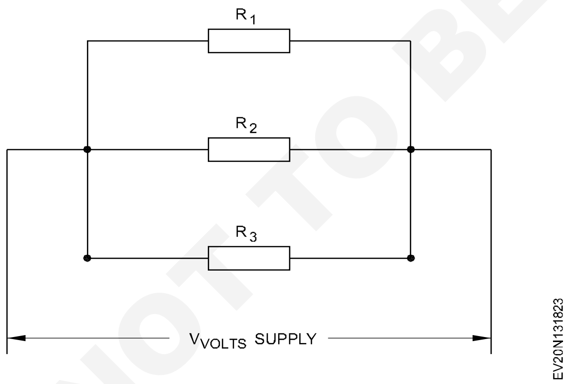


Fig 3



Resistance in parallel circuit (Fig 4)

In a parallel circuit, individual branch resistances offer opposition to the current flow though the voltage across the branches will be same.

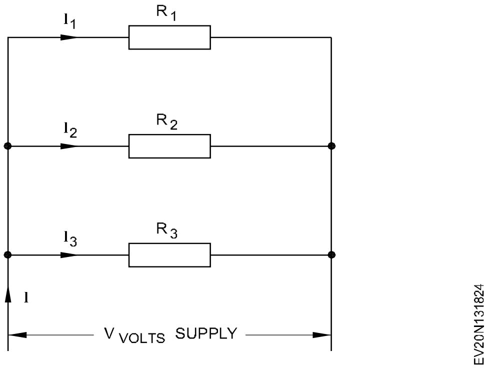
Let the total resistance in the parallel circuit be R ohms.

By the application of Ohm's law

we can write

$$R = \frac{V}{I} \text{ ohmsorl } = \frac{V}{R} = \text{amps}$$

Fig 4



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

$$I = I_1 + I_2 + I_3$$

$$\text{or } R = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_2}$$

As V is the same throughout the equation and dividing the

above equation by V, we can write

$$\frac{1}{R} + = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}$$

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.

Special case: Equal resistances in parallel

Total resistance R, of equal resistors in parallel (Fig 5) is equal to the resistance of one resistor, r divided by the number of resistors, **N.**

$$R = \frac{r}{N}$$

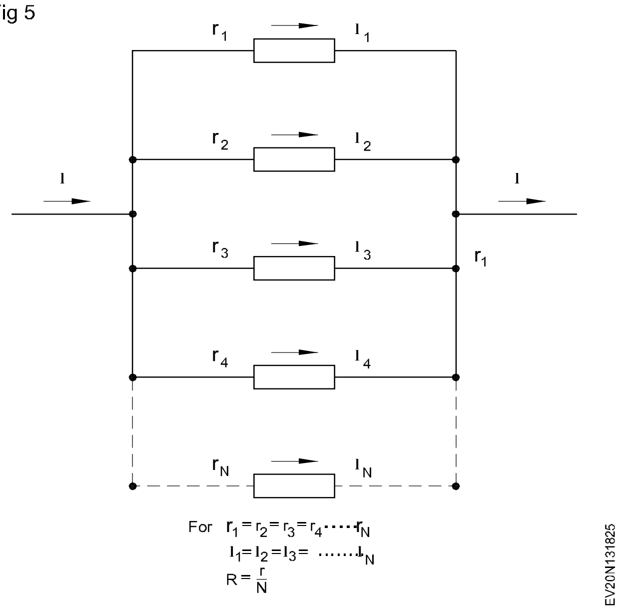
Applications of parallel circuits

An electric system in which section can fail and other sections continue to operate in parallel circuits. As previously mentioned, 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 independently.

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.

Fig 5



Resistors in Series parallel combination circuit

Objectives: At the end of this lesson you shall be able to
- **compare the characteristics of series and parallel circuits**
- **solve the series-parallel circuit problems**
- **calculate the current in series-parallel circuits.**

Comparison of characteristics of DC series and parallel ciruits

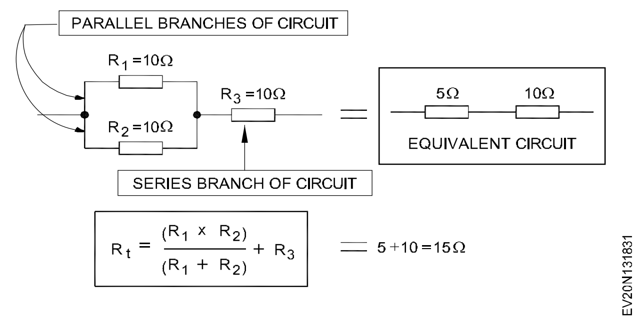
Series circuit	Parallel circuit
1 The sum of voltage drops across the individual resistances equals the applied voltage.	The applied voltage is the same across each branch.
2 The total resistance is equal to the sum of the individual resistances that make up the circuit. Rt = R1+R2+R3+... etc	The reciprocal of the total resistance equals the sum of the reciprocal of the resistances. The resultant resistance is less than the smallest resistance of the parallel combination.
3 Current is the same in all parts of the circuit.	The current divides in each branch according to the resistance of each branch.
4 Total power is equal to the sum of the power dissipated by the individual resistances.	(Same as series circuit) Total power is equal to the sum of the power dissipated by the individual resistances.

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)

Thus, R_1 and R_2 form the parallel component, and R3 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).

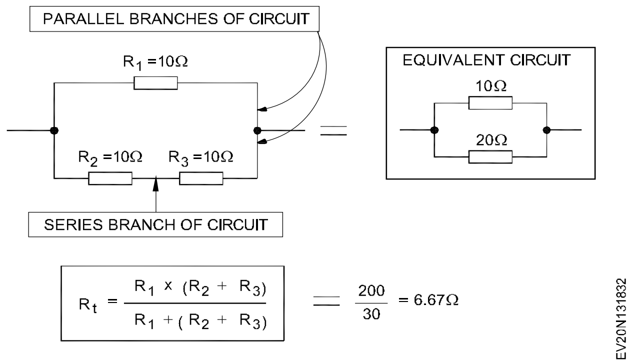
Fig 1



Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor(R3), 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 R2 and R3 . To find the total resistance of this series -parallel circuit, first combine R2 and R3 into an equivalent 20-ohm resistance. The total resistance is then 20 ohms in parallel with 10 ohms, or 6.67 ohms.

Fig 2



Combination circuits

A series-parallel combination appears to be very complex.

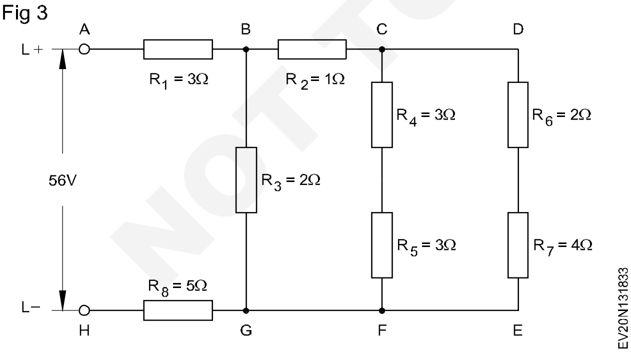
However, a simple solution is to break down the circuit into series/or parallel groups, and while solving problems, each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

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.

Example

Determine the combined resistance of the circuit shown in (Fig 3).

Fig 3



Procedure

1 Combine R6 and R7.

$R_a = R_6 + R_7$

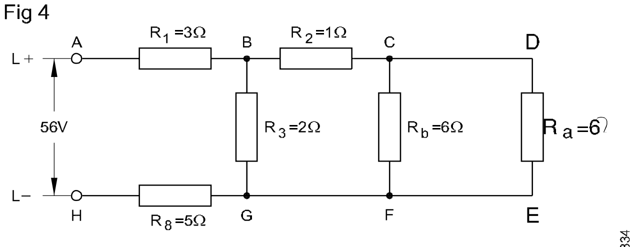
$R_a = 2 + 4$

$R_a = 6$ ohms.

2 Draw an equivalent circuit with resistance Ra. (Fig 4)

3 Combine R4 and R5 of Fig 4.

Fig 4



EQUIVALENT CIRCUIT TO FIG 3. R_4 AND R_5 ARE REPLACED WITH ONE RESISTOR(R_b) OF 6Ω

$R_b = R_4 + R_5$

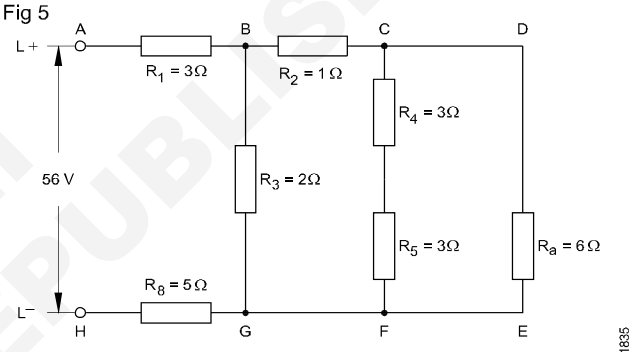
$R_b = 3 + 3$

$R_b = 6$ ohms.

4 Draw an equivalent circuit as per Fig 5.

5 Combine R_a and R_b and call the equivalent resistance value as R_C. (Fig 5)

Fig 5



EQUIVALENT CIRCUIT OF FIG 3. R_6 AND R_7 ARE REPLACED WITH ONE RESISTOR (R_a) OF 6Ω

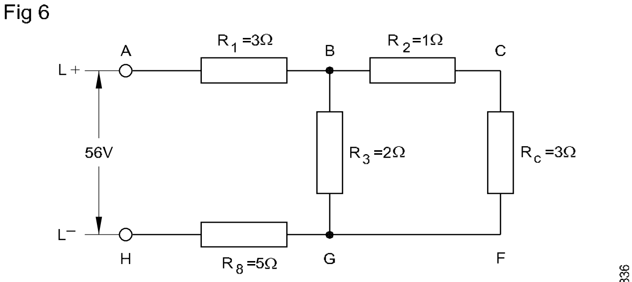
$\frac{35}{12}$ R_C =

$$\frac{R_a \times R_b}{R_a + R_b} = \frac{6x6}{6+6}$$

$$= \frac{35}{12} \quad 3 \text{ ohms}$$

6 Draw the equivalent circuit. (Fig 6)

Fig 6



EQUIVALENT CIRCUIT TO FIG 3, R_4, R_5, R_6, R_7 ARE REPLACED WITH ONE RESISTANCE (R_c) OF 3Ω .

7 Combine R_2 and R_c and call the equivalent resistance R_d.

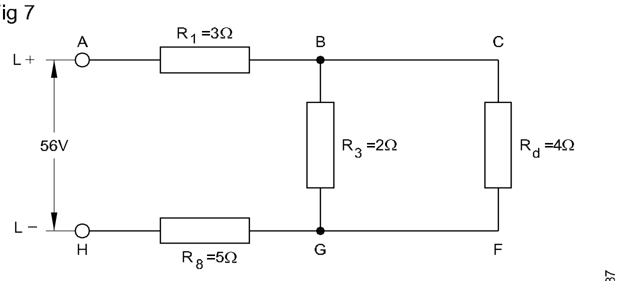
$$\mathbf{R_d = R_2 + R_c}$$

$R_d = 1 + 3 \quad R_d = 4$ ohms.

8 Draw an equivalent circuit. (Fig 7)

9 Now combine R_2 and R_d and call it R^e

Fig 7



EQUIVALENT CIRCUIT TO FIG 3, R_2, R_4, R_5, R_6, R_7 ARE REPLACED WITH ONE RESISTANCE (R_d) OF 4Ω.

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$= \frac{8}{6} = \frac{4}{3}$ 11/3 ohms

10 Draw an equivalent circuit. (Fig 8)

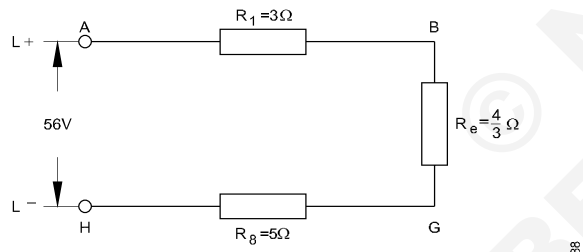
11 Combine R_1, R_e, and R_8.

$R_t = R_1 + R_e + R_8$

$R_t = 1\frac{1}{3} + 5$

$R_t = 9 = \frac{1}{3}$ ohms

Fig 8



EQUIVALENT CIRCUIT IN FIG 3, R_2, R_3, R_4, R_5, R_6, AND R_7 ARE REPLACED WITH ONE RESISTANCE (R_e) EQUAL TO $\frac{4}{3}\Omega$.

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The total combined resistance of the circuit is ohms.

Application

Series-parallel circuits can be used to form a specific resistance value which is not available in the market and can be used in the voltage divider circuits (Fig 9).

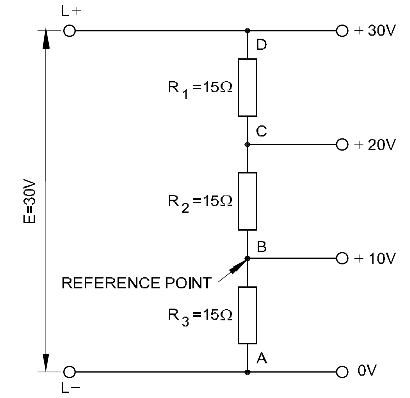
Voltage divider

To have different voltages for different parts of a circuit, construct a voltage divider. In effect, a voltage divider is nothing more than a series-parallel circuit.

A good voltage divider cannot be designed without first looking at the load resistance. Note in (Fig 9) that a voltage divider is made with three 15 ohm resistors to get 10 volts drop across each one.

However, as soon as another resistor (load) is added as in (Fig 10), there is a further change. The load resistor

Fig 9



VOLTAGE VALUES ARE GIVEN FOR VOLTAGE DROP TESTS TAKEN ACROSS RESISTORS FROM A TO B (+10V), B TO C (+10V) AND B TO D (+20V). NOTE THAT THE CIRCUIT IS GROUNDED AT REFERENCE POINT B.

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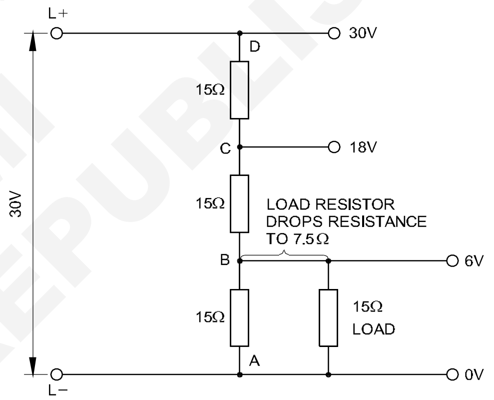
serves to drop the total resistance of the lower part of the voltage divider. Use this formula for finding the equivalent resistance (Req) of resistors of equal value in a parallel circuit:

Fig 10



THREE 15 OHMS RESISTORS AND ONE 15 OHM LOAD RESISTOR SERVE AS A VOLTAGE DIVIDER THAT ROUTES DIFFERENT VOLTAGES TO DIFFERENT PARTS OF THE CIRCUIT.

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$R_{eq} = \frac{r}{N}$

$R_{eq} = \frac{15}{2} = 7.5$ ohms

The equivalent resistance of these two 15 ohm resistors in the lower part of the voltage divider is 7.5 ohms. What will happen to the current and voltage in the circuit as a result of this resistance change.

Remember that, as resistance goes down, current goes up. Therefore, with the addition of the load resistor, the circuit will now carry higher amperage but the voltage between points A and B as well as A and C changes. It is important, then, when constructing a voltage divider circuit, to watch the resistance values which change both voltage and current values. Study Figure 10 carefully to make sure you understand how a voltage divider works.

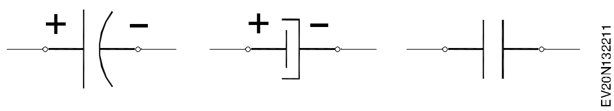
Capacitors

Objectives: At the end of this lesson you shall be able to
- **State the function of capacitor**
- **Describe the energy storing of capacitor**
- **State the factors that determine capacitance value**
- **Explain the types of fixed value capacitors**

Capacitors and capacitance

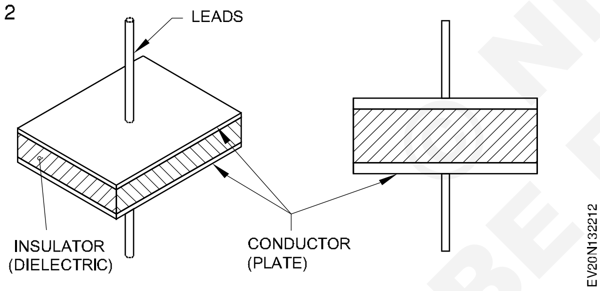
Capacitors are electronics components which can store electric energy in the form of electric charge. The charge storage ability of a capacitor is called as capacitance of a capacitor. Symbols used to represent capacitors are shown in the Fig. 1 Alphabet 'C' is used to represent the capacitance of a capacitor.

Fig 1



A simple capacitor consists of two pieces of conductors separated by an insulator as shown in Fig.2

Fig 2



In capacitors the conductors shown in Fig.2 are called plates and insulator is called dielectric.

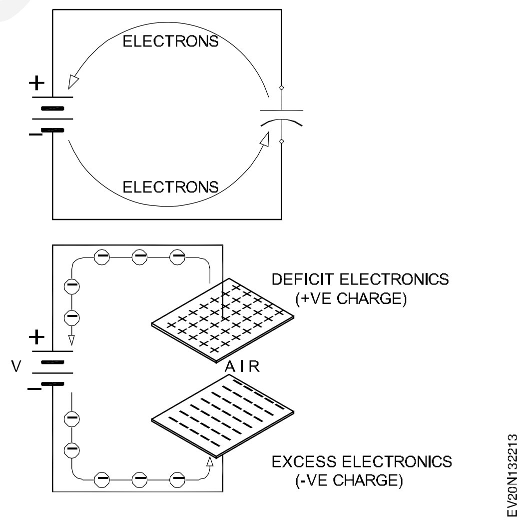
The plates of a capacitor can be of any size and shape and dielectric may be any one of several insulator materials. Depending upon the type of insulator/ dielectric used capacitors are called as paper, mica, glass, polyester, air electrolyte capacitors etc.

Capacitor action of storing charge

When electric charge is forced on to the plates of a capacitor by some energy source, such as battery, the capacitor stores these changes.

When a capacitor is connected to a battery as shown in the Fig.3 the electrons from the negative terminal of battery move through the connecting leads and pile up on one of the plates of the capacitor. At the same time free electrons from other plate of the capacitor (remember the plates of a capacitor are conductors having free electrons) move through the connecting lead to the positive terminal of the battery to a battery as shown in the Fig.3 the electrons from the negative terminal of battery move through the connecting leads and pile up on one of the plates of the capacitor. At the same time free electrons from other plate of the capacitor (remember the plates of a capacitor are conductors having free electrons) move through the connecting lead to the positive terminal of the batter. This process is known as "charging of capacitor". As the process of charging continues the net result is that one plate of the capacitor ends up with excess of electrons (negative charge) and the other plate with deficiency of electrons (positive charge). These changes of the plates of the capacitor represents a voltage source similar to that of the charges on the terminals of a battery /cell. The process of charging stops once the energ**y** stored on the capacitor develops a voltage equal to that of a battery.

Fig 3



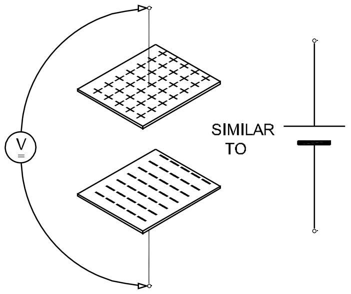
It is important to note that during the process of charging, although the electrons are moving from and to the capacitor plates causing current flow in the circuit (You can connect an ammeter to connect it), no electrons moved nor did the current flow from one plate through the dielectric to the other plate of the capacitor. The charging current through the current stops when the voltage across the capacitor becomes equal to and in opposition to the battery voltage. This charged capacitor can be disconnected from the circuit and used as a new energy source as shown in the Fig.4

If a voltmeter is connected across this disconnected charged capacitor, the voltmeter reads the voltage equal to that of the battery which charged it.

If a lamp is connected across this charged capacitor, the bulb glows for a moment indicating current flow through it.

The instructor to demonstrate charging of a capacitor, voltage across a disconnected charged capacitor and discharge of a charged capacitor through a lamp using a suitable demonstration circuit.

Fig 4



The charge stored in the capacitor is sufficient to supply current through the bulb only for a short duration after which the charge filed up on the capacitor plates gets exhausted. A capacitor has limited use as a primary storage device of energy for two reasons:

1 For its weight and size, the amount of energy it can store is very small when compared with that of a battery.

2 The voltage available from the capacitor diminishes rapidly as energy is removed from the capacitor.

Unit of capacitance

The ability of capacitor to store electrical energy in the form of electrostatic field is known capacitance. The unit used to measure capacitance is **Farad** abbreviated as **F**.

Farad(F) is a very large quantity of capacitance. As most circuits use capacitance values much lower than one farad (F), smaller quantities of capacitance given below are generally used:

1 Microfarad or 1μF = 1/1000000 F or 10^{-6} farads

1 Nanofarad or 1 nF = $1/10^{9}$ F or 10^{-9} farads

1 Picofarad or 1pF = $1/10^{12}$ F or 10^{-12} farads

Factors that determine the value of capacitance

The capacitance of a capacitor is determined by the following three main factors;

1 Area of the plates

2 Distance between the plates

3 Type of dielectric material (dielectric constant k)

In addition to the above factors affecting the value of capacitance, the temperature of the capacitor also affects the capacitance although not very significantly. Increase or decrease in temperature affects the characteristics of dielectric material which in-turn increases or decreases the capacitance value. Some dielectrics cause an increase in capacitance as temperature increases. These are called positive temperature coefficients, abbreviated as P. Other dielectric materials have negative temperature coefficient, abbreviated as N, in which case, increase in temperature decreases the capacitance. There are dielectric materials having zero temperature coefficient abbreviated as NPO. The temperature coefficient of a capacitor is specified by the capacitor manufacturer in parts per million per degree Celsius (PPM).

Types of capacitors

Capacitors can be classified under two main categories:

1 Fixed value capacitors

The capacitance value of these capacitors is fixed at the time of manufacture. This value cannot be varied/ altered by the user.

2 Variable capacitors

The capacitance of such capacitors can be varied between the specified minimum to the specified maximum values by the user.

Amongst fixed value capacitors, many different types of capacitors are manufactured to satisfy the needs of the electronic industry. These different types of capacitors are named according to the

1 Type of dielectric material used in capacitor

Example:

a If paper is used as dielectric, the capacitors are called paper capacitors.

b If ceramic is used as dielectric, the capacitors are called Ceramic capacitors.

2 Type of construction of the capacitor

Example:

a If the foils of the conductor and dielectric are rolled to form a capacitor, such capacitors are called as Rolled foil capacitors.

b If the plates and dielectric are in the form of Discs, such capacitors are called as Disc capacitors.

Different types of fixed value capacitors, their sub types, available values, rated voltage and a few applications are given in Chart 1 at the end of this lesson. Also refer to Chart 3 for illustration of some of the popular fixed value capacitors.

Specifications of capacitors

While ordering capacitors, one has to indicate the specifications needed to ensure that the desired capacitor is received. The minimum specifications to be indicated while purchasing/ordering capacitors for general use are;

1 **Type of capacitor**

For example: Ceramic, disc, styroflex, electrolytic and so...on.

2 **Capacitance value**

For example: 100μF, 0.01μF, 10pf and so....on.

3 **DC working voltage rating (DCWV)**

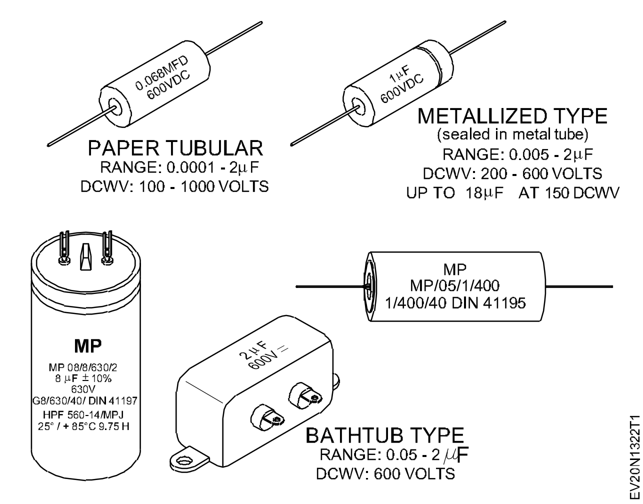
For example: 100μF-12V, 100μF-100V, 0.01μF-400V and so...on.

4 **Tolerance**

Like resistors, capacitors also have tolerances over its rated value. Tolerance of capacitors may range from ±1% to ±20%. Some capacitors may have tolerance specified as -20%, +80%.

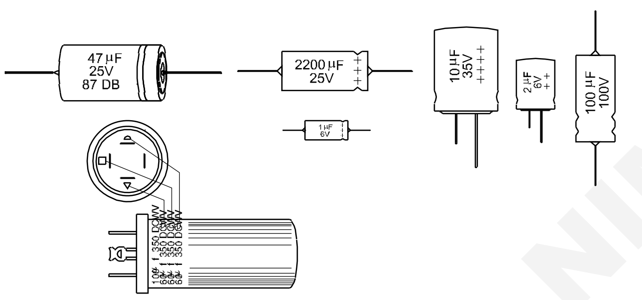
CHART- 1 : physical appearance of types of fixed value capacitors

PAPER CAPACITORS

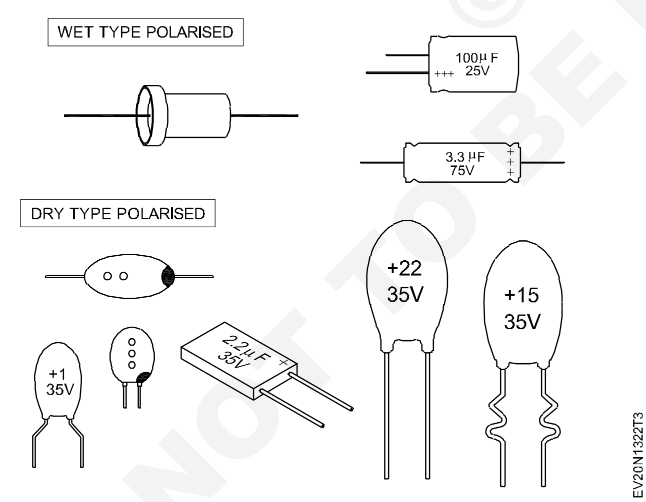


ELECTROLYTIC CAPACITORS

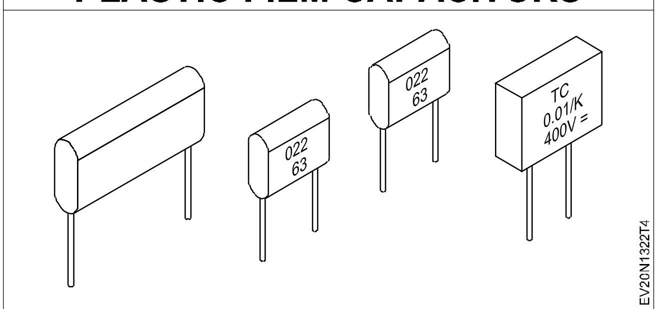
ALUMINIUM TYPE



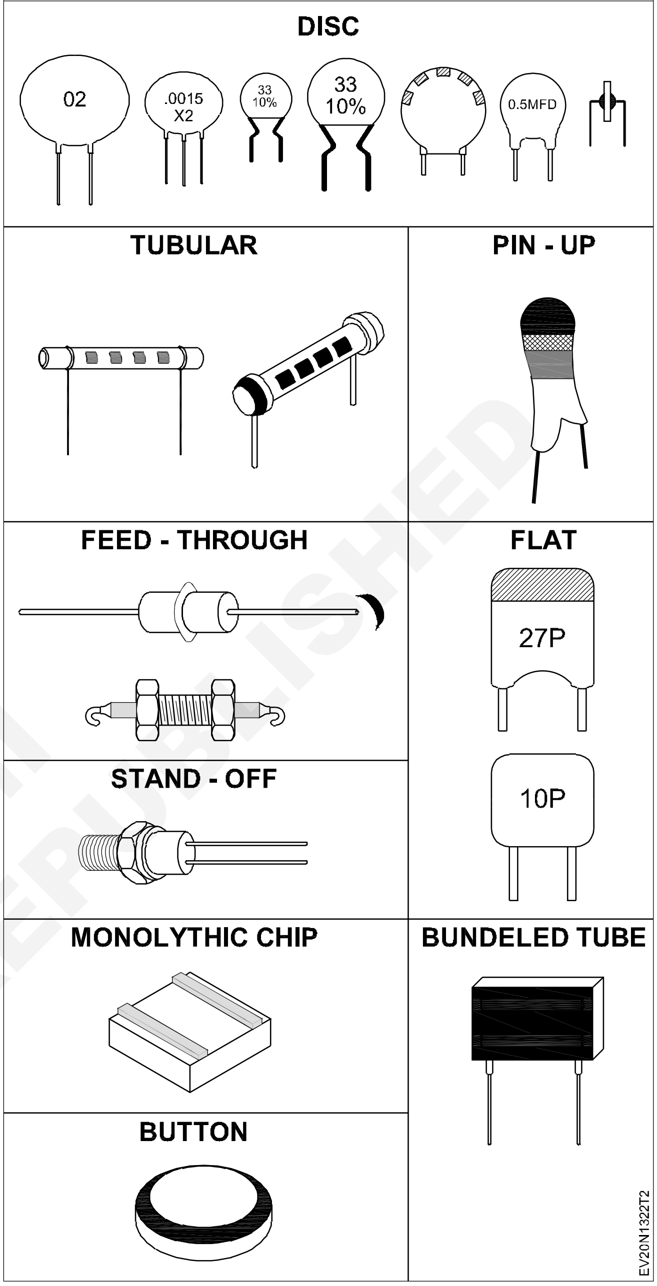
TANTALUM TYPE



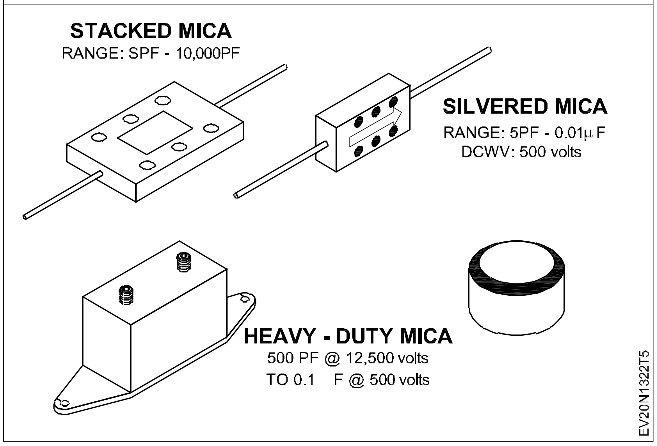
PLASTIC FILM CAPACITORS



CERAMIC CAPACITORS



MICA CAPACITORS



Grouping of capacitors

Objectives: At the end of this lesson you shall be able to
- **state the necessity of grouping of capacitors**
- **list the conditions for connecting capacitors in parallel**
- **determine the values of capacitance and voltage in parallel combination**
- **list the conditions for connecting capacitors in series**
- **determine the values of capacitance and voltage in 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.

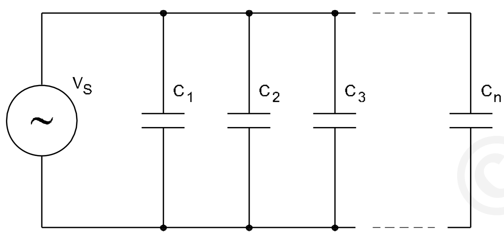
Necessity of parallel grouping

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.

Fig 1



CAPACITORS 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.

By comparing (Fig 2a and 2b), you can understand that connecting capacitors in parallel effectively increases the plate area.

General formula for parallel capacitance

The total capacitance of parallel capacitors is found by adding the individual capacitances.

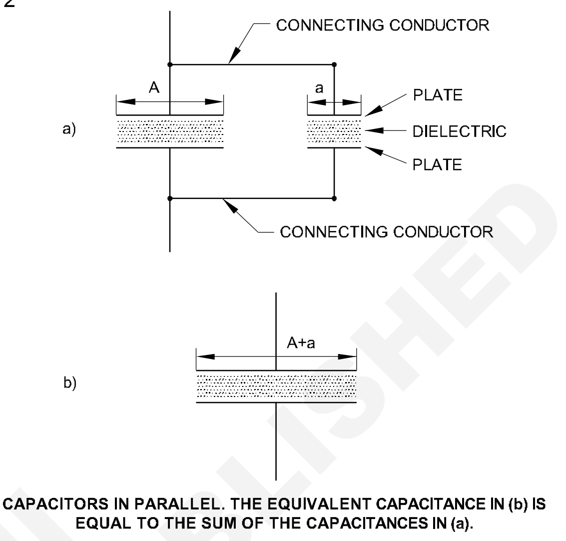
$C_T = C_1 + C_2 + C_3 + \ldots\ldots\ldots\ldots + C_n$

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.

Fig 2



CAPACITORS IN PARALLEL. THE EQUIVALENT CAPACITANCE IN (b) IS EQUAL TO THE SUM OF THE CAPACITANCES IN (a).

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.

$Q_T = Q_1 + Q_2 + Q_3 + \ldots\ldots + Q_n$

where QTis the total charge

$Q_1, Q_2, Q_3 \ldots\ldots$etc. are the individual

charges of the capacitors in parallel.

Using the equation Q = CV,

the total charge QT = CTVS

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, $C_T = C_1 + C_2 + C_3$

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. But, the voltage drop across each capacitor depends upon the individual capacitance. If the capacitances are unequal, you must be careful not to exceed the breakdown voltage of any capacitor.

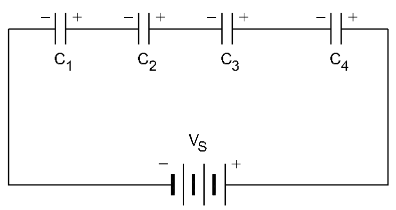
Conditions for series grouping

- 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



SERIES CONNECTION OF CAPACITORS

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Total capacitance

When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

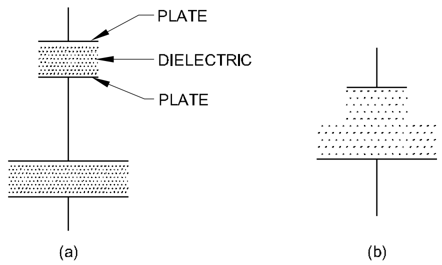
– the effective plate separation thickness increases

– 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.

By comparing (Fig 4a and 4b) you can understand that connecting capacitors in series increases the plate separation thickness, and also limits the effective area so as to equal that of the smaller plate capacitor.

Fig 4



THE EQUIVALENT CAPACITANCE IN (b) IS LESS THAN THE LOWER OF THE TWO CAPACITANCES IN (a).

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General formula for series capacitance

The total capacitance of the series capacitors can be calculated by using the formula

$$C_r = \frac{1}{\frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3} + \dots\dots\dots + \frac{1}{c_n}}$$

or

$$\frac{1}{C_T} = \frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3} + \dots\dots\dots + \frac{1}{c_n}$$

If there are two capacitors in series

$$\frac{1}{C_T} = \frac{C_1 C_2}{C_1 + C_2}$$

If there are three capacitors in series

$$C_r = \frac{C_1 C_2 C_3}{Cr\ C_2 + (C_2 C_3 + (C_3 C_1)}$$

If there are `n' equal capacitors in series

$$C_r = \frac{c}{n}$$

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.

$$V_x = \frac{C_r}{C_x} \times v_s$$

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.

Example: Find the voltage across each capacitor in Fig 3.

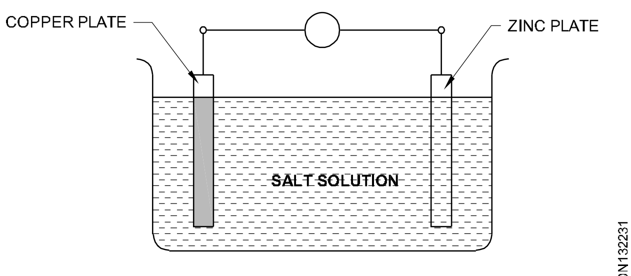
Electricity effects

Objectives: At the end of this lesson you shall be able to
- **state the electro chemical process**
- **state the effect of an electric currents.**
- **state the thermo couple**
- **state the thermo electric energy**
- **state the piezo electric energy.**
- **state the photo voltaic energy.**

Chemical sources (Electro chemical process)(Fig 1)

If two electrically conducting materials (metals) are immersed in salt solutions, an electric charge is produced between the two metals (electrodes, poles). Two examples are given below.

Fig 1



ELECTRICITY GENERATION BY DISSOLVING IN ELECTROLYTES

Copper and Zinc in salt solution is one combination

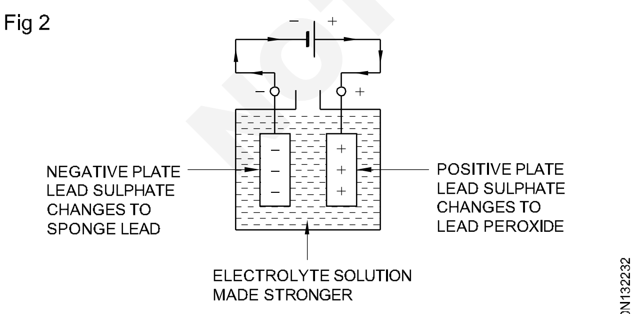
Lead and sulphuric acid is another combination.

This arrangement is known as wet cell and gives direct current. The second combination is used in a Lead Acid Battery for Motor vehicles.

Dynamic electricity (Fig 2)

The current is produced by A/C or D/C generators, by conversion of mechanical energy into electrical energy. The generation of electric current is based on the fact when a conductor is moved in a magnetic field an E.M.F is set up in the conductor. When a large number of conductors are moved in a powerful magnetic field, high voltages and current are produced. This is the Principle of Dynamo.

Fig 2



DURING CHARGING PROCESS

The effect of an electric current

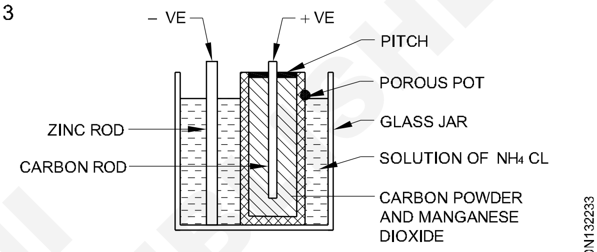
Let us now study effects of an electric current. When an electric current flows through a circuit, its presence could be analysed by its effects. They are stated below.

Chemical effect (Fig 3)

When a current is applied to a battery from a battery charger various chemical reactions are produced which enable the electrical energy to be stored in a chemical form.

The process is called charging a battery by electrolysis method (using electric current).

Fig 3

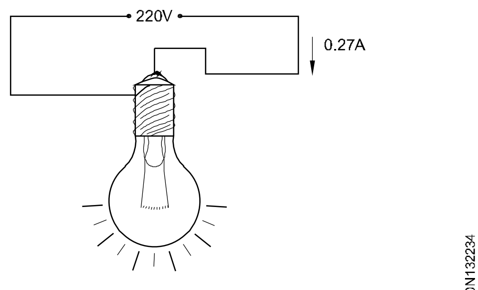


LECLANCHE CELL

Heating effect (Fig 4)

When a current is applied to a bulb filament (fine wire) it becomes white hot and thus produces light.

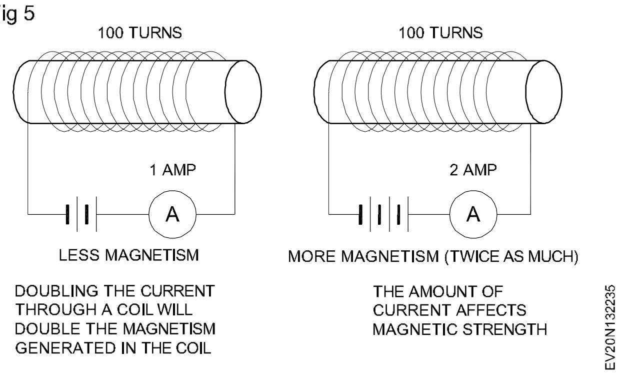
Fig 4



HEATING EFFECT

Magnetic effect (Fig 5)

Fig 5



- If a soft iron bar is placed in a coil of wire and a current is passed through the wire, the iron bar becomes magnetised. If the current is withdrawn the bar with retain some magnetism depending on the materials.
- If a bar magnetic is moved in a coil of wire, to and fro then Current flow is occurred in the coil of wire. This can be find by connecting a "Galvanometer". The current, will flow only when the bar magnet is moving actually. Because, the turns of coil of wire should cut the lines of force.

Shock effect

If the current flow through Human body, it may give a severe stock or cause even death of the individuals so one must be careful in dealing with electrical current during work.

Note :

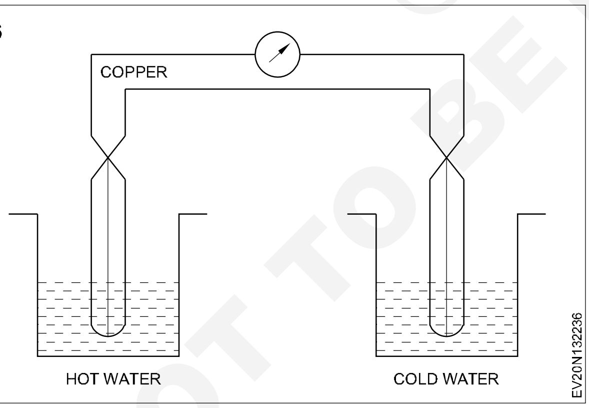
In motor vehicle trade application, the following effect electric current are widely used

- Chemical effect-for battery.
- Heating effect-Head lamp bulbs for lighting.
- Magnetic effect-Electro magnets in relays and cuts.

Thermocouple (Fig 6)

This is such an arrangment where circuit is closed by wires of different metals. One metal wire is kept at low temperature and the other at high temperature. In this way thermo-electro motive force is created which can be seen by galvanometer. This works on the effect of seebake.

Fig 6



Thermo electric energy

Thermo electric energy is the electrical energy produced by waste heat of an IC engine using seeback effect.

Thermo electric generation can convert waste heat from an engine coolant or exhaust into electricity.

Piezo - electric energy

Piezo electric sensor is a device that uses the piezo electri effect to measure the changes in pressure, acceleration or force, by convertring them to an electrical charge.

Application

It is used to initiate combustion in the IC engine mounted into a holes into the cylnider head.Glow plug is a in-built miniature piezo-electric sensor.

Photo voltaic energy

Photo volatile (PV) is a term which covers the conversion of light into electricity by using semiconducting materials that exhibit the photovoltaic effect. This effect is seen in combination of two layers of semi conductor materials, one layer of this combination will have it depleted number of electrons.

When sunlight strikes on this layer, it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer. This phenomenon creates a charge difference between the layer and resulting to a tiny potential difference between them.

The unit of such combination of two layers of semi conductor materials, for producing electric potential deference in sunlight is called solar cell. Silicon is normally used as solar cell. For building cell, silicon material is cut and very thin wafers. Some of these wafers are doped with impurities. Then both doped and undated wafers are and switched together to build solar cell. A metallic strip is reached to two extreme layers to collect current.

A desired number of solar cell are connected together in both parallel and series to form a solar module for producing desired electricity.

The solar cell can also work in cloudy weather as well is moon light but the rate of production of electricity low as and it depends up on intensity of incident light ray.

Fig 1 describes the typical system of solar panels, controller, energy storage, inverter for converting DC into AC and how the system is connected to power grid.

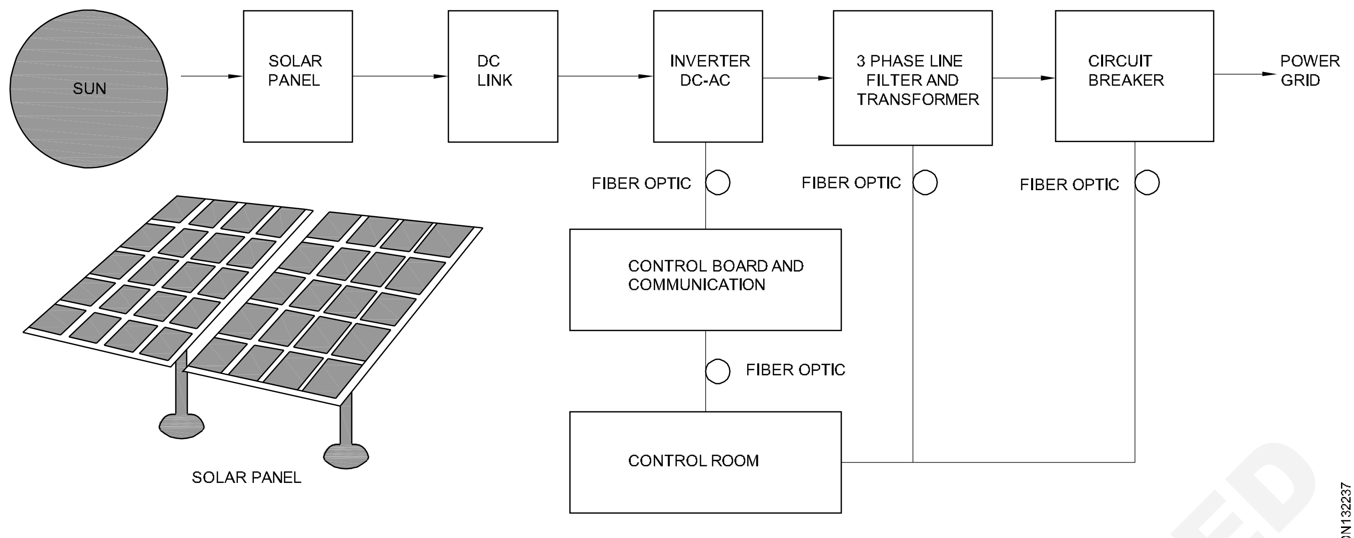
Solar panels installation may be ground, rooftop or wall mounted. The solar panels mount may be fixed a solar tracker to follow the sun across the sky.

Photo voltaic systems have long been used in specialized applications and stand alone and grid-connected PV systems have been in use since the 1990. After hydro and wind powers, PV is the third renewable energy source in term of global capacity. The PV energy covering approximately two percent of global electricity demand. It is an environmentally clean source of energy and it is free and available in adequate quanties in all the parts of world.

Advantages of solar photo voltaic: Solar panels once installed. Its operation generates no pollution and no green house gas emissions it is simple salability in respect of power needs and silicon has large availability in earth

Disadvantages of solar photovoltaic (Fig 7): The power output is dependent on direct sunlight. That 10-25% is lost, if a tracking system is not used. Dust, clouds and other obstruction in the atmosphere also diminish the power output. Solar photovoltaic power needs to be stored for later use.

Fig 7



SOLAR POWER PLANT

Electromagnetic induction, self-induced emf - inductors

Objectives: At the end of this lesson you shall be able to

- **state the principle and law of electromagnetic induction.**

Faraday's Law of Electromagnetic induction are also applicable for conductors carrying alternating current.

What are Faraday's Law 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

The second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

According induced emf can be produced either by moving the conductor in a stationery magnetic field by changing magnetic flux over a stationery conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Ex. generators.

When changing flux produces emf the emf is called as statically induced emf as explained below. Ex: Transformer.

Magnetic field around a current-carrying conductor

When current is passed through a conductor, a magnetic field is produced around it. It is important to note the following two factors about the magnetic lines of force around a current carrying conductor.

1 The magnetic lines are circular and the field is symmetrical with respect to the current carrying wire in the centre.

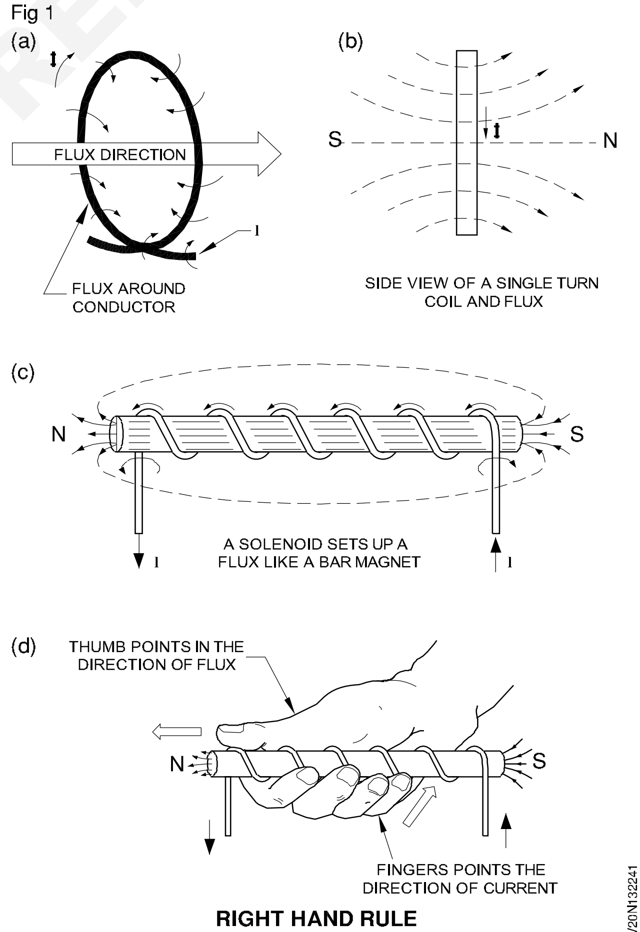
2 The magnetic field with circular lines of forces is in a plane perpendicular to the current in the wire.

The direction of the magnetic lines around the conductor can be determined by the right hand screw rule. The direction of magnetic lines reverses, if the direction of current through the conductor is reversed. This magnetic field around a single conductor is too weak to make the wire behave as a useful magnet.

Magnetic field around a coil

Consider the effect of passing a current through a one-turn coil of wire as shown in Fig a.

Fig 1



RIGHT HAND RULE

Fig 1a and b shows the magnetic flux generated by the electric current passing through the centre of the coil. Therefore, a one-turn coil acts as a little magnet. It has a magnetic field with an identifiable N pole and S pole. Instead of a single turn, a coil may have many turns as shown in Fig 1c. In this case, the flux generated by each of the individual current -carrying turns, tends to link-up and pass out-of one end of the coil and back into the other end as shown in Fig 1c. This type of coil, also known as a solenoid has a magnetic field pattern very similar to that of a bar magnet.

The right hand rule for determining the direction of flux from a solenoid is illustrated in Fig 1d. When the solenoid is gripped with the right hand such that, the fingers are pointed in the direction of current flow in the coils, the thumb points in the direction of the flux as shown in Fig 1d. The coil now behaves like an electromagnet.

The solenoid acts like a bar magnet whether it has an iron core or not. Adding an iron core in a solenoid increases the flux density inside the coil. In addition, the field strength will then be uniform for the entire length of the core. It should be noted that, adding an iron core into a solenoid does not change the N and S pole positions of the solenoid.

When the direction of the current through the coil is changed, it changes the direction of magnetic lines, thereby changing the poles of the solenoid.

Applications of electromagnet

Electromagnets are used in various applications such as electrical circuit breakers, relays, door bells etc.

Lenz;s Law

The basic principle used to determine the direction of induced voltage or current is given by lenz's Law

Lenz law states that the direction of induced current is such that the magnetic field set-up due to the induced current opposes the action that produced the induced current.

Relays:

Introduction

In addition to solenoids, one other most popular application of electromagnets is in what are called electromagnetic relays.

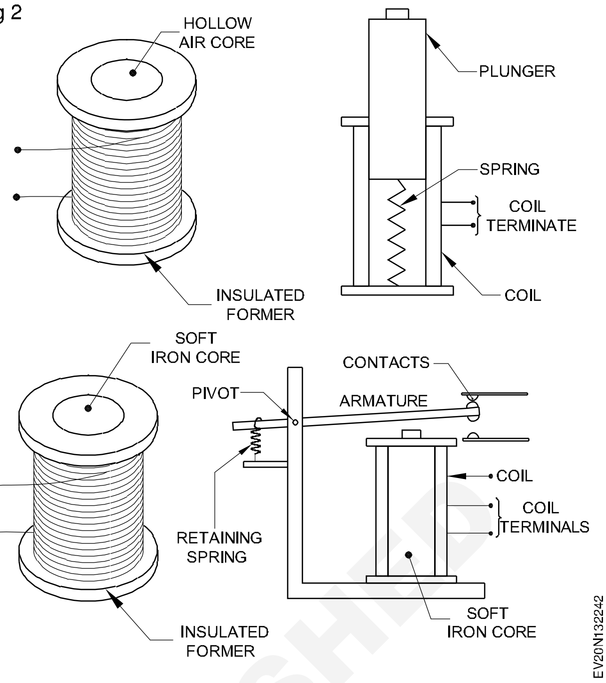
Important similarities and differences between a solenoid and a relay is illustrated in Fig 2.

Electromagnetic relays

The term relay was used for the first time, to describe an invention made by Samuel Morse in 1836. The device invented by Morse was a Telegraph Amplifying Electromagnetic Device. 'This device enabled a small current flowing in a coil to switch-ON a large current in another circuit, and thus helped in relaying of telegraph signals.

In any application, the object of a relay is generally to act as a remote switch or as a electrical multiplier switch. This means, a relay enables a comparatively weak current to bring into operation a much stronger current or currents.

Fig 2



Construction and operation of a simple relay

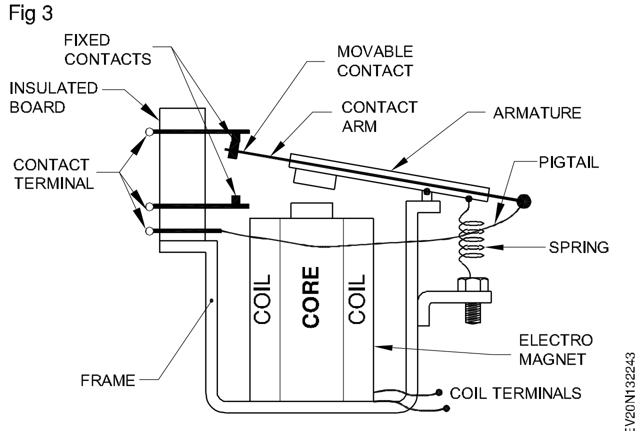
Electromagnetic relay is basically a switch or a combination of switches operated by magnetic force generated by a current flowing through a coil.

Essentially, a typical relay shown in Fig 3 consists of the following parts;

- an electromagnet comprising of a core and coil
- a movable armature,pivoted and held in tension by a spring
- a set of contacts
- a frame to mount all these components.

As shown in Fig 3, a typical relay consists of a core surrounded by a coil of wire. This is mounted on a metal frame. The movable part of the relay is the armature. One end of the armature is hinged and connected to a spring. On the armature is mounted a contact arm carrying movable contacts. The fixed relay contacts and its terminals are mounted on an insulated terminal board.

Fig 3



When the relay is OFF or not energized, the contact arm touches the top contact. When the relay is energized by applying voltage to the coil terminals, the metallic armature is attracted. The armature and contact arm assembly move downward so that the contact arm mounted on the armature touches the bottom contact. Thus, the relay is doing the function of a single pole, double throw (SPDT) switch.

On removing the voltage applied to the coil, the spring attached to one end of the armature returns the armature to its original position and the contact arm touches the top contact.

Operating delay of relays

When an energizing voltage is applied to a relay coil, the relay does not work instantaneously. It takes some time, usually a few milliseconds to operate. Reasons for this delay are given below:

- Due to inductance of the relay coil, current grows slowly and takes some time to reach the required current value.
- Due to inertia, the armature takes sometime to move from one position to another.

When rated voltage is applied to terminals of a relay coil, the gradual build up of current in the coil is due to the initial opposition to the current flow by the self-inductance of the coil. After some delay, when sufficient magnetization is built up and when the force of attraction is sufficient to overcome the opposition of the tension due to return spring plus, tension of contact springs, the armature is attracted and it closes the relay contacts. The relay is then said to be energized or pulled-in or picked.

Once the relay is energised then, only a small amount of energy is required to maintain it in energized condition. The rest of the electrical energy is wasted as heat.

When the current through the coils falls below a certain value, the relay gets de-energised and the return spring pulls the armature back. This is called as relay drop-out.

From above it can be seen that, very little amount of electrical power is consumed for the switching of relay whereas most of the power is consumed while holding.

Parts of a Relay

Each part of a relay is as important as the other in the overall performance of the relay. Details of the parts of a relay and their purpose are given below:

Frame and core : One of the main function of the relay frame is to provide a base for mounting other relay parts. But, the most important function is, the frame forms a part of the complete magnetic path between the armature and core. The core, frame and armature are made of an easily magnetizable material such as iron.

Hinges : The hinges connect the armature to the frame. A good hinge must be as free from friction as possible. They must also be strong enough to support the weight of the armature and contacts. The hinges must provide low reluctance to the magnetic flux in its path from the core through the frame and the armature.

Return springs : The springs are usually very thin and cannot concentrate any large amount of flux. Spring steel, which has a lower reluctance than other materials acts to retain its magnetism and remain attracted to the core after the relay is de-energised. Springs also have a disadvantage of being stiff and are likely to break after a few operations.

Relay coil : The coil is usually wound on a former and slipped over the magnetic core in the relay frame. This permits easy replacement of damaged coils by new ones.

Coil Specifications

Generally relays are made to operate at different voltages such as, 6, 12, 18, 24, 48, 100 or 240 volts AC or DC. A coil resistance chart is usually given with relays which helps in calculating the coil current and power dissipation. Maximum wattage, maximum permissible temperature and the wattage for satisfactory operation, are specified along with relays.

Operate current	– is the minimum current required to energize a relay.
Hold current	– is the minimum coil current required to continue to hold the relay energized.
Release current	– is the maximum current which releases the relay.

Relay coils are always insulated from the frame of the relay. The electrical resistance between the coil and the body is a measure of the isolation of energising voltage from the ground. Similarly, the electrical resistance between the coil and the contacts is a measure of the electrical isolation between the energising driving and the driven circuits. These resistances will be of the order of hundreds or thousands of megohms.

Relay contacts

The contacts on a relay are the parts that actually perform the electrical switching of the controlled circuits. Also, these contacts are the ones that cause most trouble and require frequent maintenance as compared to any other part of a relay.

Contact materials and design

The relay contacts are made of material which are very good conductors as well as corrosion-resistant.

An arc is created when the contacts open and close. This arc burns and oxidises the contacts. An oxide coating make the contacts either poor conductors or non-conductors. For this reason, contacts are made of silver, palladium and palladium-iridium alloys, gold alloys, gold plated silver, tungsten and alloys of other highly corrosion-resistant materials that do not oxidize easily.

Even with these materials, some oxidation still takes place. To get rid of the oxide, the contacts are designed to have a wiping action. As the contacts close and open, the surfaces rub together. This action rubs off any oxide or dirt which might cause poor contact.

Contacts come in many shapes and sizes, and in a variety of contact arms. These contact arms are generally called contact springs because they maintain good contact pressure.

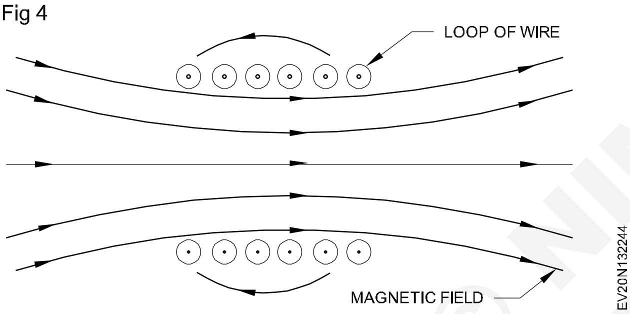
Size of the contacts determines the current handling capability. The larger the contacts, the more current they can switch without excessive deterioration.

The contact arms or springs are made thick and wide enough to carry the current for which the contacts are rated. They are also made spongy enough to ensure good contact. If the springs are too soft they may vibrate when the relay opens, causing contact bounce when the contacts open and close repeatedly. This bounce can also occur on closing. The bouncing of contacts is always undesirable. Contact debouncing circuits are used to overcome the undesirable effects of contact bouncing in sensitive circuits such as digital electronic circuits.

Solenoid

Solenoid is a coil wound into a tightly packed to a long thin loop of wire, often wrapped around a metalic core, which produces a uniform magnetic field in a volume of space. (Fig 4)

Fig 4

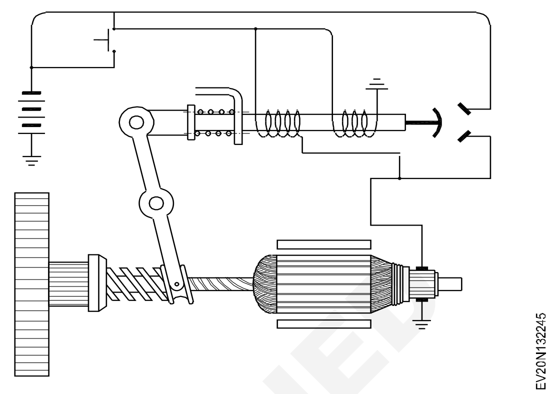


Application

Need for solenoid switch: The solenoid switch is a strong electromagnetic switch. It is used to operate the over running clutch drive pinion to engage with the fly wheel ring gear. It also acts as a relay to close the contacts between the battery and the staring motor.

Construction of solenoid switch (Fig 5) : In a solenoid there are two windings, a pull-in winding (1) and a hold - in winding (11). The pull - in winding (10) is wound with

Fig 5



thick wires (series winding) and the hold - in winding (11) is of thin wires (shunt winding). The pull-in winding (10) is connected to the starter switch (3) in the solenoid.

The hold in winding (2) is connected across the switch terminal and ground. The two windings are wound around a hollow core (4). An iron plunger (5) is placed inside the core (4). The other end of the plunger moves a shift lever (7) to engage the pinion (8) with the fly wheel ring gear (9).

Function of solenoid switch: When the starter switch (Fig.3) (3) is turned, current flows the battery to the solenoid windings (1) and (2). This energises the windings which pull the plunger (5). The plunger (5) operates the shift lever (7) to engage the pinion (8) on the flywheel ring gear (9). Then it closes the circuit between the battery (10) and the starter motor.

Transformers and alternators

Objectives: At the end of this lesson you shall be able to
- **describe a two winding transformer**
- **explain the ignition coil as a step up transformer**
- **state the function of a transformer**
- **describe a function of a alternator and its parts.**

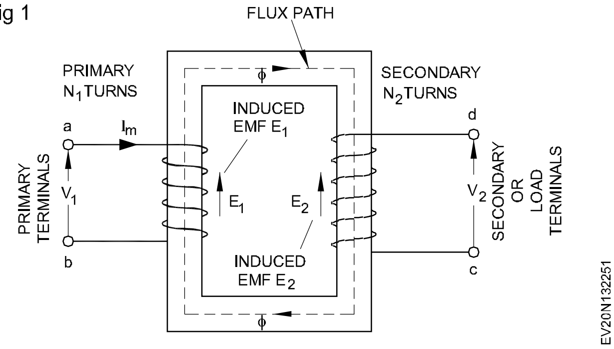
Two- winding transformers

A transformer in its simplest form consists of two stationary coils coupled by a mutual magnetic flux (Fig 1). The coils are said to be mutually coupled because they link a common flux.

Laminated steel core transformers are used in power applications. As shown in Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.

The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Fig 1



Transformers are efficient and reliable devices used mainly to change voltage levels. Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are in the range of 92 to 99%. The higher values apply to the large power transformers. There is no change in frequency of voltage.

Transformer

A transformer is an electrical device that transforms the AC voltage between two circuit through an electromagnetic induction.

A transformer may be used as a safe and efficient voltage convertor to change the AC/DC voltage and its to a higher / lower voltage its output without changing the frequency and power.

Types

1 Step up transformer 2 Step down transformer

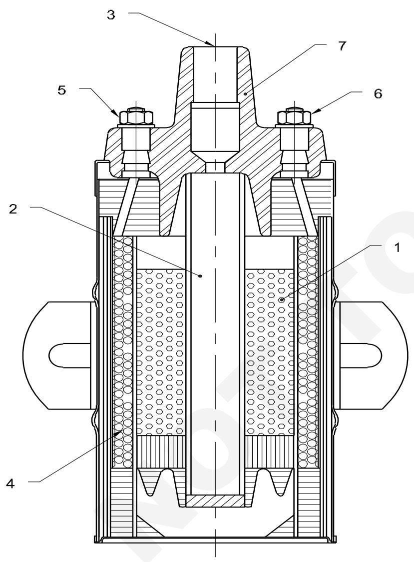
Application

Transformer is used in (1) ignition coil in petrol engine ignition system.

Ignition coil (Fig 2)

It is used to step up low voltage to high voltage to generate sparks. In consists of two windings, one is wound over soft iron core. The secondary winding (1) is wound over the core (2). It consists of about 21,000 turns. One end of the winding is connected to the secondary terminal (3) and the other end to the primary winding (4). The primary winding (4) is wound over the secondary winding (1) and consists of about 200-300 turns. The ends are connected

Fig 2



to the external terminal (5,6) of coil. The bakelite cap (7) insulates the secondary terminal from the container and primary terminals.

Alternator

Alternators are used in cars trucks tractors and two wheelers.

Alternators has two main functions

1 To charge the battery.

2 To supply current to the vehicle while it is running.

Description

The alternator is a 3 phase machine of the revolving field and stationary armature type. Its output from the stator windings is rectified by means of built in silicon diodes in heat sinks mounted within the slip diodes in heat sinks mounted within the slip ring end shield. Output control is effected by varying the rotor excitation. The machine is self limiting in terms of output current. Cooling is provided by a radial fan mounted on the drive end of the rotor shaft. The standard machine is insulated return version. The regulator is housed in the alternator itself.

Terminal arrangement

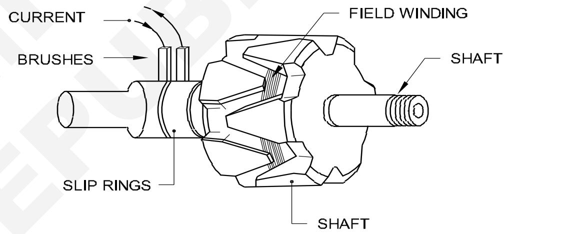
The alternator has three terminals i.e. positive terminal, negative terminal and warning lamp terminal 'WL'.

Rectifier

The rectifier pack comprises of nine silicon diodes, six main output diodes and three field diodes .

Rotor - Forged claw or pressed claw rotors are used. A pair of four fingered claws envelope the field shaft from the 8 pole imbricated rotor. The ends of the windings are brought out an connected to two slip rings at the end of the rotor assembly. The rotor is supported by bearings housed on the two end brackets (Fig 3).

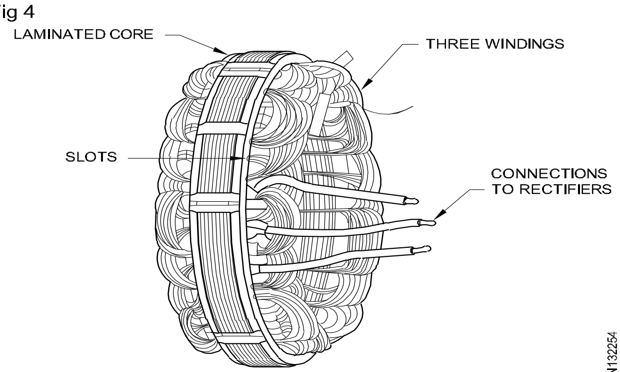
Fig 3



Stator

The stator assembly comprises of a pack of laminations housing a three phase winding in the slots. The stator is held in position by the Drive End (DE) and Slip Ring End (SRE) shields (Fig 4).

Fig 4



STATOR ASSEMBLY

In-built regulator - This is a fully transistorised device with no moving parts, requiring no service attention. The transistors, diodes and resistors are fixed on a printed circuit base and then encapsulated. No cutout relay is necessary as the diodes in the alternator prevent reverse currents from the battery flowing through the stator when the machine is stationary or when generating less than

Switches

Objectives: At the end of this lesson you shall be able to
- **state the function of SPST switch**
- **state the function of relays, solenoids and buzzers.**

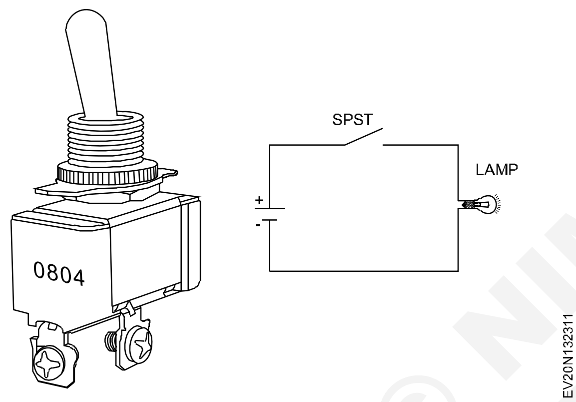
Switch

Switch is an dectrical component that can disconnect or connect the conducting path in an electrical circuit.

Single pole single throw switch (Fig 1)

A single pole single throw switch is a switch that only has a single input and can connect only to one output. This mean it only has one input terminal. The SPST switch serves in circuits as ON-OFF switches.

Fig 1



When the SPST is closed the circuit is closed and light from the lamp switch ON when the SPST is then opened, the light from the lamp goes out and the circuit is OFF.

The above circuit shows the basic nature and function of a SPST switch.

Mercury switch

A Mercury switch is an electrical switch that opens and closes a current when a smalll amount of the liquid metal mercury connects metal electrodes to close the circuit. There are several different basic designs but they all share the common design strength of non eroding switch contacts. This type of switch performs much better than the ball tilt switch the liquid metal connection is unaffected by dirt, debris oxidation it wets the contacts ensuring a very low resistance bounce free connection and movement and vibration do not produce a poor contact.

Ganged switches

Gang - operated switches are used in circuit up to the highest voltages

Relays

Relays are switches that open and close circuits electromechanically relays control one electrical circuit by opening and closing contacts in another circuit.

ISO Relay: Many of the electromechanical relays used in automotive applications are termed ISO relays an ISO relays is one which adheres to a standard pattern for its electrical terminals, that has been spelled out by the international standards organisation. ISO relay terminal patterns include super ISO, ISO 280, Mini 280 ISO and micro 280 ISO. They are widly used in both Erope and the us.

Devices in the super ISO format generally handle about 70 -A loads. Those with the 280 ISO foot print have general purpose application within automotive power control most new developments in relate to fielding smaller devices able to fit into more compact spaces. These relays are used in switching applications such as motors, lamps, resistive loads cooling fans HVAC and window defrost system.

Solenoids

Solenoid is a device composed of a coil the housing and a movable plunger (armature) when an electrical current is introduced a magnetic field forms around the coil, which draws the pluger in more simply, a solenoid converts electrical energy into mechanical work.

The coil is made of many turns of tightly wound copper wire, when on electrical current flows through this wire, a strong magnetic field/ flux is created.

The housing usually made of iron or steel, surrounds the coil concentrating the magnetic field generated by the coil.

The plunger is attached to the stop through the concentration of the magnetic field providing the mechanical force to do work.

Buzzers

A buzzer is an audio signaling device which may be mechanical, electro mechanical or electric typical uses of buzzer and beepers include alaram devices tuners and conformation of user input such as a mouse click or keystroke.

Resistors

Objectives: At the end of this lesson you shall be able to
- **name the types of resistors, construction and power rating**
- **state the meaning of tolerance in resistor**
- **find the value of a resistor using colour code**
- **state the application and types of resistor leads.**

Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

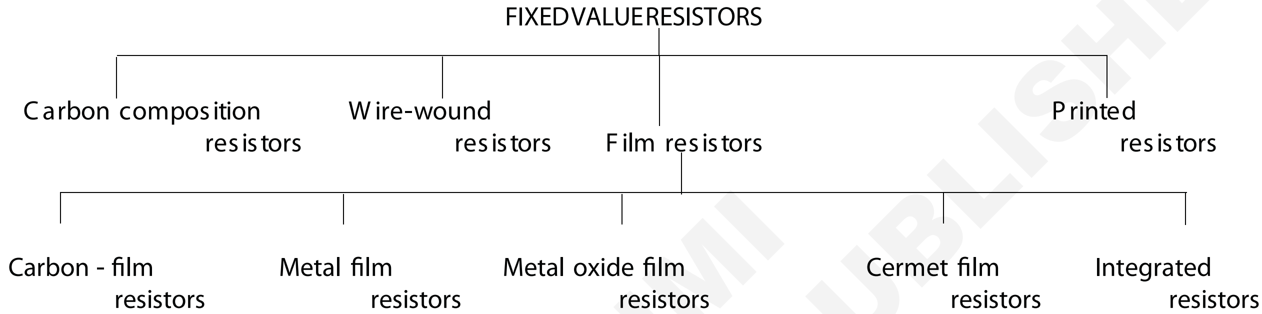
Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process.

Carbon composition resistors

Construction

These are the simplest and most economical of all other types. Brief constructional detail of the simplest type of carbon composition resistors commonly called carbon resistor.

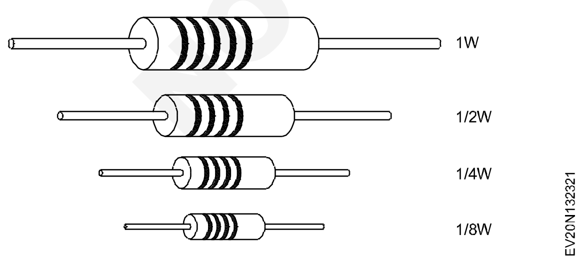


A mixture of finely powdered carbon or graphite(A), filler and binder is made into rods or extruded into desired shapes. Leads(B) made of tinned copper are then attached to the body either by soldering or embedding(C) in the body. A protective layer/tube(D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

Resistor values - coding schemes (Fig 1)

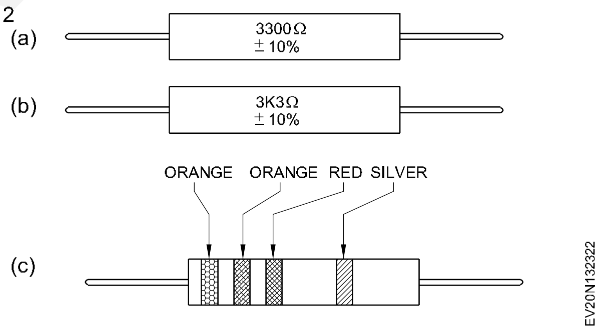
For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.

Fig 1



Selection of a particular type of resistor is possible based on its physical appearance. Table 1 at the end of this lesson illustrates the physical appearance of most commonly used fixed value resistors. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in Fig 2a or using a typographic code as shown in Fig 2b or using a colour code as shown in Fig 2c.

Fig 2



Colour band coding of resistors

Colour band coding as shown in Fig 2c is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult. Refer Table 1.

Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured. This variation will be specified in percentage tolerance. Tolerance is the range(max -to-min) within which the resistance value of the resistor will exist.

TABLE 1

Resistor Colour Code

Colour	Significant figures	Multiplier	Tolerance
Silver	-	10^{-2}	± 10%
Gold	-	10^{-1}	± 5%
Black	0	1	-
Brown	1	10	± 1%
Red	2	10^{2}	± 2%
Orange	3	10^{3}	± 3%
Yellow	4	10^{4}	± 4%
Green	5	10^{5}	± 0.5%
Blue	6	10^{6}	-
Violet	7	-	-
Grey	8	-	-
White	9	-	-
(None)	-	-	± 20%

1, 2 and 3: 1st, 2nd and 3rd significant figures ;

M : Multiplier ; T : Tolerance ; Tc : Temperature co-efficient

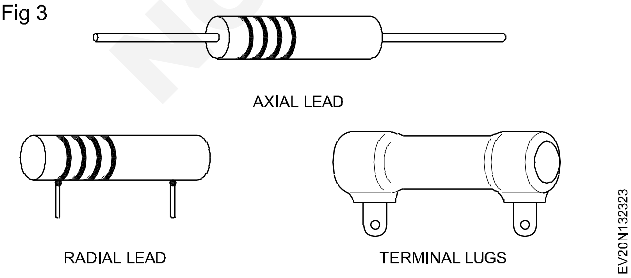
Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

Types of resistor leads

Resistors are available with different types of lead attachment as shown in Fig 3. This make it easy for the user to mount the resistors in different ways on lug boards, PCBs and other types of circuit boards.

Fig 3



Stepped resistor

Stepped resistance stepped or trapped resistors have two or more fixed values. The different resistance (Carbon or wire) are connected to different terminals in a switch. As the switch is moved, different resistance values are placed in the circuit.

Variable resistors

A variable resistor is a resistor of which the electric resistance value can be adjusted. A variable resistor is in essence an electro - mechanical transducer and normally work by sliding a contact (wiper) over a resistve element. when a variable resistor is used as a potential divider by using 3 terminals it is called a potentiometer. when only two terminals are used it functions as a variable resistance and called a rheostal electronically controlled variable resistors exist. which can be controlled electrically instead of by mechanical action. These ressistors are called digital potentiometers.

Potentiometer

The potentiometer is the most common variable resistor. It functions as a potential divider and is used to generate a voltage signal depending on the position of the potentiometer. This signal can be used for very wide variety of applications including. Amplifier gain control (audio volume), measurement of distance, angles, tuning of circuits and much more when variable resisters are used to tune or calibrate a circuit or application, timmer potentiometers or trimpotsd are used these are mostly small potentiometers mounted on the circuit board, which can be adjusted using a screw driver.

Rheostat resistor

Rheostats are very similar in construction to potentiometers but are not used as a potential divider, bus as a variable resistance. They use only terminals insteed of the 3 terminals potentiometer use one connection is made at one end of the resistive element. the other at the wiper of the variable resistor paset variable resistor wired as rheostats are used in circuits to perform tuning or calibration.

Diode

A diode is a two - terminal electronic component that conducts current primarily in one direction it a plate in which electrones can flow in only on direction in the other. A diode vacuum tube or thermonic diode is a vacuum tube with two electrods, heated cathode and has low resistance in one direction and high resistance from cathode to plate.

Types of diodes

The PN junction diodes discussed so far are commonly referred to as rectifier diodes. This is because these diodes are mostly used mostly in the application of rectifying AC to DC.

Classification of diodes

1 **Based on their current carrying capacity/ power handling capacity, the diodes can be classified as**

- Low power diodes

  Can handle power of the order of several milliwatts only.

- **Medium power diodes**

  Can handle power of the order of several watts only.

- **High power diodes**

  Can handle power of the order several 100's of watts.

2 **Based on their principal application, diodes can be classified as**

- **Single diodes**

  Low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing.

- **Switching diodes**

  Low power diodes used in switching circuits as digital electronics etc.for fast switching ON/OFF of circuits.

- **Rectifier diodes**

  Medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

Polarity marking on the diodes

The cathode end of a diode is usually marked by a circular band or by a dot or by plus(+) sign. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

Type number or diode code number

Unlike resistors, capacitors or inductors, the diodes do not have any value that can be printed or coded on its body. The other reason for this is, there are almost innumerable types of diodes with carried handling and other specifications. Hence, instead of printing its specification on its body, all diodes will have a type number printed on their body. This type number carries a set of specification s which can be found out by referring to a diode data manual. Diode data manuals give data of several thousands of diodes from different manufacturers. Some of the popular type numbers of diodes are

OAxx,	xx - from 70 to 95.	examples: OA79, OA85 etc
BYxxx,	xxx - from 100 onwards	examples: BY 127,BY 128 etc
DRxxx,	xxx- from 25 onwards	examples: DR25, DR150 etc
1Nxxxx	examples: 1N917	1N4001, 1N4007 etc.

Diode identification and rating

There are number of common, standard and manufacturers driven numbering and cooling schemes for diode. The rating of diode is important to circuit design and component section. Diode manufacturers provide detailed specifications on their products . diode's identification and ratings are found in reference book and websites up to date.

Clamping diodes

It consists of a diode which conducts electric current in only one direction and prevents the signal exceeding the reference value and a capacitor, which provides a DC offset from the stored charge. The capacitor forms a time constant with the resistor load. Which determines the range of frequencies over which the clamper will be effective.

Zener diodes

Zener diode is basically like an ordinary PN junction diode but normally operated in reverse based condition. But ordinary PN junction diode connected reverse based condition is not used as Zener diode practically. A Zener diode is a specially designed, highly doped PN junction diode.

Avalanche diode

An avalanche diode is a type of semiconductor diode, which is designed to experience avalanche breakdown at a specified reverse biased voltage. The PN junction of an avalanche diode is designed to prevent current concentration and resulting hot spot. So that the diode is undamaged by avalanche breakdown.

The construction of the avalanche diode is similar to the zener diode and indeed both zener breakdown conditions. So they exhibit small but significant voltage drop under breakdown condition, unlike zener diodes always maintain a voltage higher than breakdown.

The normal diode allows an electric current in both direction ie. forward and reverse direction but it is specially designed to work in reverse biased condition. Avalanche diode is used for the protection of the circuit against unwanted voltage and surge voltage.

Photo diode

The photo diode is a kind of PN junction semiconductor diode, which works with intensity of light falling on it at the reverse biased condition

The photo diodes are available in a metallic package. The diode is PN junction mounted in an insulated plastic substrate. Then use seal the plastic substrate in the metal case- ON the top of the metal case, there is a transparent window, which allows light to entire up to the PN junction Two leads anode and cathode of the diode come out from the bottom of the metal case. A tab extending from the side of the bottom portion of the metal case identifies the cathode lead, photo diode is used in alarm and counter circuit.

Light Emitting diode (LED)

Alight emitting diode is a special type of PN junction diode. The light emitting diode is doped and made of a special type semi conductor. This diode can emit light when it is forward biased state. Aluminium indium, gallium phosphate and indium gallium nitride are two of the most commonly used semi conductors for LED technologies. The color of LED device is expressed in terms of the dominant wave length emitted. The color and forward voltage of LEDs depends upon the temperature of the LED PN junction.

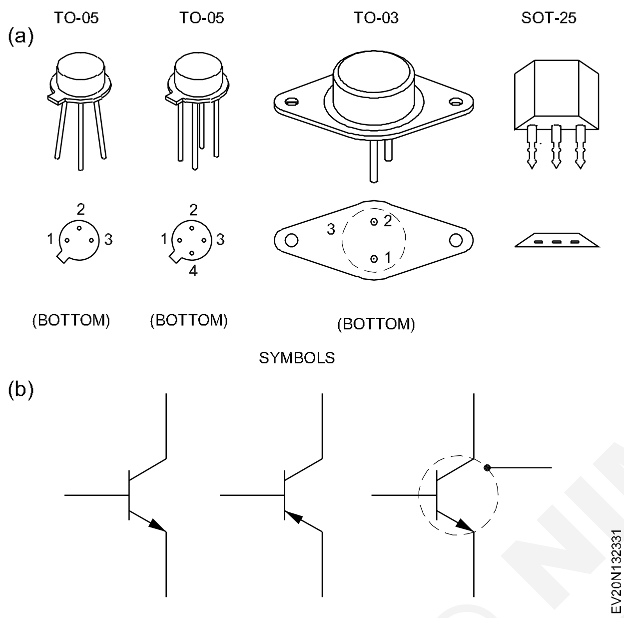
Transistors and classification

Objectives: At the end of this lesson you shall be able to
- **State the Uses of transistors**
- **List the important classification of transistors**

Introduction to Transistors

Transistors are semi conductor devices having three or four leads/terminals.Fig.1 shows some typical transistors . Fig 1 b shows the symbols used for different types of transistors.

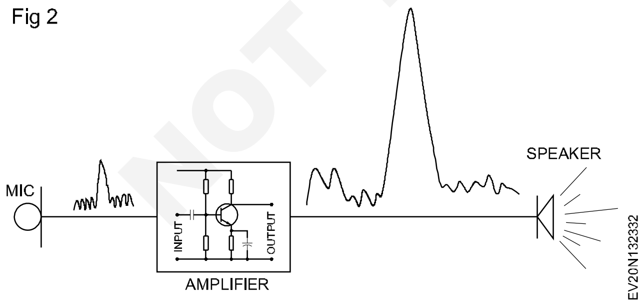
Fig 1



Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.

Other important application of transistors is its use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

Fig 2



Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.

Before the transistors were invented (1947), there was vacuum tubes which were used in amplifiers. A typical vacuum tube is shown in Fig 4a.

Compared with the present day transistors the vacuum tubes were big in size , consumed more power, generated lot of unwanted heat and were fragile. Hence vacuum tubes became obsolete as soon as transistors came to market.

Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

– Very small in size (Fig 4)
– Light in weight
– Minimum or no power loss in the form of heat
– Low operating voltage
– Rugged in construction.

To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in Transistor data books.

Fig 3

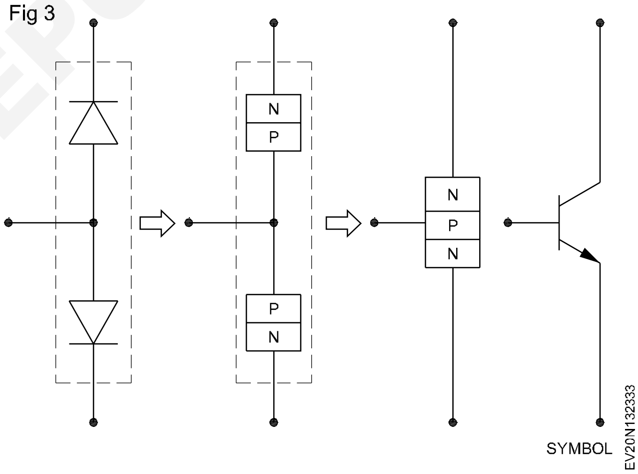
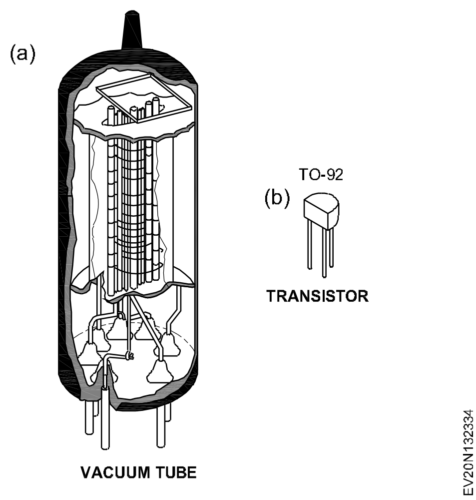


Fig 4



Classification of Transistors

1 **Based on the semiconductor used.**

– Germanium transistors

– Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

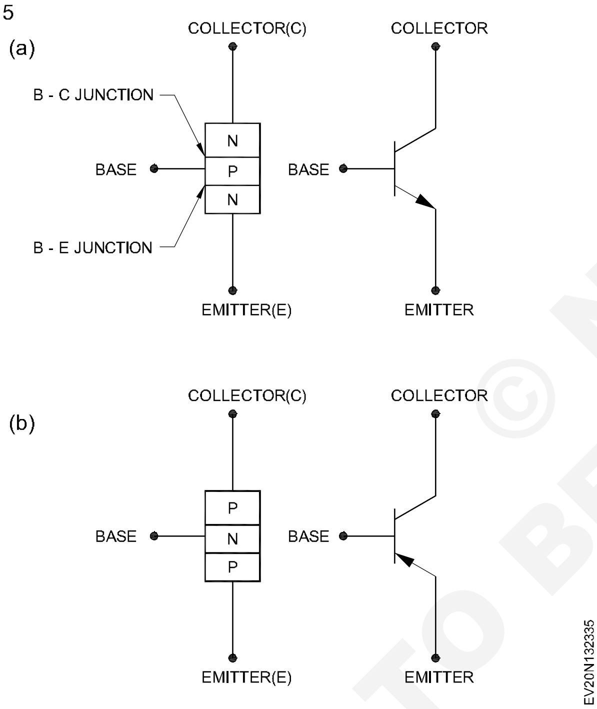
Transistor data books give information about the semiconductor used in any particular transistor.

2 **Based on the way the P and N junctions are organized as shown in Fig 5.**

– NPN transistors

– PNP transistors

Fig 5



Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher switching speed compared to PNP.

Whether a transistor is PNP or NPN can be found with the help of transistor data book.

3 **Based on the power handling capacity of transistors as shown in Table below (Fig 6)**

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium

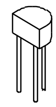
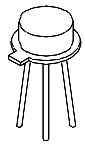
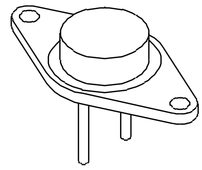
Low power transistors (less than 2 watts)	**Medium power transistors** (2 to 10 watts)	**High power transistors** (more than 10 watts)
		

Fig 6

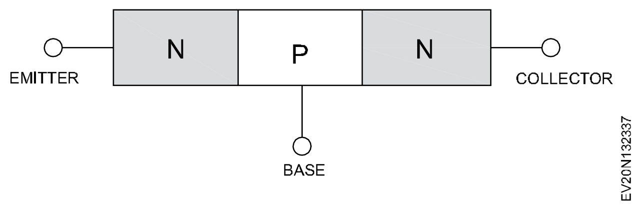
to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

Transistor data books give information about the power handling capacity of different transistors.

NPN transistors (Fig 7)

The transistor in which one -P- type material is placed between two n- type materials is NPN transistor, In NPN transistor, the direction of the movement of an electron is from the emitter to collector region due to which the current constitutes in the transistors. The NPN transistors amplifies the weak signals enter into the base and produces strong amplify signals at the collector end. In NPN transistor the direction of the movement of an electron is from the emitter to collector region due to which the current constitutes in the transistor such type of transistor is mostly used in circuit because their majority charge carriers are electrons which have high mobility as compared to holes.

Fig 7



PNP Transistor

The transistor in which one n- type material is dropped with two p- type materials such type of transistor is known as PNP transistor. It is current controlled device. The small amount of base current controlled both the emitter and collector current. The PNP transistor has two crystal diodes connected back to back. The left side of diode is known as the emitter as the collector - base diode. The PNP transistor turns on when a small current flows through the base. The direction of the current in PNO transistor is from the ammeter to collector.

The letter PNP transistor indicates the voltage required by the emitter, collector and base of the transistor. The base of the PNP transistor has always been negative with respect to the emitter and collector. The current which enters into the base is amplified in to the collector ends.

Photo transistor

A photo transistor is a device that has the ability to detect the level of the incident radiation accordingly change the flow of current between emitter and collector terminal. It is a three layer semi conductor device that consists of a light sensitive base region. It is basically a transistor whose action depends upon the application of light. Hence, named photo transistor. The photo transistor is basically an enhancement of photo diode. Both photo diode and light transistor are light sensing devices but the sensitivity of photo transistor is somewhat more as compared to photo diode. A photo transistor has the ability to give larger gain than that of the photo diode. Photo transistor operates on the principle of photo electric effect.

Field effect transistors

Objectives: At the end of this lesson you shall be able to
- **explain the difference between bi-polar transistors and field effect transistors**
- **state about JFET, its construction and working**
- **explain about biasing a JFET.**
- **State the function of IGBT.**

Field Effect Transistor (FET)

The main difference between a Bi-polar transistor and a FET is, bi-polar transistor is a current controlled device.

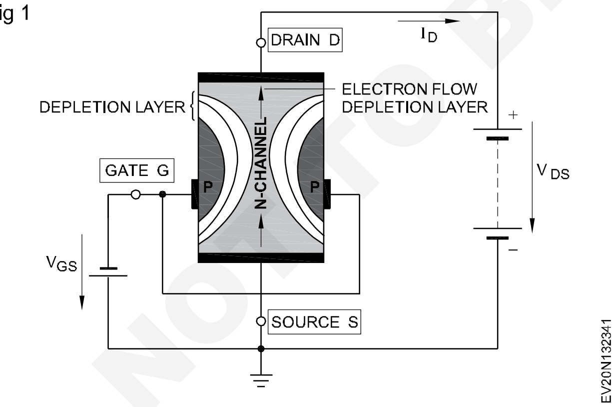
In simple terms it means that the main current in a bi-polar transistor is controlled by the base current.

FET is a voltage controlled device.

This means that the voltage at the gate controls the main current.

In addition to the above, in a bi-polar transistor, the main current always flows through N-doped and P-doped semiconductor materials. Where as in a FET the main current flows either only through the N-doped semiconductor or only through the P-doped semiconductor as shown in Fig 1.

Fig 1



If the main current flow is only through the N-doped material,then such a FET is referred as a P-channel or P type FET.The current through the P-doped material in the P-type FET is only by Holes.

Unlike in bipolar transistors in which the main current is both by electrons and holes.In contrast in FETs depending on the type(P or N type) the main current in either by electrons and holes and never both.for this reason FETs are also known as Unipolar transistors or unipolar device.

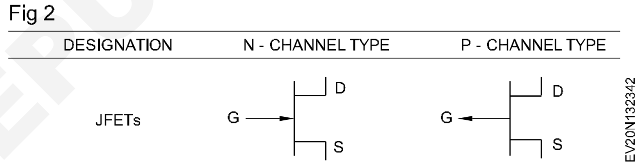
Junction Field effect Transistor (JFET)

It is a three terminal device and looks similar to a bi-polar transistor. The standard circuit symbols of N-channel and P-channel type FETs are shown in Fig 2.

Construction

As shown in Fig 3a, a n-channel JFET has a narrow

Fig 2



bar of n-type.To this,two p-type junctions are diffused on opposite sides of its middle part fig 3a.These diffused junctions form two PN diodes or gates.The N-type semiconductor area between these junctions/gates is called the channel. The diffused P regions on opposite sides of the channel are integrally connected and a single lead is brought out which is called gate lead or terminal. Direct electrical connections are made at the two ends of the bar.One of which is called source terminal, S and the other drain terminal, D.

A p-channel FET will be very similar to the n-channel FET in construction except that it uses P-type bar and two N-type junctions as shown in Fig 3b.

FET notation listed below are essential and worth memorizing.

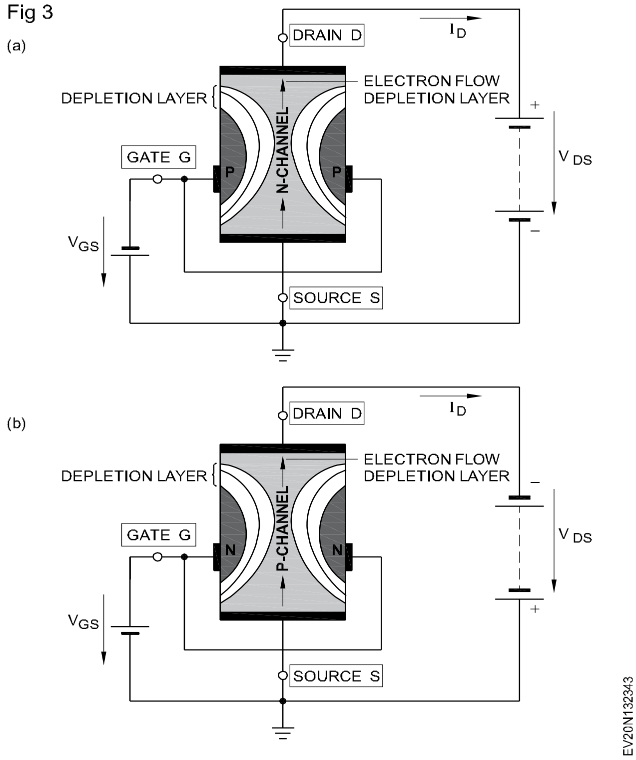
1 **Source terminal:** It is the terminal through which majority carriers enter the bar (N or P bar depending upon the type of FET).

2 **Drain terminal:** It is the terminal through which majority carriers come out of the bar.

3 **Gate terminal:** These are two internally connected heavily doped regions which form two P-N junctions.

4 **Channel:** It is the space between the two gates through which majority carriers pass from source to drain when FET is working (on).

Fig 3



Working of FET

Similar to Bipolar transistors, the working point of adjustment and stabilization are also required for FETs.

Biasing a JFET

Gates are always reverse biased. Therefore the gate current Ig is practically zero.

The current source terminal is always connected to that end of the supply which provides the necessary charge carriers. For instance, in a N-channel JFET source terminal S is connected to the negative of the d.c power supply.And, the positive of the d.c power supply is connected to the drain terminal of the JFET.

Where as in a P channel JFET,Source is connected to the positive end of the power supply and the drain is connected to the negative end of the for the drain to get the holes from the P-channel Where the holes are the charge carriers.

Where as in a N channel JFET, the drain is made positive with respect to source by voltage Vds as shown Fig 4a. When gate to source voltage Vgs is zero, there is no control voltage and maximum electron current flows from source(S)-through the channel-to the drain (D). This electron current from source to drain is referred to as Drain current,Id.

When gate is reverse biased with a negative voltage as shown in Fig 4b,the static field established at the gate causes depletion region to occur in the channel as shown in Fig 4b.

This depletion region decreases the width of the channel causing the drain current to decrease.

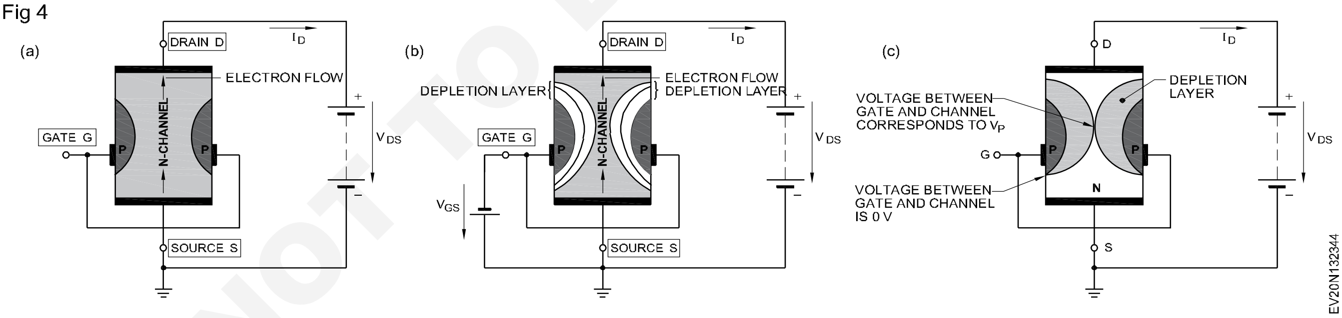
If Vgs is made more and more negative, the channel width decreases further resulting in further decreases in drain current. When the negative gate voltage is sufficiently high, the depletion regions meet and block the channel cutting off the flow of drain current as shown in Fig 4c.This voltage at which this effect occurs is referred to as the pinch off voltage, Vp.

Thus, by varying the reverse bias voltage between gate and source (-Vgs),the drain current can be varied between maximum current (with –Vgs=0) and zero current (with –Vgs=pinch off voltage).So,JFET can be referred as a voltage controlled devices.

P channel JFET operates in the same way as explained above except that bias voltages are reversed and the majority carrier of channel are holes.

Insulated Gated Bipolar transistor (IGBT): The IGBT is a power switching transistor, which is combined with the advantages of MOSFET and BJT, for use in

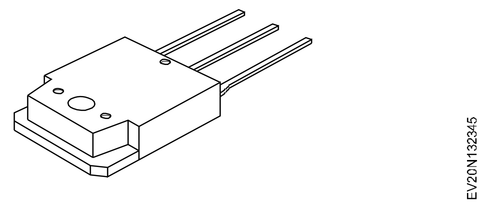
Fig 4



power supply and motor control circuits. This transistors have high input impedance and high switching speeds of a MOSFET with low saturation voltages of bipolar transistor and combine them together to produce another type of transistor switching device that is capable of handling large collector emitter currents with virtually Zero current drive.

The IGBT is mainly used in power electronics applications such as invertors, convertors, and power supplies with the demands of solid state switching device. When we use as static controlled switch the IGBT has voltage and current ratings to that of the bipolar transistor. Fig 5 (IGBT) There is no second breakdown problem in the IGBT by chip design and structure the equivalent drain to source resistance is controlled to have like that of a BJT.

Fig 5



Fuse

Objectives: At the end of this lesson you shall be able to
- **state the need of a fuse in the circuit**
- **explain the construction of a fuse**
- **list out the types of fuses**
- **explain the working of fuses**
- **explain the circuit with and without a fuse**
- **explain circuit breakers.**

Introduction

A fuse is a protective device. It is a weakest portion in the electrical circuit.

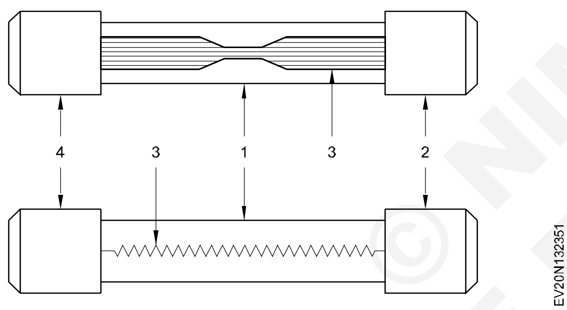
An electric current heats the wire when the current passes through it. The amount of heat depends upon the current and resistance in the wire.

In automobiles, this heating effect is utilized in heaters, bulbs and gauges etc.

The heating effect in the circuit is limited by the fuse. If this limit is not controlled, the circuit an accessories will be overloaded causing severe damage to them.

Purpose of fuse (Fig 1)

Fig 1



A fuse opens the circuit by blowing out when current (overload) flows in the circuit to prevent severe damage to the accessories.

The flow of excess current in a circuit may be caused by a short circuit.

Construction

Fuse elements are of lead-tin or tin-copper alloy wire in strip of correct amperage for each circuit.

The fuse is assembled in a fuse carrier of glass or ceramic material.

Nowadays fuse elements assembled in glass tubes, called cartridges, are widely used in automobiles.

It consists of a glass tube (1) with metal end caps (2) & (4).

A soft fine wire or strip (3) carries the current from one cap to another (4).

The conductor (3) is designed to carry a specific maximum current.

Fuse

A fuse is an electric/electronic or mechanical device which is used to protect circuits from over current, over load and make sure to protection of the circuit. Electric fuse as invented by thomas alva edison in 1890. These are many types of fuses, but function of all these fuses is same. working principle of a fuse is based on the heating effect of current. Fuse ratting = (Power/voltage) x 1.25 For example (100 w/230v) x 1.25 = 5.4A

Cartridge fuses

Cartridge fuses are used to protect electrical appliances such as motors air conditions, refrigerators, pumps. There are two types of fuses.

1. Generel purpose fuse with no time delay and 2. Heavy duty cartridge fuses. with time delay cartridge fuses are enclosed in a base and can be divided in further in link type cartridge fuses and D type cartridge fuses. When the circuit is completed the tip of the cartridge make contacts through the fuse linke coductor.

Blade type and bolted type fuses - These type fuses comes in plastic body and two metal caps to fit in the socket mostly, they used in automobiles for wiring and short circuit protection. Expect this fuse limiters, glass tube are widely used in automotive industry. The rating of vehicle fuses 12v to 42v. In bolted types of fuses, the base of the fuse contacted directly to the base of the fuse same like HRC fuses.

Maxi fuse

Maxi - fuse is a fast - acting blade fuse standard for vehicle circuit protectietion designed to provide predictable time delay and low heat dissipation. Colour coded for easy identification of fuse ratings. Rated at 32v. maxi fuse circuit protection. maxi type fuses - Blade type, Glass tube type.

Working

The current flows through the conductor (3) between two metal caps (2) & (4) and then to the equipment.

If the current value exceeds the limit prescribed on the fuse, the fuse element (3) melts and opens the circuit and prevents the equipment from damage.

Identification of blown fuse

If you look at the burnt fuse and if the element is broken the fuse is burnt due to overloading.

The glass is foggy white or black the fuse is blown out due to short circuit.

Circuits protected with fuse

- Headlight circuit
- Tall - light circuit
- Number -plate circuit
- Panel lamp circuit
- Interior lamp circuit
- Side indicator circuit
- Horn circuit
- Wiper circuit
- Dashboard / panel instruments circuit

- Header and air conditioner
- Charging circuit
- Radio
- Cigarette lighter
- Reversel amp

Circuits without fuse

- Starting circuit
- Ignition circuit
- Fuel pump
- Stop - light circuit
- Oil pressure lamp circuit
- Ignition warning lamp circuit.

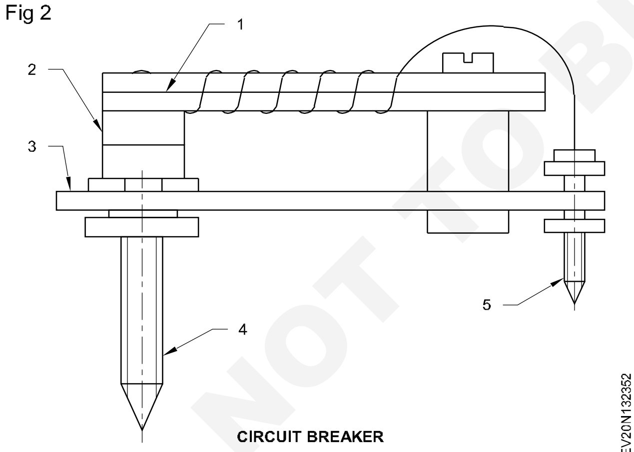
Fuse rating and colour

Rating	Colour
3 Amp	Violet
5 Amp	Tan
10 Amp	Red
20 Amp	Yellow
25 Amp	White
30 Amp	Light green

Circuit Breaker

Circuit Breaker (Fig.2): These units are regarded as a non- replaceable type of fuses. Generally fitted in the headlight circuit, it consists of a bimetallic strip (1) with moving contact (2). A fixed contact (3) is provided with the terminals (4) & (5). The strip (1) bends as soon as the current exceeds the maximum permissible value for the electrical component concerned. This way it opens the points to break the circuit. When this type of device is used in the lighting circuit, the lamp willl light and then go out. Thus giving an indication of a faulty circuit. The circuit breakers are made in ratings up to 50 amps.

Fig 2



CIRCUIT BREAKER

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Electrical circuit protection

Electrical circuit protection is the purposeful use of a failsafe device, that automatically causes a disruption in an electrical circuit when it recognizes an excess and unsafe load of power in a circuit common circuit protection devices and components include circuit breaker, fuses, surge protection and protective relays.

Circuit Breaker

Circuit breaker is a device for interrupting an electric circuit to prevent excessive current, as that caused by a short circuit from damaging the automotive parts in the electrical circuit or from the fire.

Positive temperature coefficient of resistance

A positive coefficient for a material means that its resistance increases with an increase in temperature. Pure metals typically (gold, silver, copper) have positive temperature coefficients of resistance, semi conductor materials (carbon, silicon, germamam) typically have negative temperature cofficients of resistance.

Fusible link

Fusible Iniks includes mechanical and electrical deviees. A mechamcal fusible link is a device consisting of two strips of metal soldered together with a fusible alloy that is designed to melt at a specific temperature these allowing the two pieces to separate mechanical fusible linkes are utilized as the triggering device in fire sprinkler systems and mechamcal automatic door relases mechanism that close fire doors in ware houses mechanical fusible links come in a variety of designs and different temperature ratings.

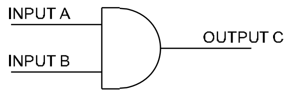
An electrical fusible is a type of electrical fuse that is constructed simply with a short pieces of wire typically four American wire gauge sizes. Smaller than the wire that is being protected for example an AWG - 16 fusible link might be used to protect AWG 12 wiring. Electrical fusible links are common in high - current automotive application. The wire in an electrical fusible link is encased in high - current automotive application. The wire in an electrical fusible link is encased in high - temperature fire - resistant insulation to reduce hazards, when the wire melts.

Basic logic gates

Objectives: At the end of this lesson you shall be able to
- **describe the AND, OR, NOT & NAND gate and their applications with simple digital circuits.**

Logic circuits (Fig 1): Digital ICs are made up of many different elements. Most important of these are transistors. This transistor circuits are called logic circuits or digital circuits and are made up of combinations of different types of so-called gates. These gates have the special ability to logically process two or more signals. Thus they are also called logic gates.

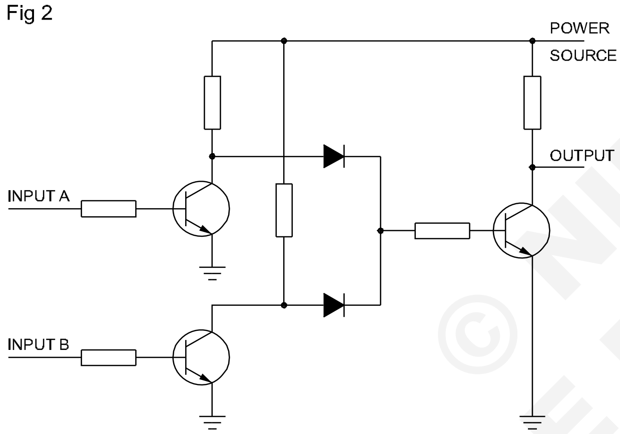
Fig 1



The "AND" Gate:

Logic circuits are usually indicated by a special symbol. Such a circuit, however is actually composed of semiconductor elements as shown in (Fig 2).

Fig 2

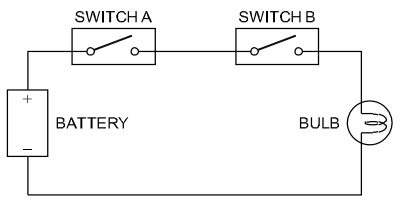


SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

To make an AND gate easily understand, a simple mechanical circuit without the use of semiconductors is shown in (Fig 3). In this circuit the switches A and B are equivalent to (C). The light bulb lights only if both switches A and B are closed. If either switch is open, the bulb will (or it both are open), not come on.

Similarly, in an actual AND gate, there will be an "on" signal (often represented as the number 1) at the output terminal (C) only if there is a voltage at both input terminals (A and B). If either A or B is zero (off) or if both are zero, C will also be zero. These combination can be shown in a truth table.

Fig 3



SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

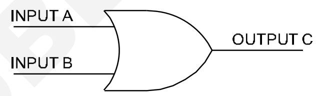
AND - gate truth table		
Inputs		**Output**
A	**B**	**C**
0	0	0
0	1	0
1	0	0
1	1	1

The "OR" Gate (Fig 4, 5 & 6)

Fig 4 shown the symbol for an "OR" gate, its corresponding semiconductor circuit, and an equivalent mechanical circuit.

If there is voltage at either input terminal (or if there is a voltage at both inputs) there will be voltage at the output terminal "OR" gate truth table is given.

Fig 4



THE "OR" GATE

Fig 5

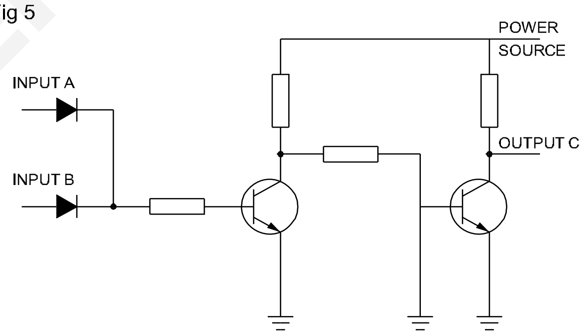
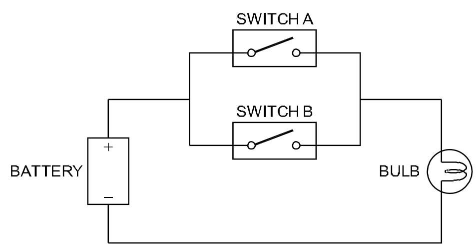
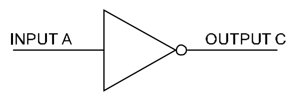


Fig 6



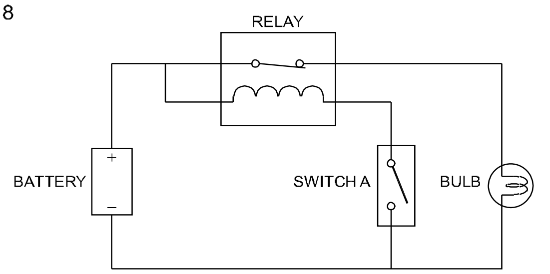
The symbol for a "NOT" gate is shown in (Fig 7). A corresponding semiconductor circuit and an equivalent mechanical circuit are as shown in (Fig 8).

Fig 7



"NOT" GATE

Fig 8

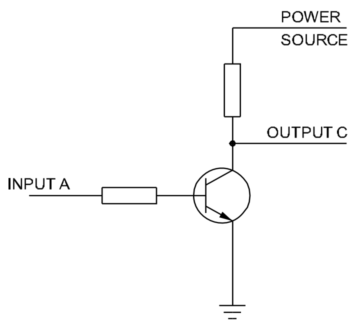


SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO "NOT" GATE

n the mechanical NOT circuit, the light bulb doesnot go on if switch A is closed. When switch A is opened the relay closes and the bulb is turned on.

As can be seen in the truth table, the “NOT” gate inverts the signal so that the output is always the opposite of the input. For this reason it is called as “inverter”. (Fig 9)

Fig 9

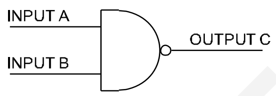


SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO "NOT" GATE

“NAND” is a combination of “AND” gate and a “NOT” gate as shown in (Fig 10).

A zero will appear at the output terminal (C) only if there is a voltage at both input terminals (A and B). If there is a zero at either A or B, an “on” signal (number 1) will appear at C.

Fig 10

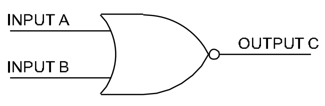


"NAND" GATE

This can be observed in Truth Table as shown.

A “NOR” gate is a combination of an “OR” gate and a NOT gate (Fig 11). For this reason, an “on” signal will appear at the output terminal only if there is an “off” signal (zero) at both input terminals. If there is an “on” signal at either A or B, terminal C will zero as shown in the truth table.

Fig 11



"NOR" GATE

PWM generation:

PWM generation is used to control techniques that generates analog signals from digital devices such as micro controllers. The PWM signal is used to reduce the electrical power supplied to an electrical device such as a motor or a lamp load by switching the signal ON and OFF at a high frequency. As the it relative on-time of the signal increases or decreases so does the average voltage of the signal.

The pulse width modulation tehniques are used to mitigate the adverse effects of harmonics in the inverter The harmonics in the output PWM voltage are not eliminated, but shifted to much higher frequency, which makes the filtering a lot easier. The controllabillity of the amplitube of the fundamental output voltage is another advantage of PWM. The PWM techniques developed over the year are sinusoidal PWM, uniform sampling PWM,selective harmonic elimination PWM, space vector PWM and random PWM. The two commonly used PWM techniques, the sinusoidal PWM and the space vector PWM,

sinusoidal pwm: In this method a sinusodal Control signal is compared with a high frequency trangular wave form to generate the inverter Switching signals. The frequency of establishes the inverter switching frequency. The magnitude and frequency of the sinusoidal signal are Controllable, but the trangular signal magnitude and frequency are kept constant. The sinusoidal Control, signal modulates the switch duty ratio and it's frequency is the desired fundamental frequency of the inverter. For the three phase voltage generation, the same is compared with their sinusoidal control voltages which are 120° out of phase with respect to each other to produce a balanced out put. The switches are controlled in pairs when one switch, in a pair is closed, the other switch is open, in practice there has to be a blanking pulse between the change of control signals for switches in a pair to ensure that there is no short circuit in the inverter of electric vehicle. This is necessary since practical switches take finite time to turn ON and turn OFF.

Space vector (SV) PWM

The voltage space vectors embedded in the d_q models and vector controllers of AC machines present a highly compatible method for the control of three-phase PWM inverters. The d_q voltage commands for the direct and quadrature axes voltages generated by the controller to drive a motor are converted into an equivalent PWM signal to be applied to the gates of the six inverter switches. For variable frequency drive applications, space vector PWM is very popular because of its superior performance compared to other voltage PWM techniques.

The three-phase voltage source inverter can assume one of eight ($2^3 = 8$) states only, since each switch in a phase leg can assume either an on or off position. Each of these eight states is associated with a specific set of values of the three- phase voltages. Based on the state, the machine Phase winding terminals are connected to the upper or lower side of the DC link. for the terminal voltages,eight voltage vectors are defined using 3-bit digital states as 000,100,110,010,011,001,101 and 111 For example, the state 011 stands for phase-a connected to the lower side of the DC bus, while phase b and c connected to the upper side. Alternatively, a 0 indicates the lower swich is turned on and a 1 indicates that the upper switch is on. This means that the inverter can generate eight stationary voltage vectors

Generation of SV PWM Switching Signals

The continuous space vector modulation technique is based on the fact that every reference voltage vector V inside the hexagon can be expressed as a combination of the two adjacent active-state vectors and the null-state vectors. Therefore, the desired reference vector imposed in each cycle is achieved by switching among four inverter states. The sector where the space vector V lies determines the two active-state vectors that will be used in generating the gate switching signals of a PWM period [6]. The phase angle is evaluated from θ=arctan (V_{qs}/V_{ds}) and $\theta \ni [0,2\pi]$. The phase angle is related to the relative magnitudes of V_{qs}, and V_{qs}. For example, in sector 1, 0 ≤ arctan (V_{qs}/V_{ds}) $<\pi/3$; Var Vds 3

hence, 0 < $V_{qs}<\sqrt{3}V_{ds}$. The following conditions are used to determine the sector where the space vector is located.

Sector1:$0<V_{qs}<\sqrt{3}V_{ds}$;

Sector 2: $V_{qs} > \sqrt{3}V_{ds}$

Sector 3:$0<V_{qs} <-\sqrt{3}V_{ds}$

Sector 4: 0> $V_{qs} > \sqrt{3}_{ds}$

Sector 5: V_{qs}, $<-\sqrt{3}V_{ds}$

Sector 6: 0> V_{qs} >-√3ds

Let us assume that V_k and V_{k+1} are the components of the reference vector V in sector k and in the adjacent active sectors (k + 1), respectively. In order to obtain optimum harmonic performance and minimum switching frequency for each of the power devices, the state sequence is arranged such that the transition from one state to the next is performed by switching only one inverter leg. This condition is met if the sequence begins with one zero-state and the inverter poles are toggled until the other null-state is reached. To complete the cycle, the sequence is reversed, ending with the first zero-state. If, for instance, the reference vector sits in sector 1, the state sequence has to be...0127210... whereas in sector 4 it is...0547450... The central part of the space vector modulation strategy is the computation of both the active and zero-state times for each modulation cycle. These are calculated by equating the applied average voltage to the desired value. Figure 12 demonstrates the on-times of vectors.

It was shown that only 78.5% of the inverter's capacity is used with sinusoidal PWM method. In SV PWM method, inverter's capability is improved by using a separate modulator for each of the inverter legs, generating three reference signals forming a balanced three-phase system. In this way. the maximum obtainable output voltage is increased with ordinary SV PWM up to 90.6% of the inverter capability. SV PWM algorithm is fairly complex and computation intensive, but still well within the capabilities of the digital signal processors available today.

Fig 12

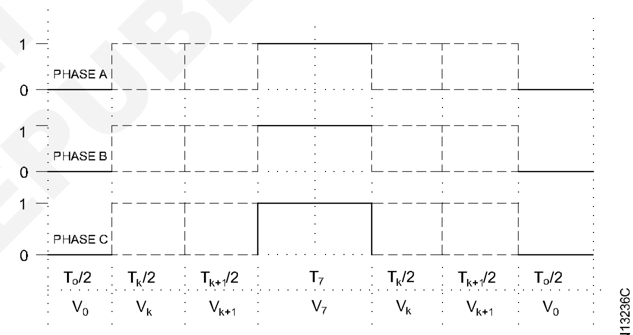


DIAGRAM OF ON-TIMES OF VECTORS

Introduction to electric vehicle technology

Objectives: At the end of this lesson you shall be able to
- **state the electric vehicle technology.**
- **describe the comparison of electric vehicle with I.C Engine**
- **state the types of electric vehicle BEV, HEV, PHEV and FCEV**
- **state the architecture and working principle of electric vehicle.**

Introduction to electric vehicle

In recent years, green house gas problem increases and also the gasoline fuel rate also increases days by day in India and global wide so that public also suffer financially due to this reason, automobile manufacture and new companies put their effort to convert the conventional vehicle into electric vehicle that provide reliable solution.

Electric vehicle is propelled with electric motors and draw power from on board electric source in an electric vehicle, it is more durable and mechanically simpler than gasoline vehicle. It gives more fuel efficiency than gasoline engine because it does not produce emission like internal combustion engine However, automobile industry is not completely moving towards pure electric vehicle production, because there is a problem of existing batteries technology for storing the electric energy. However now a days increasing the usage of hybrid and electric vehicle in our country and globalize.

Internal combustion engine vehicle : This type of vehicle uses Internal combustion engine and it has use fuel like petrol, gas, diesel which fuel combusts inside of the combustion chamber with the help of an oxidizer and ignition by spark plug or compressed air heat.

Electric vehicle : This type of vehicle uses one or more electric motor for propulsion. Electric vehicles are the automobiles that are propelled by one or more electric motors using the energy stores in batteries.

Comparison between IC engine vehicle with electric vehicle. The following table highlights the points that differentiate and IC Engine vehicle from an electric vehicle

Point of comparison	Internal combustion engine vehicle	Electric vehicle
Source of power	The source of power for ICEV is different types of fuels such as diesel or petrol	Electricity obtained from charged batteries, ultra-capacitors, etc. is the source of power in electric vehicles.
Prime mover	Internal combustion engine (ICE) is the prime mover or powertrain.	Electric motor is the prime mover in the electric vehicles.
Specific energy	There is high specific energy of fuel	In electric vehicles, low specific energy of battery.
Power density	Fuels used in ICEV have high power density.	In power density of power source is low.
Impact on Environment	ICEV emits green-house gases which have adverse effect on environment.	EV does not have adverse effect on environment.
Travelling distance	ICEV can travel more than around 300 miles per fill.	EV travels less than around 100 miles per charge.
Refilling time	ICEV requires less refilling time (approx. less than 5 min)	EV has long charging time, about 0.5 to 8 hours.
Space & weight fuel tank	In ICEV, fuel tank takes less space and the weight of fuel is very less.	In EV, batter bank takes large. Also, the batteries are very heavy.
Maintenance & running costs	The maintenance and running costs of internal combustion engine vehicles are high.	The electric vehicles requires low running and maintenance costs.
Efficiency	The efficiency of IC engines is about 30%.	The electric motors used in electric vehicles have approximately 80% efficiency.

Point of comparison	Internal combustion engine vehicle	Electric vehicle
Noise production	IC engine vehicles produces noise	Electric vehicles have noise free operation
Recovery of braking energy	In case of IC engine vehicles, the braking energy cannot be recovered.	In case of EVs, the braking energy can be recovered by using regenerative braking.
Time required for maximum torque	IC engine vehicles require to pick up some speed to deliver maximum torque	Electric vehicles produce maximum torque instantly after starting of motor
Capital cost	IC engine vehicle have average initial cost	The initial cost of electric vehicles is high.
Power transmission	IC engine vehicles, have the system of power transmission load is mechanical only.	Electric vehicles have both mechanical as well as electrical power transmission system.

Types of electric car : An Electric car is a vehicle that is fully or partially propelled by electric motors using energy stored in rechargeable batteries. Some electric vehicles run solely on battery power, others known as hybrids combine an electric motor with an internal combustion engine in various ways. Then there are fuel cell electric vehicles and even solar electric cars. There are different types of electric cars changed and developed continuously giving users and potential users choice. Now a days the world is increasingly familiar with the terms BEV, HEV PHEV and FCEV.

Electric cars common method. When pedal of the Electric car is pressed then the controller takes and regulates electrical energy from batteries and then inverters with the controller set tot the inverter then sends a certain amounts of electrical energy to the motor (according to the depth of pressure on the pedal)

Types of electric cars : There are 4 types of electric car mainly used by card users. They are as follows :-

- Battery Electric Vehicle (BEV).
- Hybrid Electric Vehicle (HEV).
- Plug in Hybrid Electric Vehicle (PHEV).
- Fuel Cell Electric Vehicle (FCEV).

Battery Electric Vehicle (BEVs). The battery electric vehicles (BEVs) also referred to as all electric vehicles pure electric vehicle. It is run entirely on battery electricity only and have no gasoline engine. BEVs are moved by one or more electric motors powered by rechargeable batteries. Most of the BEV auto manufactures choose lithium due to their high power to weight ratio resulting in a more extended range in a smaller physical foot print the battery packs are charged using electricity delivered through an Electric vehicle charger. (Fig 1)

Unlike gasoline powered vehicles, BEVs are Zero emission vehicle that do not produce any harmful emission or air pollution. This vehicle driving range per battery charge of between 50 to 350 miles although new models with longer ranges being released over 500 to 900 miles.

Architecture and main components of BEVs

- Electric motor
- Inverter
- Battery
- Controller

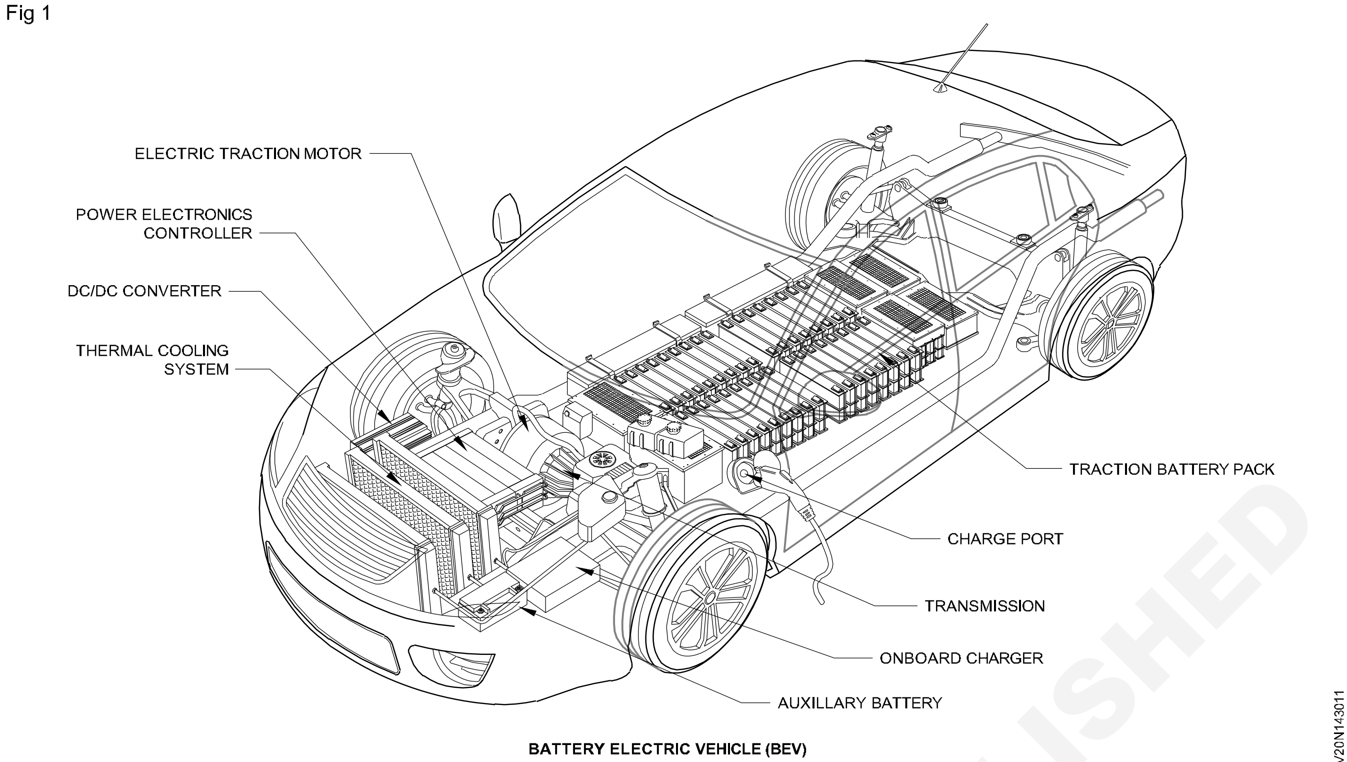
Working principles of BEV

- Power is converted from the DC battery ti AC for the electric motor
- The acceleration pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor
- The motor connects and turns the wheels through a cog.
- When the brakes are pressed or the electric car is decelerating, the motor becomes and alternator and produces power, which is sent back to the battery.

Hybrid Electric Vehicles (HEVs):

Hybrid Electric Vehicles (HEVs), sometimes referred to as 'self-charging hybrids', use both an internal combustion engine and an electric motor, which uses electricity stores in a battery pack. The main difference between a PHEV and an HEV is that you cannot plug in HEV into an EV charger to charge the battery. Instead, the onboard battery pack is charged via the engine and regenerative braking. The additional power generated by the electric motor may allow for the vehicle to have a smaller engine. The battery pack can work as an auxiliary battery for the car, helping to reduce idling when stopped; this results in better fuel economy and lower emissions when compared to a conventional engine car. Toyota was one of the pioneers in introducing and popularizing Hybrid Electric Vehicles with the Toyota Prius.

Fig 1



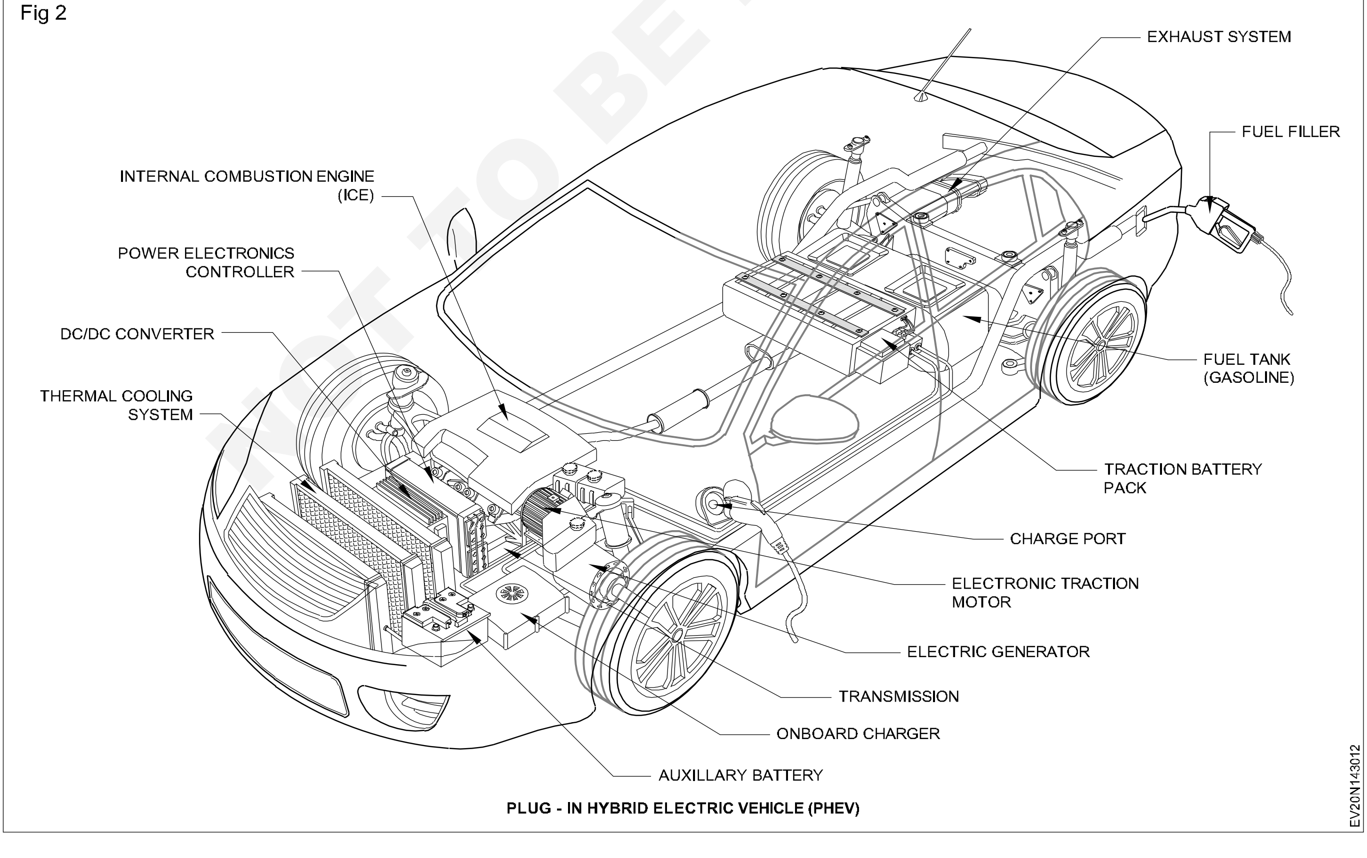
BATTERY ELECTRIC VEHICLE (BEV)

There are different types of HEVS, they include :

- **Mild Hybrid Electric Vehicles (MHEVs) -** Also referred to as 'Micro Hybrids,' 'Power Assist Hybrids' and 'Battery Assisted Hybrid Electric Vehicles (BAHEVs)'. It uses the battery pack and electric motor to help power the vehicle and enables the engine to be shut off when the car has stopped. MHEVs cannot drive the vehicle on electricity alone and are not as fuel-efficient as a full hybrid.

- **Full Hybrid Electric Vehicles (FHEVs) -** Full Hybrids have larger capacity battery packs and more powerful electric motors that mild hybrids and can travel short distances at low speeds on battery power. (Fig 2)

Fig 2



PLUG - IN HYBRID ELECTRIC VEHICLE (PHEV)

Architecture and Main Components of HEV

Components of HEV

- Engine
- Electric motor
- Battery pack with controller & inverter
- Fuel Tank
- Control module

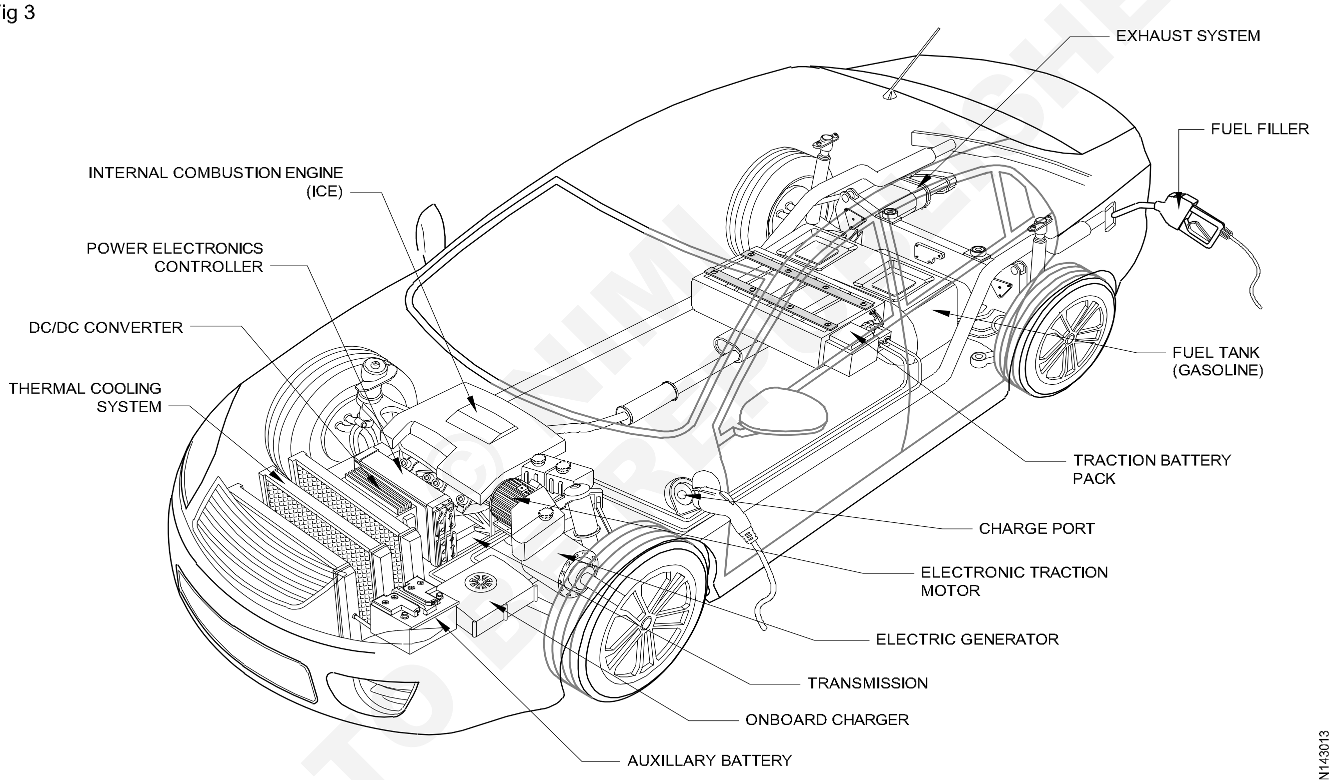
Working Principles of HEV

- it has a fuel tank that supplies Fuel to the engine like a regular car
- It also has a set of batteries that run an electric motor
- Both the engine and electric motor can turn the transmission at the same time.

Plug-in Hybrid Electric Vehicle (PHEVs):

Plug-in hybrids Electric Vehicles (PHEVs) use batteries to power an electric motor and incorporate an Internal Combustion Engine (ICE) that can recharge the batteries to enable longer driving ranges. A PHEV typically runs on electricity stores in the battery until nearly depleted generally around 50-90 Kms depending on the vehicle model and battery size and capacity. Then the car automatically switches over to use the ICE and can travel several hundred Kms on a tank of fuel. This can dramatically reduce fuel use and emissions especially on short journeys. When no electricity is available, a plug-in hybrid can run on fuel alone all types of PHEV batteries can charged by a level-1 and level-2 type Electric Vehicle charger. (Fig 3)

Fig 3



PLUG - IN HYBRID ELECTRIC VEHICLE (PHEV)

Architecture and main components of PHEV

Components of PHEV

- Electric motor
- Engine
- Inverter
- Battery
- Fuel tank
- Control module
- Battery Charger (if onboard model)

Working Principles of PHEV

PHEVs typically start up in all electric mode and operate on electricity until their battery pack is depleted. Some models shift to hybrid mode when they reach highway crusing speed, generally above 60 or 70 miles per hour. Once the battery is empty, the engine takes over and the vehicle operates as a conventional, non-plug-in hybrid.

In addition to plugging into an outside electric power source, PHEV batteries can be charged by an internal combustion engine or regenerative braking. During braking, the electric motor acts as a generator, using the energy to charge battery. The electric motor supplements the engine's power; as a result smaller engines can be used, increasing the car's fuel efficiency without compromising performance.

Fuel Cell Electric Vehicles (FCEVs)

Fuel Cell Electric Vehicles (FCEVs) create zero tailpipe emissions powered by hydrogen. An FCEV uses a similar system as a Battery Electric Vehicle to run the vehicle. In the case of an FCEV, the energy is stored as hydrogen and then converted into electricity by the fuel cell to propel the vehicle. Fuel Cell Electric Vehicles have a gas tank used to store the pure hydrogen; the tank can be fuelled up in just a few minutes, similar to how conventional ICE vehicles are filled up today.

FCEVs can reach around 450 Kms on one tank of pure hydrogen. They also utilize regenerative braking technology and capture energy lost during braking, which is stored in a battery pack. There are a limited number of production FCEVs available to the public, and as of today, the refueling infrastructure isn't anywhere near where it needs to be to support a mass rollout of FCEVs.

Architecture and Main Components of FCEV

Components of FCEV

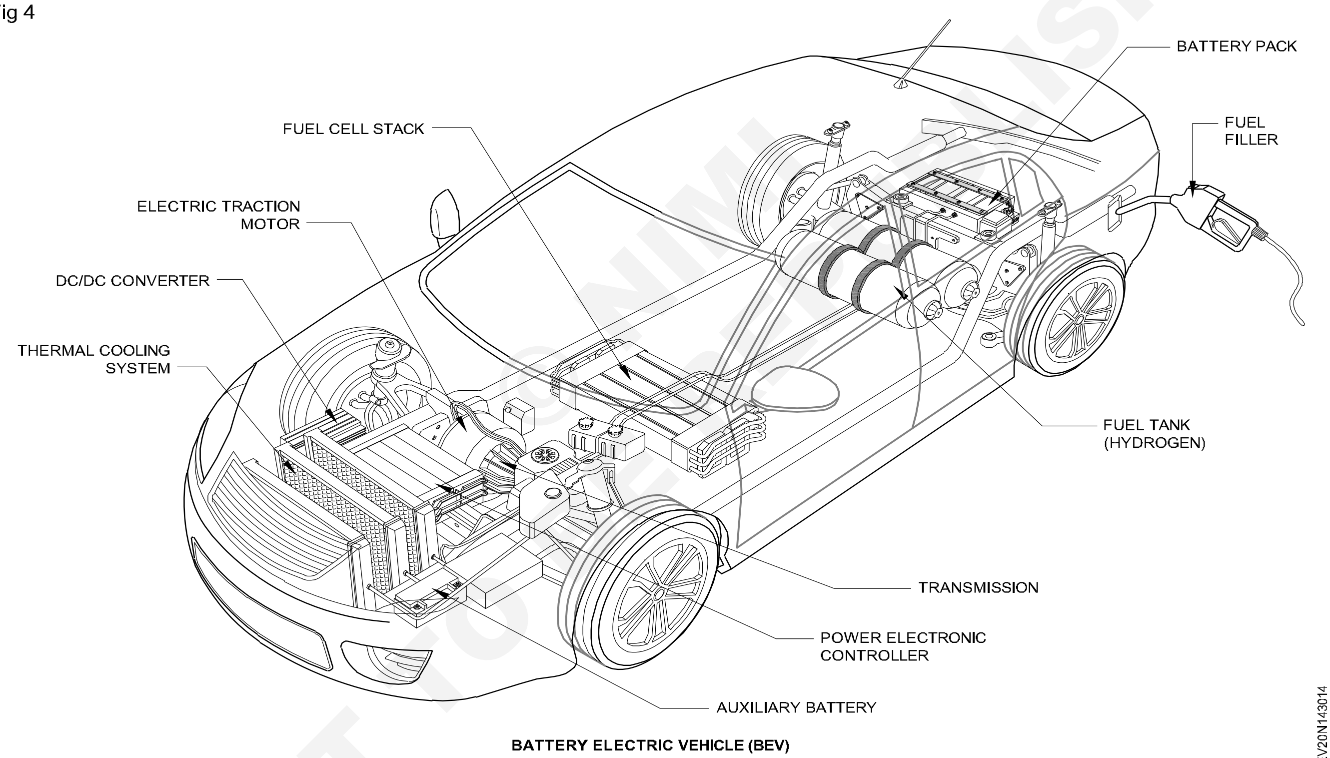
- Electric motor
- Fuel-Cell Stack
- Hydrogen storage tank
- Battery with converter and controller

Working principles of FCEV (Fig 4)

Fuel cell cars are powered by compressed hydrogen gas tank feeds into an onboard fuel cell stack that does not burn the gas, but instead transforms the fuels chemical energy into electrical energy. This electricity then power the cars electric motors. Tailpipe emissions are zero, and the only waste produced is pure water the construction of the fuel cell is similar to a battery.

A fuel, such as hydrogen is fed to the anode and air is fed to the cathode in a hydrogen fuel cell a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through and external circuits creating a flow of electricity.

Fig 4



BATTERY ELECTRIC VEHICLE (BEV)

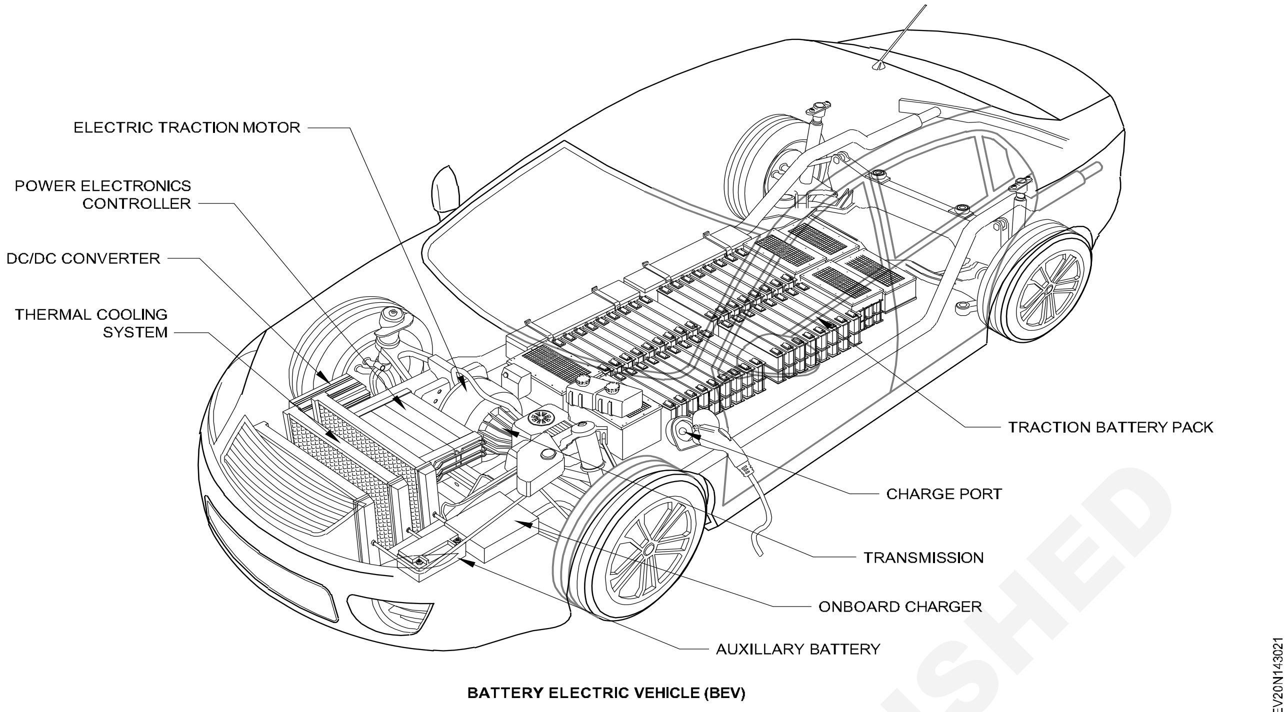
Electric Vehicle of major components and their functions

Objectives: At the end of this lesson you shall be able to
- **state the major components of electric vehicle and their functions**
- **state the Basic motors of electric vehicle**
- **describe the EV motor selection, sizing and electric transmission**
- **state the EV motor characteristic of motor and calculation for motor effort**
- **state the electric vehicle drive systems,**
- **state the EV battery management systems.**

Introduction

Electric vehicle consists of many components. This lesson will discuss various common main electric vehicle components or parts and their functions. (such as traction batteries, inverters, traction motors on board chargers and controllers. The different types of electric vehicle components determines how the components are consist and work in a electric vehicle. (Fig 1)

Fig 1



BATTERY ELECTRIC VEHICLE (BEV)

Method of electric vehicles move

EV's are like an automatic car. They have a forward and reverse mode. When you place the vehicle in gear and press on the accelerator pedal these things happen:

- Power is converted from the DC battery to AC for the electric motor
- The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor
- The motor connects and turns the wheels through a cog
- When the brakes are pressed or the car is decelerating, the motor becomes an alternator and produces power, which is send back to the battery

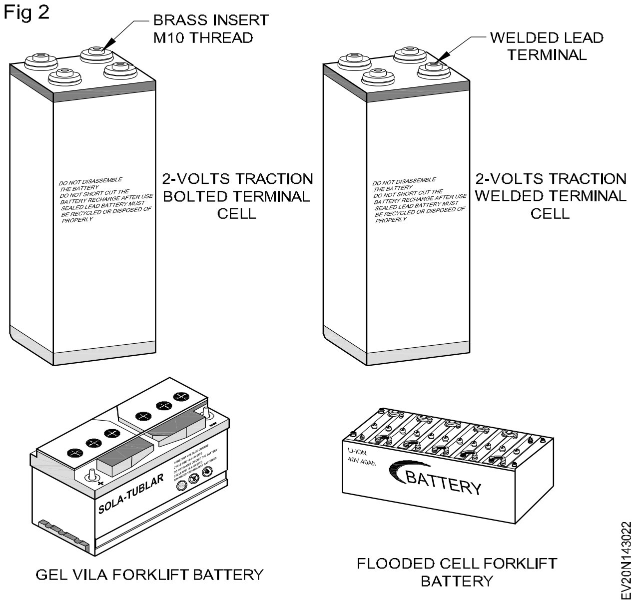
Main components of electric vehicle

- Traction battery pack
- DC-DC Converter
- Electric Motor
- Power Inverter
- Charge Port
- On board charger
- Controller
- Auxiliary batteries
- Thermal System (cooling sys for battery)
- Power transmission motor to wheel

Traction battery pack (Fig 2)

Traction battery pack is also known as Electric Vehicle Battery (EVB). Electric vehicle batteries undergo cycles of discharge that occur when electric vehicle is driving and charge when the car's plugged in repeating this process over time affects the amount of charge the battery can hold. This decrease the range and time needed between each journey to charge. EVs don't use a single battery like a phone, use instead of a pack battery cells working together, whether cars charging up

Fig 2



electricity is used to make chemical changes inside its batteries. When its on order these changes reversed to produce electricity the battery connects to one or more electric motors which they drive the vehicle wheels. When the accelerator the car instantly feeds power to the motor which consume the energy stores in the batteries. The battery acts as an electrical storage system. it stores energy in the form DC current. The range will be higher with increasing KW of the battery. The life and operation of the battery depends on its designs. The life time of a traction battery pack is estimated to be around 3,50,000 Kms. Most manufactures have a 5 to 15 years warranty on their battery. The current prediction is that an electric car battery will last 10-20 years before they need to be replaced.

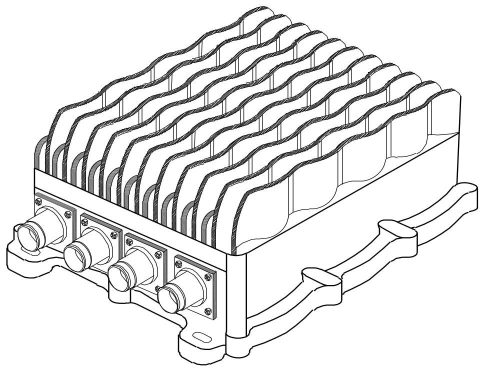
There are different types of batteries too. Let's compare the types on some basic parameters related to batteries.

Lithium-ion batteries are used commonly used because they are reliable, easy to use, cheaper, energy-efficient.

DC-DC converter (Fig 3)

The traction battery pack delivers a constant voltage. The DC-DC converter distributes the power that comes from battery to the lower voltage DC power needed to run the electric vehicle accessories and it also provides the voltage required to recharge the auxiliary battery.

Fig 3

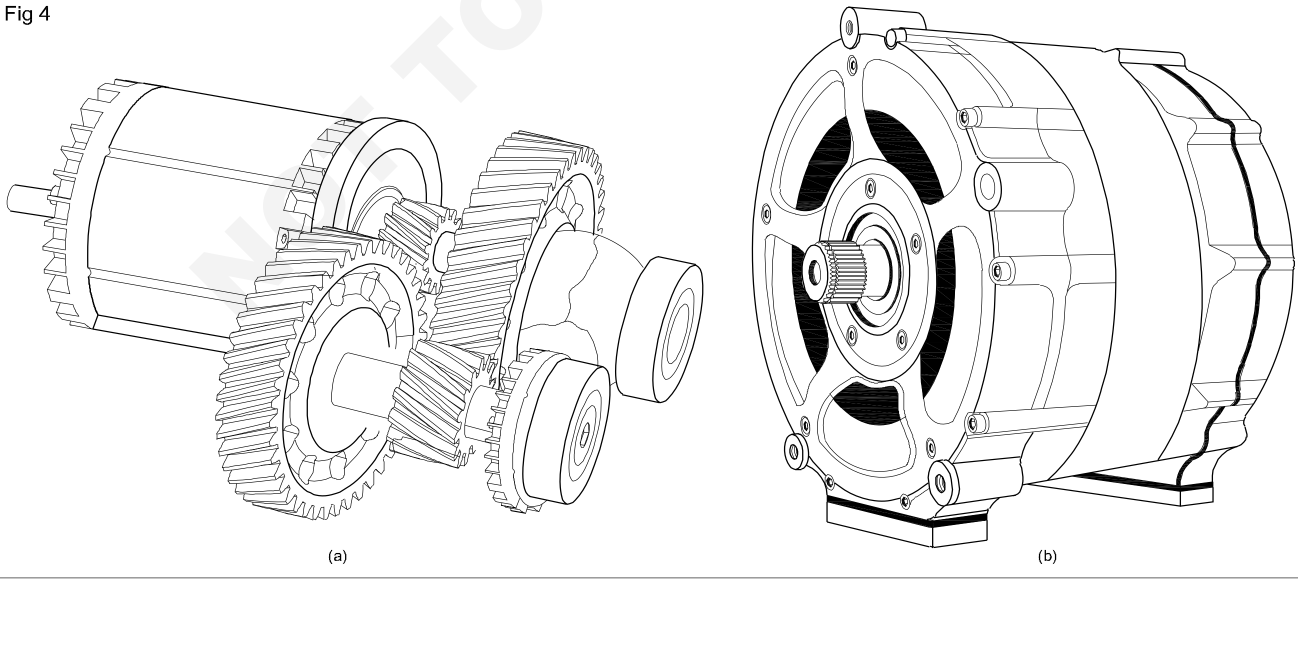


Parameters	Lithium-ion	Nickel-metal	Lead-acid	Ultra capacitors
Low Cost	√	X	√	X
Energy efficient	√	√	√	√
Temp Performance	√	X	X	√
Low Weight	√	√	√	√
Life Cycle	√	X	√	X

Electric motor (Fig 4): Electric traction motor is the main component of an electric vehicle. The motor converts the electrical energy into kinetic energy. This energy rotates the wheels. Electric motor is the main component that differentiates and electric vehicle from conventional vehicle. An important feature of an electric motor is the regenerative braking mechanism. This mechanism slows down the vehicle by converting its kinetic energy into another from and storing it for future use. There are basically two types of motors DC and AC motors. In general the BLDC electric motor is used (brush less motor). Some hybrid electric vehicle use a type of generator motor that performs the function of propulsion and regeneration.

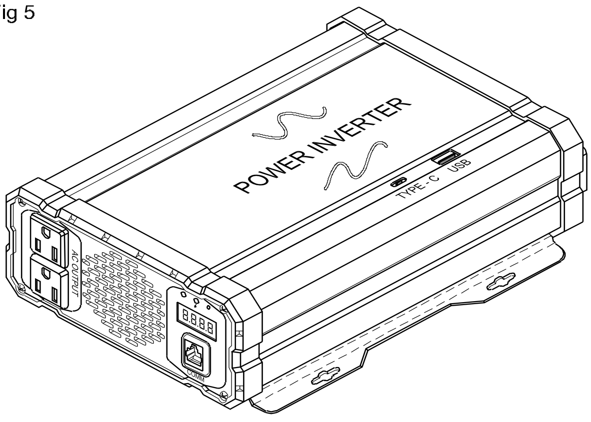
Power inverter (Fig 5): The power inverter converts DC power from the batteries to AC power. it also converts the AC current generated during regeneration braking into DC current. Power inverter further used to recharge the batteries. This type of inverter used in some electric vehicle models is the bi-directional.

Fig 4



(a) (b)

Fig 5



Types of Electric Traction motor:- There are two main types of electric traction motor

- Permanent magnet synchronous motor (PSM). The rotation frequencies of the magnetic field of the stator and rotor coincide in this motor.
- Asynchronous motor (ASM) – The rotation speed of the stator magnetic field is higher than the rotation speed of the rotor in this type of motor.

Charge port (Fig 6): Electric vehicle charge port connects the electric vehicle to an external incoming AC electricity supplies via vehicle charge port and converts it to DC power for charging the traction battery pack it also communicates with the charging equipment and monitors battery characteristics such as voltage current temperature and state of charge while charging the battery pack. The charge port is sometimes located in the front or rear park of the vehicle

ON board charger (Fig 7): ON board charger takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery pack it also communicates with the charging equipment and monitors battery characteristics such as voltage, current, temperature and state of battery charge which charging the battery pack. The on board charger is located and installed inside the car.

Controller (Figure 8&9): This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and torque it production. While the controller itself gets the main input from the car pedal . The pedal getting will determine the frequency variation or voltage variation that will enter the motor and at the same time determine the car's speed. Controller is determine how electric car work.

Fig 6

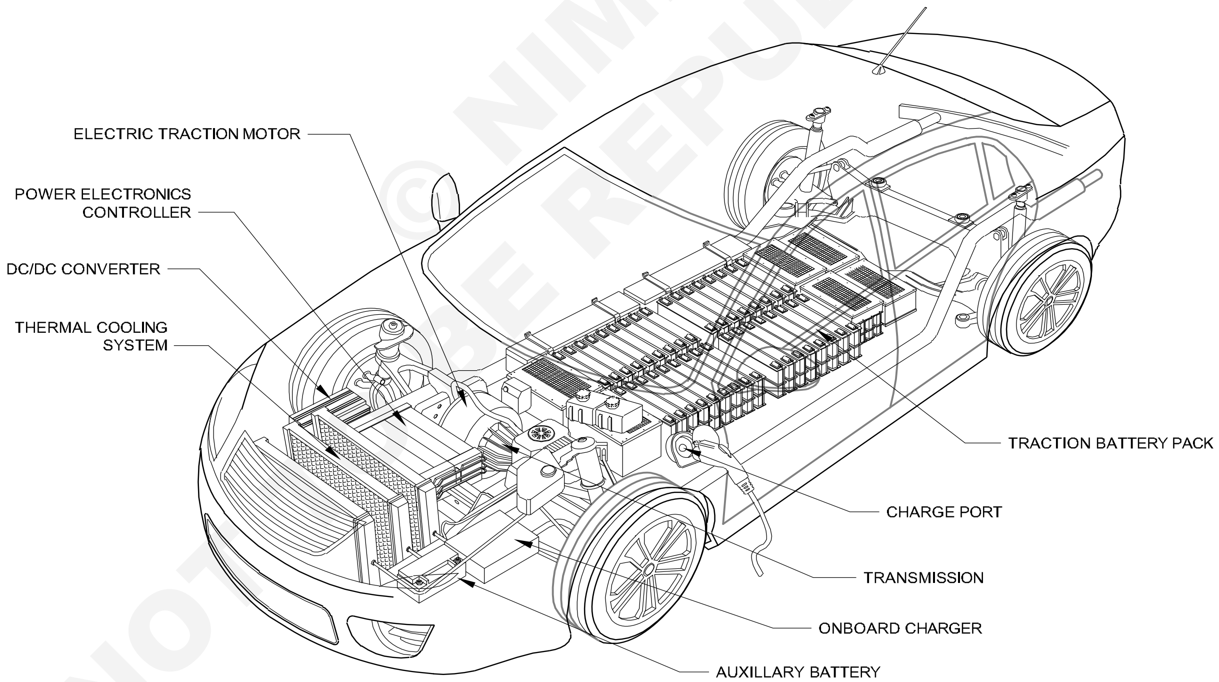


Fig 8

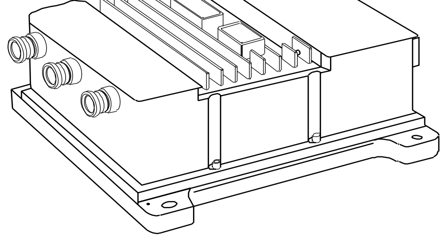


Fig 9

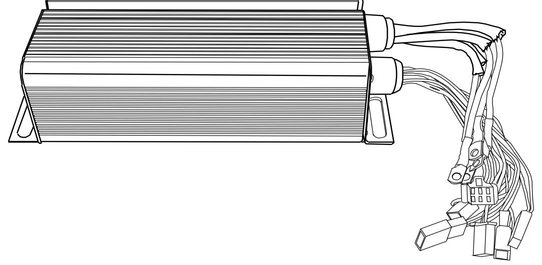
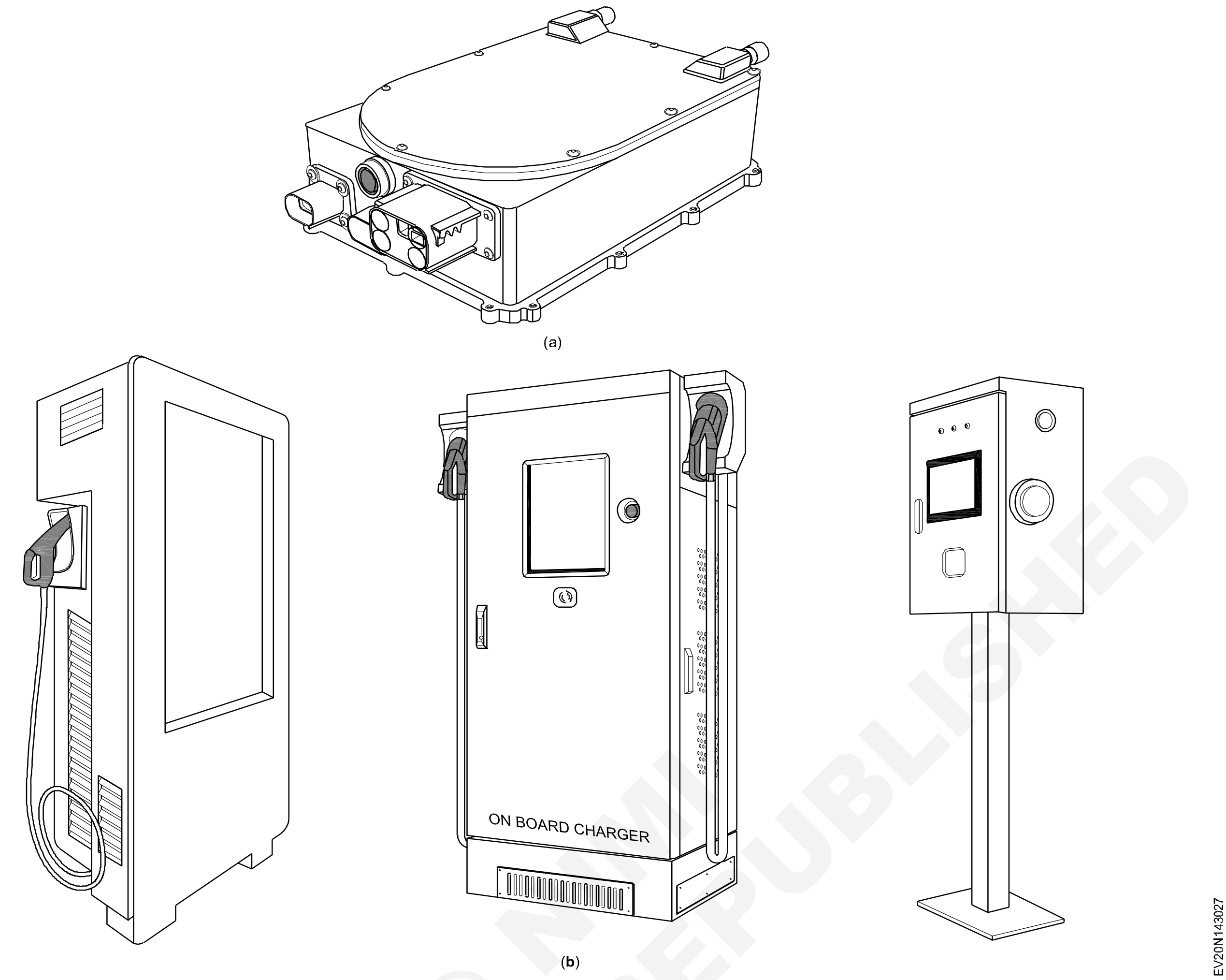
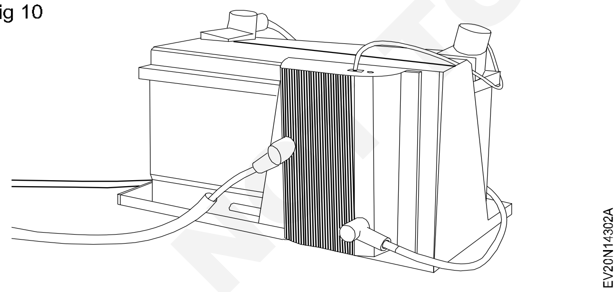


Fig 7



Auxiliary batteries (Fig 10): Auxiliary batteries are the source of electrical energy for the accessories in electric vehicles. In the absence of the main battery, the auxiliary batteries will continue to charge the car. It prevents the voltage drop, produced during engine start from affecting the electrical system.

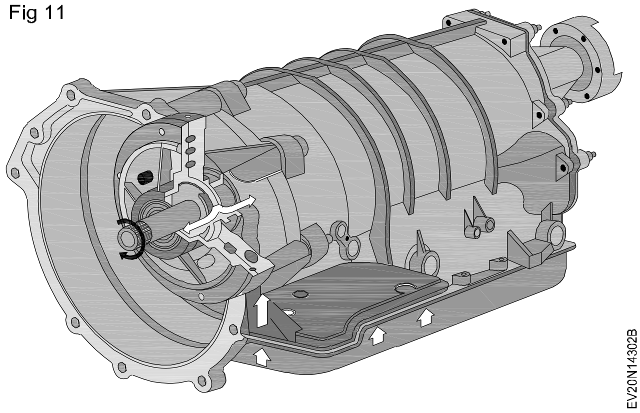
Fig 10



Thermal system (Cooling): This system maintains a power operating temperature range of an electric vehicle such as electric motor, power electronics and other components it functions during charging as well as obtain maximum performance it uses a combination of thermo electric cooling forces air cooling and liquid cooling.

Electric vehicle transmission (Fig 11): This vehicle transmission used to transfer the mechanical power from the electric traction motor to the drive wheels, through gear box. The advantage of electric vehicle is that they do not require multi-speed transmissions. The transmissions efficiency should be high to avoid power loss.

Fig 11



Basic function of electric motor: The main function of motor is to convert supplied electric energy current into mechanical energy. Brushless DC motor is much focused for many motor manufactures this type of motor is more effective to term of system cost, size higher in efficiency, excellent controllability and also power savings than other motors. BEV is propelled with electric motors and draw power from on board electric source is an electric vehicle.

Motor selection for electric vehicle: Selecting the right electric motor to fit a particular vehicle is not always straight forward. There are so many variables to consider that it can be difficult to know where to start given the price of batteries and electric motors in order to find the most economical solutions and power train that will full required vehicle performance as close as possible. Basically you need to determine the most demanding requirements of a vehicle as well as evaluate how various road conditions will in pack performance of the power train.

Keep in mind the following points before select the electric vehicle motor.

- **Vehicle characteristics:** The properties of the vehicle such as size, weight, overload and aerodynamic are curial vehicle characteristics that will determine the vehicle speed, torque and power requirements of the electric motor.
- **Driving cycles:** How is the vehicle being used it also very important vehicle will be driven as long distance with many stops or few stops.
- **Vehicle Configuration** is the vehicle hybrid or full electric
- **Maximum speed of the vehicle:** The electric vehicle is the targeted maximum speed of the vehicle. The electric vehicle speed is depend on gear box gear ratio available and differential ratio and rolling radius of the wheel.
- **Maximum torque:** Maximum torque enables the vehicle to start in given slope, highest grade the vehicle will need to ascend.
- **Maximum power:** Select the motor to full fill the need of your electrical vehicle carrying the load, road condition, torque and maximum power need to perform the vehicle function.

Battery capacity: The battery capacity is typically calculated using a simulator to go through a reference cycle typical of the usage of the vehicle. The simulator can output the consumption of the vehicle in Kwh/ Km from that value, the capacity of the battery can be calculated by multiplying it with the desired range.

Battery voltage: The battery voltage is dependent on the size of the vehicle. As the battery voltage increases the current output is lowered. so in the cases where the vehicle continuous power is high like in bigger vehicles. To keep the size of the conductors at a manageable level by increasing the battery voltage.

Gearbox: The high torque/low speed of the motor allows it to directly interface with standard axis differentials with out the need for an intermediate gearbox. While improving system reliability and reducing overall maintenance costs, removing the transmission in an electric vehicle also increases the power trains efficiency considerably, allowing optimal use of the energy stored in the battery pack.

Cost: Select the motor by cost and their pros and cons and their relative usage in electric vehicles.

Signing and characteristic of EV Motor. The electric motor has only two basic main parts rotor and stator. The rotor is rotating part, which carry permanent magnet and their stator is stationary part and containing stator winding the structure of stator is similar to the induction motor it is made up of steel lamination with axially cut for winding.

Motor size: Motor sizing refers to the process of picking the correct motor for a given load. It is important to size a motor correctly because a if a motor is to small for an application it may not have sufficient torque to stat the load and run it up to the correct vehicle speed

Motor coil burns, higher current will also lead to higher alternate current and smaller volume. Motor speed unit an increase in motor speed the required torque to get the same output power reduces and hence the volume and weight of the motor will reduce, power the torque required is reduced by 50%. There are three factors to calculate when sizing a motor moments of inetia, torque and speed.

Types of DC motor: There are two types of DC motors

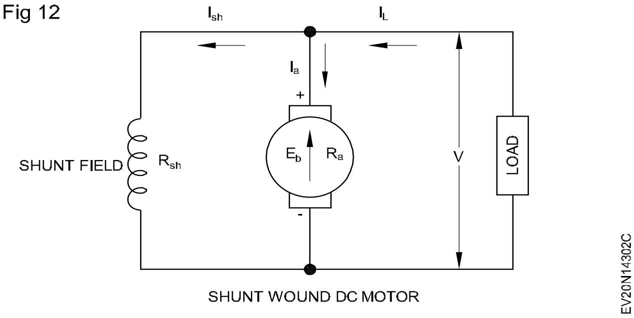
- separately excited DC motor.
- self excited DC motor.

Separately excited DC motor has two voltage sources to supply the armature and field windings separately

The self excited DC motor the other way only has one voltage source to supply both armatures and field windings this type can be divided further into three types.

- **Shunt winding DC motor:** In a shunt wound motor the field winding is connected parallel to the armature) (Fig 12)

Fig 12



- **Series winding DC motor (Fig 13):** In a series wound DC motor, the field winding is connected in series with the armature winding.
- **Compound winding DC motor (Fig 14):** DC motors having both shunt and series field winding is known as Compound DC motor, as shown in the figure. The compound motor is further divided into:

• Cumulative Compound Motor

• Differential Compound Motor

Fig 13

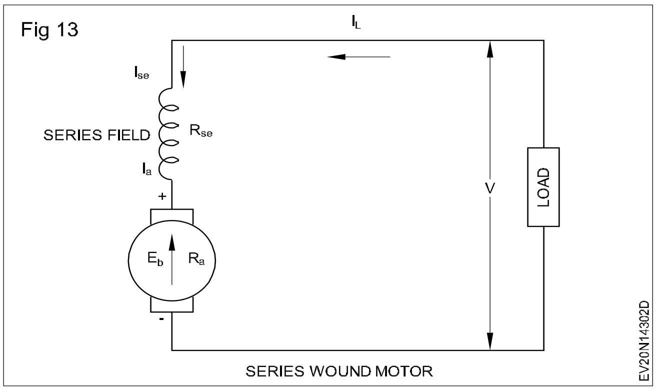
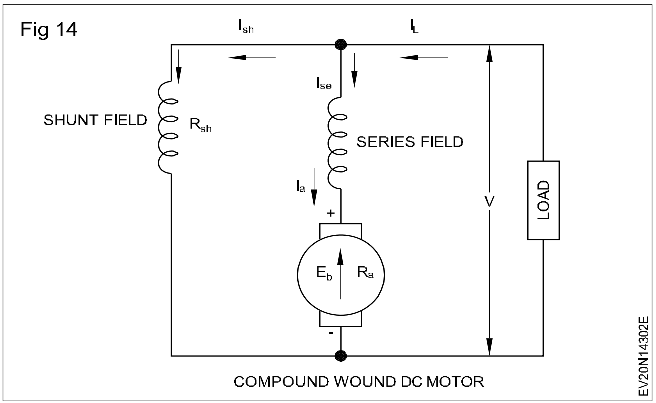


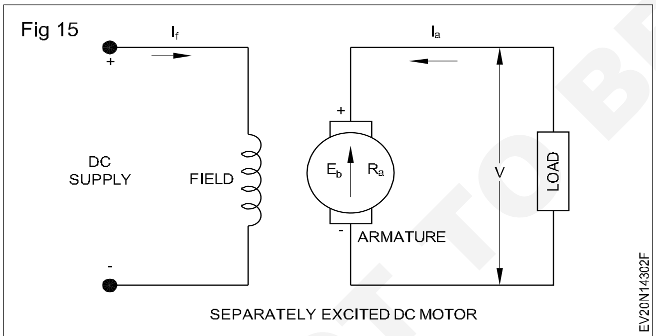
Fig 14



In a cumulative compound motor, the magnetic flux produced by both the windings is in the same direction. In a differential compound motor, the flux produced by the series field windings is opposite to the flux produced by the shunt field winding.

Separately excited DC motor (Fig 15): In a separately excited DC motor, the field coils are energised from an external source of DC supply as shown in the figure.

Fig 15



Characteristic of DC motor (Separately excited)

This motor has characteristic of

- The armature (rotar) and field (stator) windings have to be supplied by voltage separately, thus we need two DC voltage sources electrically separated from each other.
- The armature and field windings are separated electrically.
- The torque is inversely proportional to the speed of the rotor.
- Stall torque is the maximum torque but the rotor is not rotating.
- No load speed is the maximum speed of the rotor when there is no torque applied to the rotor.

Characteristic of DC motor (Shunt): This type of motor has the following characteristic of

- The armature and field windings are connected in parallel
- Only one voltage source is needed to supply both armature and field windings.
- This motor relatively has constant torque in a wide range of speed.
- The torque speed characteristic and equation for shunt DC motor is the same with the separately excited DC motor.

Characteristic of DC motor (series)

- The armature and field windings are connected in series.
- Only one voltage source is needed to supply both armature and field windings.
- The current in the field winding is the same as the current in the armature winding
- Series motor has a special trail that we can apply AC or DC voltage to it.
- Even if we reverse the supply polarity the motor will always rotate in the same direction

Characteristic of DC motor (Compound)

- Compound DC motor use both series and shunt field windings
- One field windings is connected in series to the armature and other one field windings is connected in parallel to the armature.

Factors affecting motor performance:

Electric motor performance depends on three elements such as voltage across terminals, resistance across terminals and magnetic force, various factors that affect these elements and change motor performance way of giving some specific examples

- Voltage of power supply
- Type of power supply
- winding specifications
- Environmental Temperature
- Type of magnet
- Flux yoke
- Phase of current

Calculation of motor effort: Calculating the motor effects force F is force in Newton (N) B is magnetic flux density (magnetic field strength), I is current is an pers also referred to as amps- A is length in meters (m).

A wire carrying a current creates a magnetic field this can interact with another magnetic field, causing a force that pushes the wire at right angles.

Calculating the motor effect force: To calculate the force on a wire carrying a current at right angles to magnetic field use the equation

Force = magnetic flux density x current x length

F= BIL this is when

F is force is Newton (N)

B is magnetic flux density (magnetic field strength)

I is current in amperes - also referred to as amps (A)

L is length in meters (M)

Calculating the strength of force: To calculate the size of the force acting on a current carrying wire, at a right angle to the directions of magnetic field use the following equation

$$F = BIL$$

Definition of the motor effect: The motor effect describes how electricity and magnets can work together to create a magnetic force. This magnetic force is the basis of all electric motors hence name motor effect.

The motor effect is the phenomenon of a force being generated on a current carrying wire in the presence of an external magnetic field. The motor effect use Fleming's left hand rule shows the directions of the force on a conductor carrying a current in an external magnetic field.

Electric Transmission: When the electric motor RPM gets too high, the automatic transmission shifts gears allowing the motor to operate at a lower RPM wheel providing steady power to the wheels. The process continues as you accelerate and works in reverse as you slowdown.

The electric vehicle uses single speed transmission because the motor is efficient in wide range of condition. The output speed of motor is reduced in two steps that is speed reduction and torque multiplication.

Working and operation of electric vehicle propulation system

The electric vehicle transmission systems consists of a motor, inverter controller, power controller and battery and these play a major role in the overall working mechanism.

- When a battery power input is given to starter, it creates rotating magnetic field and hence induces a current in rotor and it starts rotating. The speed of induction motor depends on the frequency of power supply, the speed of drive can be changed.
- Electric vehicle can work on any speed, it does not require a speed varying transmission.
- The power generated in the electric vehicle motor is transferred to a drive wheel via gear box. The EV uses single speed transmission because the motor is efficient in wide range of condition.
- The output speed of motor is reduced in two steps that is speed reduction and torque multiplication.
- Open differential can control torque rather than slip differential the arrangement of differential is another important feature of electric vehicle.
- The traction control of differential can be overcome by two methods that is selective braking and cutting the power supply.
- EV can be run by first pedal, it saves huge kinetic energy in the form of electrical as soon as acceleration pedal is applied and hence regenerative braking is introduced in electric vehicle
- During regenerative braking, motor acts as generator so wheels drive the motor.
- Motor rotor speed less than real motor speed.
- Generator rotor speed greater than rms speed.
- The generated electric energy can be stored in battery after conversion
- opposing electromagnetic field acts on the rotor, so drive wheel and car will slow down so that vehicle stopped can be controlled using single speed.
- Electric vehicle has planetary gear set and torque convertor instead of clutch pack.
- Most of electric cars have just one electric motor found on either the rear axle or front axle wheel drive. On an all wheel drive electric car, there will be two motors - one for each aside. There are four types of transmission used in all types of vehicles. They are as follows;
- Automatic transmission (AT)
- Manual Transmission (MT)
- Automated Manual Transmission (AMT)
- Continuously Variable Transmission (CVT)

Components of electric vehicle propulsion system :- There are many components are used in electric vehicle propulsion system. Thus are as follows :-

- Software DTC- SVM control system
- Energy storage - Power Battery
- Two level inverter
- PMSM - Traction motor
- Transmission - differential wheels

Types of electric vehicle drive systems: There are three types of electric vehicle drive systems followed. They are as follows

- Electric drive system with a clutch (Fig 16a)
- Electric drive system without the clutch (Fig 16b)
- Integrated electric drive system (Fig 16c)

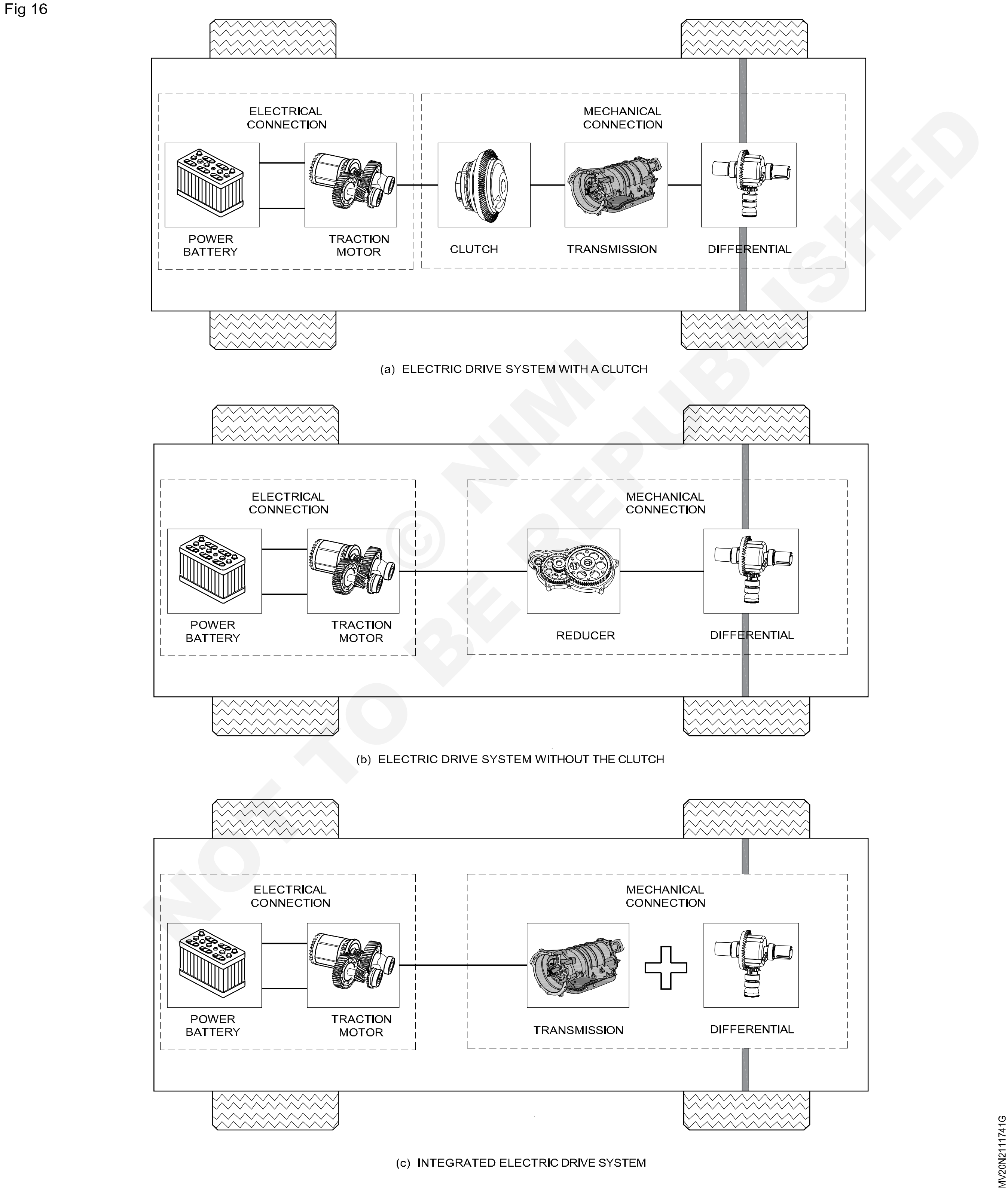
The propulsion system in an EV consists of an energy storage system, the power converter and the population motor and related controllers differential are used in EV population system. The battery is undely used as energy storage system and its charging is an integral park of the EV systems. Each parts function is explained is above mentioned main components of Electric Vehicle.

EV power systems (motor and controllers): The power system of an electric vehicle consists of two components such as the motor that provides the power and the controller that controls the application of this power. The electrical drive system is defined as the system which is use for controlling the speed, torque and direction of electrical motor.

Electric motor: Electric Motor convert electrical energy into mechanical energy. Two types of electric motors are used in electric vehicles to provide power to the wheels: the direct current (DC) motor and the alternating current (AC) motor.

DC motor (Brushed) (Fig 17 (a)): DC Current from the battery is delivered to the rotor windings via spring-loaded "brushes" of carbon or lead that energize spinning contacts connected to wire windings. Every

Fig 16



few degrees of rotations, the brushed energize a new set of contacts; this continually reverses the polarity of the electromagnet on the rotor as the motor shaft turns. (This ring of contacts is known as the commutator).

The housing surrounding the rotor's electromagnetic windings typically features permanent magnets. (A "series DC" or so-called "universal motor" may use an electromagnetic stator). Advantages are low initial cost, high relaibilty, and ease of motor control. Varying the voltage regulates the motor's speed, while changing the current controls its torque. Disadvantages include a lower lifespan and the cost of maintaining the brushes and contacts. The motor is seldom used in transportation today.

Brushless DC motor (BLDC) (Fig 17 (b)): The brushed and their maintenance are eliminated by moving the permanent magnets to the rotor, placing the electromagnets on the stator (housing), and using an external motor controller to alternately switch the various field windings from plus to minus, thereby generating the rotating magnetic field.

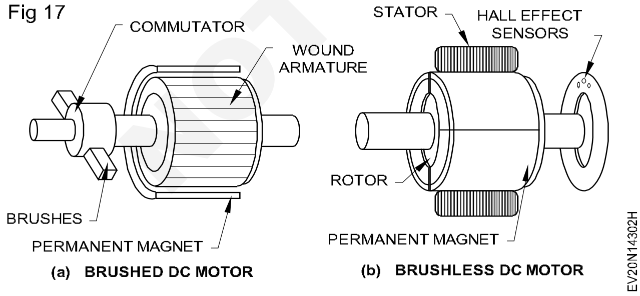
Advantages are a long lifespan, low maintenance, and high efficiency. Disadvantages are higher initial cost and more complicated motor speed controllers that typically require three hall-effect sensors to get the stator-winding current phases correctly. That switching of the stator windings can result in "torque ripple"-periodic increases and decreases in the delivered torque. This type of EV motor is popular for smaller vehicles like electric bikes and scooters, and it's used in some ancillary automotive applications like electric power steering assist.

Different types of electric vehicle drive electric motors

There are many types electric motors are used in electric vehicle, but mainly six different types of electric motors which are being used in current and upcoming EVs BLDC motors. They as follows

- DC series motor.
- Brushless DC motor (BLDCM).
- AC Induction Motor (ACIM)

Fig 17

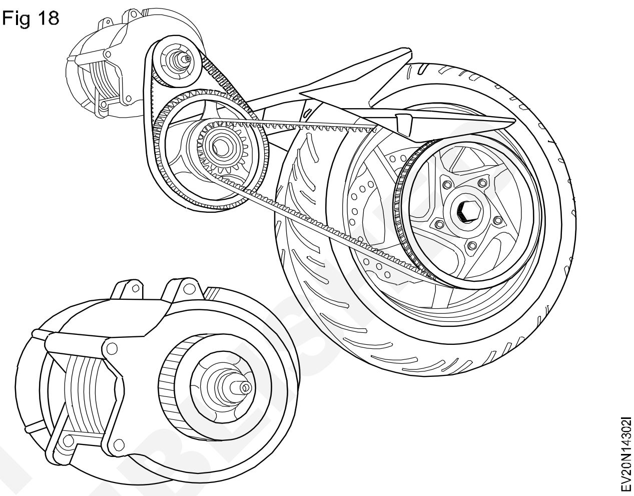


- Interior Permanent Magnet Motor (IPMM).
- ACI motor (ACIM)
- Permanent Magnet Switched Reluctance Motor (PMSRM).

1 **DC series motor:** It was a widely used motor back in the 1990s. This motor is capable of producing high initial torque. The easy speed control and sudden load increase bearing capacity make these motors a good choice. But the high maintenance due to the brushed and commutators is a major drawback in the DC series motor which are also known as brushed DC motors. These motors are still in use by the Indian Railways.

2 **Brushless DC motor (BLDC) (Fig 18):** Brushless DC Motor (BLDCM) are being used in most of the lightweight 2 wheeler & 3 Wheeler EVs like electric scooters, electric motorcycles and electric auto.

Fig 18



For examples in electric scooters

- Ampere primes Kinetic – luna
- Ather energy 450 x TVS creon. Iqube electric optima C x Ola Electric S1 pro
- Niu Electric Scooters Bajaj Chetak
- Yamaha EC-03, etc Hero Vida, Komaki SE-2023

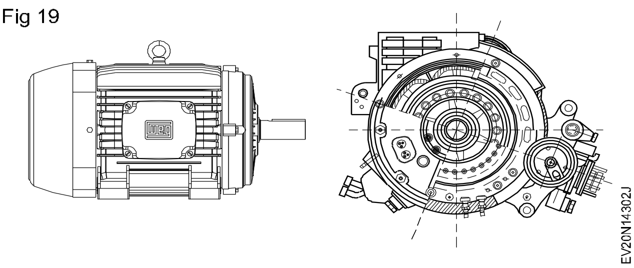
For examples in electric motorcycles

- Komaki Ranger Revolt RV 400
- eMotion Motors, oben rorr
- Menza Motors, Tork Kratos

3 **PMSMs (Fig 19)**

Permanent magnet synchronous motor (PMSM) are also being used by many EV manufactures for their high-performance electric motorcycle, electric cars, electric buses.

Fig 19



For examples in electric cars:

- Chevy bolt EV – Tata EV
- Nissan leaf EV – Hyndai EV

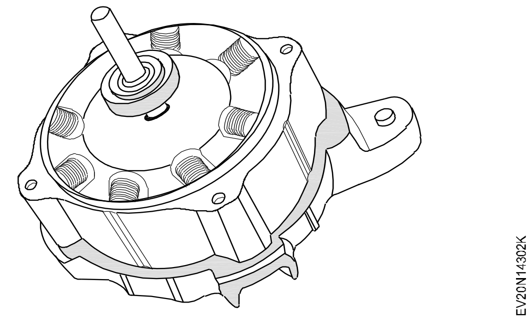
For examples in electric buses

- TATA Ultra Urban 6/9 & 6/12

4 IPM Motors (IPMM) (Fig 20)

Interior Permanent Magnet Motor (IPMM) are also being used by some 2 Wheeler EV Manufacturer for their High-Performance Electric Motorcycle.

Fig 20



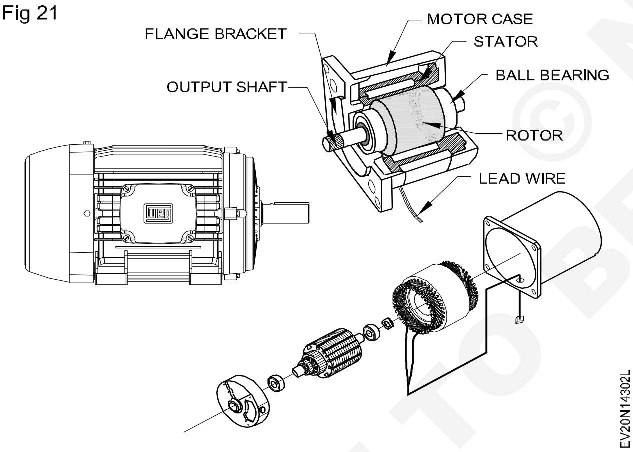
For Example:

- Zero motorcycles (Model S/SR, DS/DSR, FX, FXS, 'SR/F')
- Lightning motorcycles (Model LS-218).

5 ACI Motors (ACIM) (Fig 21)

AC Induction motor (ACIM) is also being used by some EV manufactures in 2 wheeler and 4 wheeler.

Fig 21



For examples in 2 wheeler:

- Emflux Motors-Emflux One,

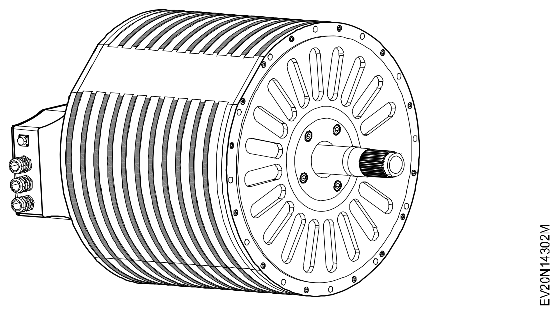
For examples in 4 wheeler:

- Tesla roadstar 2008, – Volvo x c 40
- Tesla model S, – Citroen E C3
- Tesla model X, – M G Comet
- Mahindra e-verito – KIA
- Mahindra e2o – Audi etron GT
- Mahindra e-supro – BMW I 7
- Mahindra X UV 400 – Hyundai Ioniq 5
- TATA Tiago – Tata nexon Ev

6 PMSRM (Fig 22)

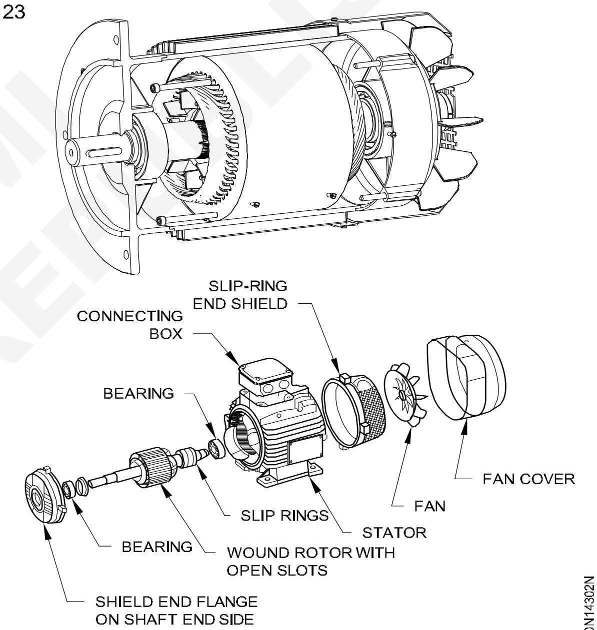
Permanent magnet switched reluctance motor (PMSRM) is used in various electric vehicles.

Fig 22



The PMSRM electric traction motor consists of a stator and rotor. A rotating magnetic field in the stator acts on the rotor winding and the induction current flows in it, so a rotating moment arises, which leads to the movement of the rotor. The electric energy supplies to the motor windings in converting into mechanical energy of rotation.

Fig 23



PARTS OF 3 PHASE SLIP RING INDUCTION MOTOR

DC electric motors have three main components

- A set of coils (field) that creates the magnetic forces which provide torque.
- A rotor or armature mounted on bearings that turns inside the field.
- Commutating device that reverses the magnetic forces and makes the armature turn, thereby providing horse power.

As in the DC motor, an AC motor also has a set of coils (field) and a rotor or armature, however, since there is a continuous current reversal, a commutating device is not needed.

Both types of electric motors are used in electric vehicles and have advantages and disadvantages, as shown here.

While the AC motor is less expensive and lighter weight, the DC motor has a simpler controller, making the DC motor/controller combination less expensive. The main disadvantages of the AC motor is the cost of the electronics package needed to convert (invert) the battery's direct current to alternating current for the motor.

Past generations of electric vehicles used the DC motor/ controller system because they operate off the battery current without complex electronics. The DC motor/ controller system is till used today on some electric vehicles to keep the cost down.

However, with the advent of better and less expensive electronics, a large number of today's electric vehicles are using AC motor/controller systems because of their improved motor efficiency and lighter weight.

Different type drive system of electric vehicle's electric motor drive system

EV DC motor drives: Motor drive system is one of the core components of electric vehicle, which requires high torque at low speed, high power at high speed wide speed control range to meet the EV performance requirements. Electric vehicle's use both alternating current and direct current motors.

DC motor armature drive voltage: When pedal of the EV is pressed, then the controller take and regulates electrical energy from batteries and inverters. With the controller set, the inverter then send a certain amount of electrical energy to the motor (according to the depth of pressure on the pedal).

EVs DC motor required high voltage to power the motor, voltage levels of 400 to 800 V or more are needed to generate sufficient power to run the vehicle.

The flow of current measured in amps, multiplying volts times amps gives power to motor. Its power that makes a car move. The normal unit of power in electricity is watts.

Watts = Volts x Amps. Tesla batteries are 375 Volts, Nissan Leaf batteries are 360 Volts.

A simple DC controller connected to the batteries and DC motor if the driver press the accelerator pedal, the controller delivers the 96 volts from the batteries to the motor.

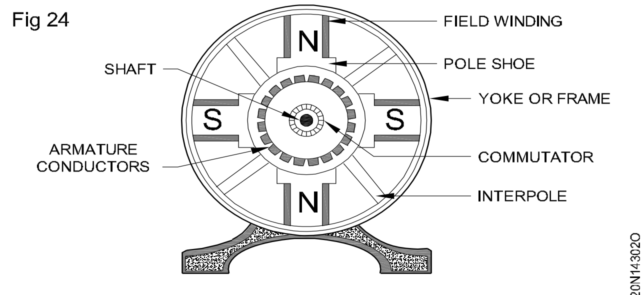
DC motor construction

EV DC motor is an electrical machine that converts electrical energy into mechanical energy. In a DC motor the input electrical energy is the direct current which is transformed into the mechanical rotation. DC motor construction parts shown in figure 24:

Different parts of a DC motor (Fig 24)

A DC motor is composed of the following main parts :

Fig 24



DC MOTOR CONSTRUCTION PARTS

Armature or Rotor

The armature of a DC motor is cylinder of magnetic laminations that are insulated from one another. The armature is perpendicular to the axis of the cylinder. The armature is a rotating part that rotates on its axis and is separated from the field coil by an air gap.

DC Motor – Drives armature voltage

DC motor is a are electric motor that convert the ectrical energy into mechanical energy. They are commonly used in a wide range of electric vehicles, robotics, and factory automation.

One important aspect of DC motor is the control of the armature voltage, which affects the motor speed and torque. The armature voltage is the voltage applied, to the armature winding of the motor, which creates a magnetic field that interacts with the magnetic field of the stator, causing the motor to rotate.

DC motor drives are used to control the armature voltage of the motor. The most common type of DC motor drive is a pulse width modulation (PWM) drive. The PWM drive uses a series of pulses to control the average voltage applied to the motor. By varying the width of the pulses, the average voltage can be controlled, which is in turn controls the speed and torque of the motor.

The armature voltage is controlled by using a feedback loop that measures the motor speed and adjusts the voltage to maintain a desired speed or torque. The feedback loop typically uses a speed or torque sensor to measure the actual motor speed or torque and compares it to a desired value. If the actual value is lower than the desired value, the voltage is increased to increase the motor speed or torque, and vice versa.

DC motor drives are essential for controlling the speed and torque of DC motors in a wide range applications. By controlling the armature voltage, the speed and torque of the motor can be adjusted to meet the specific requirements of the application.

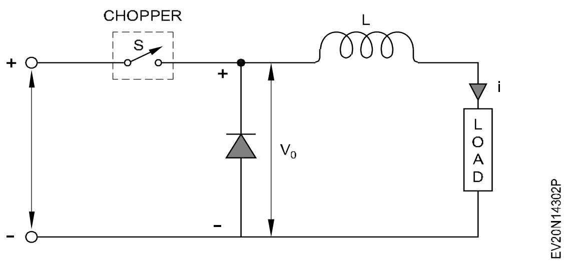
Chopper Circuit

A chopper circuit is a type of DC motor drive circuit that uses a switch to control the voltage applied to the motor. It operates by rapidly switching the voltage on and off to the motor, effectively creating a chopped voltage waveform that averages out to the desired voltage level. The switching frequency can be adjusted to regulate the motor speed, and the duty cycle of the switch determines the average voltage applied to the motor. Chopper circuits are commonly used in DC motor control applications as they provide high efficiency and precise control of the motor speed and torque. They are particularly useful in applications where the motor must operate over a wide speed range or where energy efficiency is critical. (Fig 25)

Step-Up, Step-Down Chopper (Fig 26)

Step-up and step-down choppers are two types of DC-to-DC chopper circuits used in DC motor control.

Fig 25



A step-up chopper, also known as a boost chopper, is used to increase the DC voltage supplied to the motor. It operates by switching the input voltage to the motor at a high frequency perse controlling the duty cycle of the switch to achieve the desired output voltage. Step-up choppers are commonly used in applications where the motor requires a higher voltage than the available supply voltage, such as in electric vehicles or renewable energy systems.

On the other hand, it a step-down chopper, also known as a buck chopper, it is used to decrease the DC voltage supplied to the motor. It operates by switching the input voltage to the motor at a high frequency and controlling the duty cycle of the switch to achieve the desired output voltage. Step- down choppers are commonly used in applications where the motor requires a lower voltage than the available supply voltage, such as in battery-powered devices.

Both types of chopper circuits provide efficient and precise control of the motor speed and torque, making them ideal for use in a wide range of DC motor control applications.

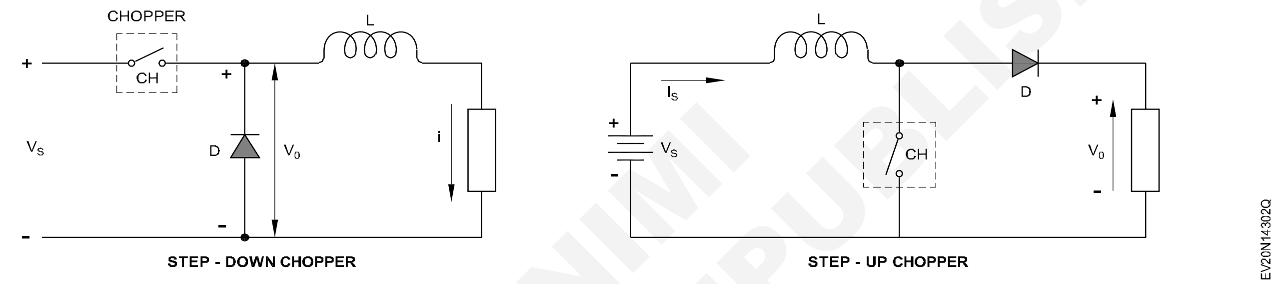
The average value of output voltage can be controlled through duty cycle by opening and closing the semiconductor switch periodically. The various control strategies for varying duty cycle are as following:

1 Time ratio Control (TRC) and

2 Current - Limit Control.

Time ratio Control (TRC) In this control scheme, time ratio (duty ratio) is varied. This is realized by two different ways called Constant Frequency System and Variable Frequency System as described below:

Fig 26



1 CONSTANT FREQUENCY SYSTEM

In this scheme, on-time is varied but chopping frequency is kept constant. Variation of Ton means adjustment of pulse width, as such this scheme is also called pulse-width-modulation scheme.

2 VARIABLE FREQUENCY SYSTEM

In this technique, the chopping frequency (f) is varied and either

i on -time Ton is kept constant or

ii off-time toss is kept constant.

This method of controlling duty ratio is also called Frequency- modulation scheme.

CURRENT - LIMT CONTROL

In this control strategy, the on and off of chopper circuit is decided by the previous set value of load current. The two set values are maximum load current and minimum load current. When the load current reaches the upper limit, chopper is switched off. When the load current falls below lower limit, the chopper is switched on. Switching frequency of chopper can be controlled by setting maximum and minimum level of current. Current limit control involves feedback loop, the trigger circuit for the chopper is therefore more complex. PWM technique is the commonly chosen control strategy for the power control in chopper circuit.

Chopper Amplifier: Chopper amplifier can be used to control the speed of a DC motor by modulating the voltage applied to the motor. The chopper amplifier is typically used in conjunction with a pulse width modulation (PWM) circuit to achieve the desired motor speed.

In this system, the chopper amplifier modulates the DC voltage supplied to the motor at a high frequency, typically several kHz. The PWM circuit then adjusts the duty cycle of the modulated signal to achieve the desired average voltage level. By changing the duty cycle, the speed of the motor can be controlled.

The chopper amplifier provides several benefits in this application. It can help to eliminate love stable and accurate motor speed control. Additionally, the chopper amplifier can help to reduce power dissipation and increase efficiency by allowing

the use of a lower average voltage while still achieving the desired motor speed Overall, the combination of a chopper amplifier and PWM circuit is a common and effective oproach to DC motor speed control, particularly in applications where precise and stable speed control is required.

Commutator and brushes

Field coil or stator

A DC motor filed coil is a non-moving part on which winding is wound to produce a magnetic field. This elector-magnet has a cylindrical cavity between its poles.

Commutator

The commutator of a DC motor is a cylindrical structure that is made of copper segments stacked together but insulated from each other by using mica. The primary function of a commutator is to supply electrical current to the armature winding.

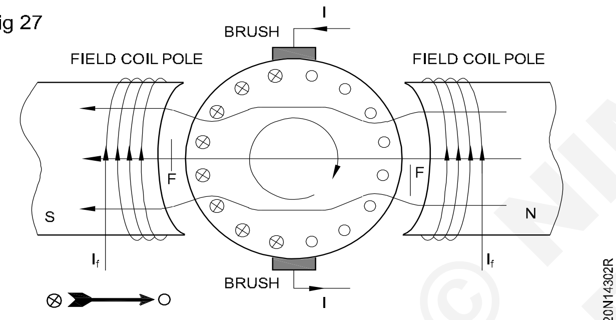
Brushes

The Brushes of a DC motor are made with graphite and carbon structure. These brushes conduct electric current from the external circuit to the rotating commutator. Hence, we come to understand that the commutator and the brush unit are concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.

DC motor working (Fig 27)

A magnetic field arises in the air gap when the field coil of the DC motor is energized. The created magnetic field is in the direction of the radii of the armature. The magnetic field enters the armature from the North pole side of the field coil and "exits" the armature from the field coil's South Pole side.

Fig 27



PRODUCTION OF TORQUE IN A DC MOTOR

Production of torque in a DC motor

The conductors located on the other pole are subjected to a force of the same intensity but in the opposite direction. These two opposing forces create a torque that causes the motor armature to rotate.

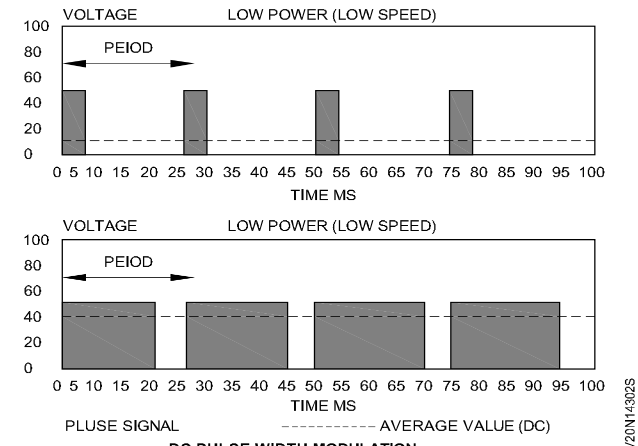
Working principle of DC motor

When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work.

Controllers (Fig 28)

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle's speed and acceleration. The controller transforms the battery's direct current into alternating current (for AC motors only) and regulates the energy flow from the battery. The controller will also reverse the motor rotation (so the vehicle can go in reverse), and convert the motor to a generator (so that the kinetic energy of motion can be used to recharge the battery when the brake is applied).

Fig 28



DC PULSE WIDTH MODULATION

In the early electric vehicles with DC motors, a simple variable-resistor-type controller controlled the acceleration and speed of the vehicle. With this type of controller, full current and power was drawn from the battery all of the time. At slow speeds, when full power was not needed, a high resistance was used to reduce the current to the motor. With this type of system, a large percentage of the energy from the battery was wasted as an energy loss in the resistor. The only time that all of the available power was used at high speeds.

PWM GENERATION:- Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation. Switching devices such as silicone-controlled rectifiers rapidly interrupt (turn on and turn off) the electricity flow to the motor. High power (high speed and/or acceleration) is achieved when the intervals (when the current is turned off) are short. Low power (low speed and/or acceleration) occurs when the intervals are longer.

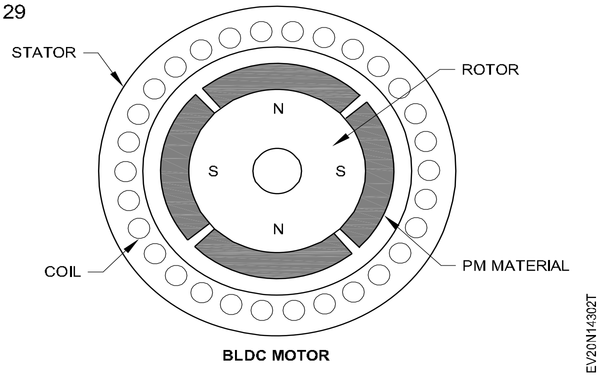
The controllers on most vehicles also have a system for regeneration braking. Regenerative braking is a process by which the motor is used as a generator to recharge the batteries when the vehicle is slowing down. During regenerative braking, some of the kinetic energy normally absorbed by the brakes and turned into heat is converted to electricity by the motor/controller and is used to re-charge the batteries. Regenerative braking not only increases the range of an electric vehicle by 5-10%, it also decreases brake wear and reduces maintenance cost.

Brushless DC motor (Fig 29)

A vehicle is propelled with electric motors and draw power from battery source is an electric vehicle. The electric vehicle is used the battery for storing the electric energy it can store large amount of energy in a small volume and weight.

The main function of motor is to convert supplied electric energy current into mechanical energy. The brushless DC motor have been much focused for many motor manufactures. These are more effective in terms of system cost, size, higher in efficiency, excellent controllability and also power saving than other motor it has only two basic main parts rotor and stator. The rotor is rotating part which carry permanent magnet and stator winding. Stator is made up of steel lamination with vocally cut for winding,

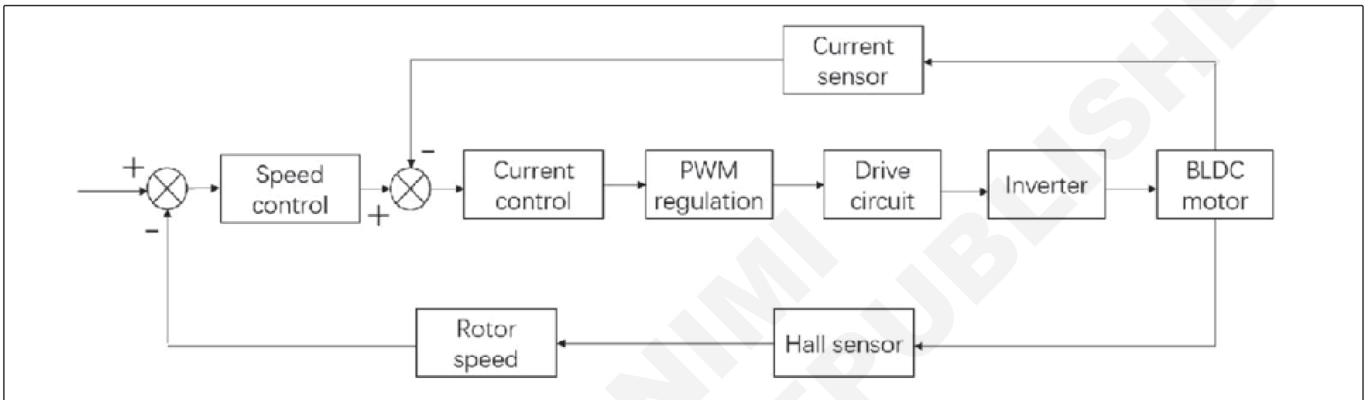
Fig 29



Motor controller and vehicle speed controller (Fig 30)

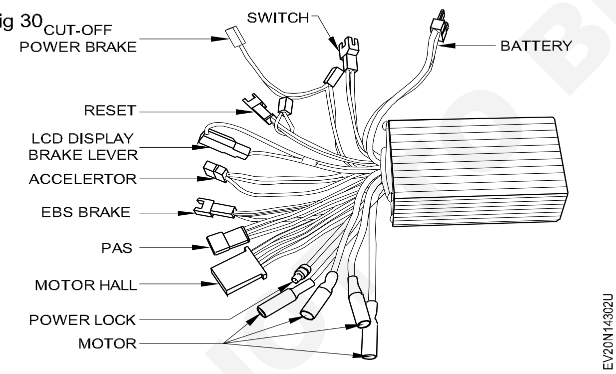
In most of the electric vehicle, brushless DC motor is used which is better that brushed DC motor, permanent magnet DC motor. Brushless DC motor does not have brush and commutator, the electric vehicle which uses brushless DC motor has to use motor controller which helps to control various properties of motor to take sufficient current and voltage applied to motor. When accelerating pedal is press, this linked variable resistor type controller gives signal to the motor controller to adjust speed as per our needs. The motor controller has no power when vehicle is at rest position.

Working principle of brushless DC motor: BLDC motor works on the principle similar to that of a brushed DC motor. When current carrying conductor placed in a magnetic field it experiences a force. As



a consequence of reaction force, the magnetic will experience an equal and opposite force in the BLDC motor, the current carrying conduct stationary and the permanent magnetic is moving.

Fig 30



When the stator coils get a supply from source, it becomes electromagnetic and starts producing the uniform fields in the air gap. Though the source of supply is DC, switching makes a generate an AC voltage wave form with trapezoidal shape. Due to the force of interaction between electromagnetic stator and permanent magnet rotor continues to rotate.

With the switching of windings as high and low signals, corresponding winding energized as north and south poles. The permanent magnet rotor with north and south poles align with stator poles which causes the BLDC motor to rotate.

Features of brushless DC motor

- Less maintenance due to absence of brushes.
- Reduce the size with far superior thermal characteristics
- Higher speed range and lower electric noise generation
- using solid state switches in commutation method
- It has no mechanical commutator and associated problems
- High efficiency and high output power to size ratio due to use of permanent magnetic rotor.
- High speed operation even in loaded and unloaded condition due to the absence of brushes that limits the speeds.
- Smaller size and lighter in weight than others.
- Long life as no inspection and maintenance is required for commutator system
- Less electromagnetic interferrance and low noise and higher dynamic response.
- No loses in brushes at high speed range
- Hall sensors, optical encoders used for detecting method of rotor position
- Reversing the switching sequence for reversal direction

Brushless direct current motor power and efficiency: There are two main efficiencies to consider in a brushless system; motor efficiency and propeller efficiency. There are several key formulas are used for brushless motor performance. The formula will helps to know how motor power and efficiency are closely related and dependent on factors such as torque, RPM, current and voltage.

$$\text{Motor efficiency} = \frac{\text{Mechanical power}}{\text{Electrical power}}$$

Mechanical power = Torque * RPM

Electrical power = Current * Voltage

Electrical power = Mechanical power + heat losses

Heat Losses = R * current

Mechanical power is the product of torque and RPM, so when there is either no torque or no rotation, no power is produced

Electrical power can be determined experimentally or theoretically and it can be a fun exercise to compare your task results to your theoretical calculation.

The efficiency of a motor is determined by dividing the mechanical power outputs by the electrical power inputs. A goal for vehicle design is therefore to maximize the overall system efficiency by using the biggest propeller possible without over loading the motor. By using a gaint propeller would drastically increase the propeller efficiency but the motor would struggle so much to make it spin, that its efficiency would be ridiculously low. During the opposite is not great either as making a tiny propeller spin very fast would lower both the motor and the propeller efficiency. The best solution is to balance both efficiencies to get the highest overall performance and system efficiency.

To achieve the highest efficiency the motor has to operate where there is a balance between torque and RPM. Testing various motors can help you, which size, KV and brand of motor will get you for best operation.

Brushless direct current motor efficiency calculation formula

Electrical motor efficiency is often denoted by the greek letter a (n) and is calculated by using the following formula.

$$n = \frac{0.7457 \times hp \times load}{P1}$$

Here hp = motor horse power

load = out put power as a percentage of rated power

P_1 = input power is KW

The constant factor 0.7457 is used to convert horse power to kilowatts. This is because 1 HP = 74watts or 0.74 KW

Electric power (watts) = voltage (V), current (A)

Motor efficiency = Mechanical power/Electrical power

Electric vehicle functional systems

Objectives:- At the end of this lesson you shall be able to
- **state the automobile functional systems and their sub systems**
- **state the power train system**
- **state the chassis and monocoque body**

Inroduction to various automotive Functional systems and their Sub systems:

The electric vehicle has made several monumental advancements in vehicular technology, that have redefined the understanding of modern transportation

Electric vehicle subsystem: The electric vehicle, subsystem. reflect the different components that make up an entire Vehicle when built together.. The vehicle it self can be Considered a larger system, which would make components like chassis, cabin suspension and battery, motor (Engine in a conventional Vehicle). the Vehicle Subsystems typically with the way products have been developed and Continues to be with in the EV market

The combination of these different subsystems and components interact more colosely with each other, while others interact much less.

Vehicle body design: The structrual frame work of the vehicle is important because it can determine the variety of possibilities in which the internal and external mechanical design houses each subsystem, like bumber, suspension, chassis's and overall structural frame work

Propulsion system: The propulsion subsystem often consist of the electric motor transmission, driveline, wheels and the motor Controller (inverter) along with other electronic Control units (ECU).

Energy Storage system: An EV's energy storage Subsystems often consist of part pertinent to the high voltage batteries! battery, fuel cell, ultra capcitor, Bms, energy charger unit, converters etc

Accessory: These components often include Stereo system, Ac units, lighting system etc.

The different ways electric vehicle subsystems interact reflect an active, internal mechanical Co-operation, that allows the final electrified products to operate within their intended functionality. Every EV components plays a significant role in how the overall EV system function and performs. The components within the propulsion and energy storage systems are placed to fit the Vehicles frame work The Vehicle control unit (vcu) configured to control turning the vehicle on and off. There is a direct interaction with the electric motor, because inverters optimize, the Vehicles torque and balance the systems energy Via motor control. The electric motor itself. is often configured near the front of the vehicle power train and it converts the electric energy needed to move the vehicle wheels There are additional compments and parts like Converters, inverters, battery packs, thermal management systems and generators involved in the EV operating systems.

Battery pack:- Electric vehicle store the electricity in rechargeable batteries and the battery power used to drive the electric motor, which turns the wheels of electric vehicle. The electric vehicle accelerate faster than vehicles with traditional fuel engine so they feel lighter to drive.

The electric vehicle has provided many functional systems along with their subsystems to operate the vehicle smoothly on the ground surface. The following sub systems are used in electric motor drive systems.

Electric Engine/motor:- The electric motor provides power to rotate the wheel it can be a DC/AC type motor drive.

Inverter: Inverter converts the electric current in the form of direct current into alternating current

Drive train: Most of the electric vehicle have a single speed transmission which sends power from the traction motor to wheels.

Batteries: Battery is used to store the electricity which is required to run the electric vehicle.

Battery charging: Plug into an outlet or EV charging point to charge the EV's battery.

The electric vehicle is propelled by using one or more electric traction motors.

DC-DC Converter: The step-up converter transform as a low voltage input into a high voltage output. Where as a step down converter high voltage input into a low voltage output.

Transmission: Electric car use a direct transmission system as opposed to the multi speed transmissions system in cars powered by fossil fuels. The electric vehicles employ drive mode selectors instead of standard transmission systems, which as less complicated and have forever movable parts than conventional gear box.

Vehicle speed control: The accelerator pedal regulates the voltage that feeds the motor and increases the electric vehicle speed

Thermal system cooling: This device ensures that the electric motor, power systems and other parts run with in the ideal temperature zone.

Automotive other functional systems: The electric vehicle have a provided by various operating systems like a power train system, steering system, transmission system, brake system, lighting system and HVAC system, suspension system etc.

Electric vehicle power train: Electric vehicle power train design are driven by the need to reduce emissions, decrease weight and best efficiency to help drivers on road longer. The electric vehicle has a different type of models available in a market. They are as follows BEV, HEV, PHEV and FCEV.

Electric vehicle power train refers to the set of electric vehicle components used for generate the power required to move the vehicle and deliver it into the wheels the electric vehicle power trains are spilt into three classes. They are follows Hybrid electric vehicle, Plug in hybrid electric vehicle and battery electric vehicle.

The electric vehicle power train categories:

- Power generation system: battery pack, on board charger
- Power distribution system: DC/AC converter (traction in water) DC/AC convertor, Battery management system
- Mechanical components: electric motors, final reduction drive, components for electronic accessories like power steering power windows, and mirrors.

The electric vehicle power train consists of engine operation and drive train system what is (given the power to move the wheels) where the electric vehicle used IC engine power train in the following CRDI engine, Engine fan, fuel pump turbo charger, in gasoline engine power train in ignition system.

HEV/EV/DC/DC converter power train system followed by methods.

- 48 V to 12 V converter
- Auxillary power supplies
- Bidirectional 400V & 800V to low voltage
- Unidirectional 400V & 800V to low voltage
- Unidirectional 48V to 12V
- Unidirectional high voltage to low voltage digital loop

Battery management power train systems are as follows

- 100V battery pack passing balancing
- 400V battery pack passive balancing
- 48V battery pack passive balancing
- 800V battery pack passive balancing
- Battery control unit (BCU)
- Battery disconnect unit (BDU)
- Battery cell supervisor circuit and active cell balancing
- Wired cell supervisor circuit passive cell balancing
- Wireless cell supervisor circuit passive cell balancing

HEV/EV inverter & motor control power train systems are critical to enable optimal electric vehicle performance.

- Electric traction motor drive
- Traction motor starter & generator
- Traction inverter high and low voltage

EV power steering power train systems are as follow

- Electric power steering electric circuit components power train sensors in electric vehicle are as follows
- Power train current sensor, exhaust sensor, fluid constration sensor, knock sensor, pressure sensor, temperature sensor, and torque sensors are consumed the battery current during their functional activity.

EV Power transmission power train occurred in the following power transmission system.

- Automatic transmission
- Drive line components
- Electric drive components in drive line
- Electric shifter system components

EV Brake system power train occurred during ABS operation

Electric vehicle chassis and monocoque body: The vehicle chassis frame is known as the backbone of the vehicle. The vehicle body is provided on the chassis frame. Chassis frame includes the engine suspension system, steering system and other mechanical parts with body. The chassis frames are usually made of steel or aluminium and sometimes composite materials. The chassis frame can be separate from the body. Some of the vehicle.

The body-over-frame has a thick metal box or 'U'-shaped stampings or rails welded and riveted together. The main structural members are two side rails connected by a series of cross members for high load carrying capabilities. The separate frame is made of much heavier gauge steel than the body panels.

A hydro formed frame is manufactured by using water under high pressure to force straight box extruded frame rails into the desired shape. A hydro formed frame is made of a thinner gauge metal than a conventional perimeter frame. Hydro formed frames are lighter a conventional perimeter frame. Hydro formed frames are lighter almost as strong and equality as stiff as conventional heavy gauge steel or aluminum frames.

Unibody construction uses body parts welded or adhesive bonded together to form an integral frame. The body structure is designed to secure other chassis parts. No separate heavy gauge steel frame under the body is needed, unibody construction is very different concept in vehicle design that requires more complex assembly techniques, new materials and complex different approach to repairs. The unibody designs, heavy gauge cold rolled steel or aluminium alloys. This requires new handling straightening and welding techniques.

Major body sections: The vehicle is commonly divided into three body sections as front, center and rear. The front section also called the nose section, includes everything between the front bumper and the fire well. The bumper grille frame rails, front suspension parts, and engine are a few of the items included in the front section of a vehicle. The nick name, front clip or dog house is used to refer to the body section.

The vehicle center section or mid section, typically includes the body parts that form the passenger compartment. A few parts in this section are the floor pan, roof panel, Cowl doors, door pillars, glass and related parts. The centre section is nicknamed the green house because it is surrounded by glass.

The rear section commonly consists of the rear quarter panels, trunk or rear floor pan, rear frame rails, rear bumper also called the cathouse. It is often sectioned of a salvage vehicle to repair severe rear impact damage.

The monocoque chassis design is mainly used in sports cars and race cars. Monocoque is a single shell car construction the monocoque structure gets its strength from entire external body. This stands in contrast to a body on frame design in which ladder frame underneath provides most of the strength and a non-structural body is just bolted on top of it.

The monocoque chassis designs are rare in road cars today monocoque body extremely light weight built with carbon fiber, aluminum it is ideal for super or hyper cars, that need to go as fast as possible, this type of body have supervisor torsional rigidity which improves handling the monocoque body

Steering system

Objectives: At the end of this lesson you shall be able to
- **state the functions of the steering system**
- **state the ackerman geometry of steering mechanism**
- **describe steering linkages**

Function

The main function of the steering system is to convert the rotary motion of the steering wheel into angular motion of the front wheels to negotiate a turn.

The other functions of steering system are as follows.

- To turn the vehicle whenever required.
- To provide stability to the vehicle on road.
- To provide true rolling motion of the wheels at all times.
- To provide self-centering action after negotiating a turn.
- To minimize tyre wear.
- To multiply the driver's effort to turn the vehicle for easy operation.
- To prevent road shocks reaching the driver.

Steering mechanisms

Two types of steering mechanism are used.

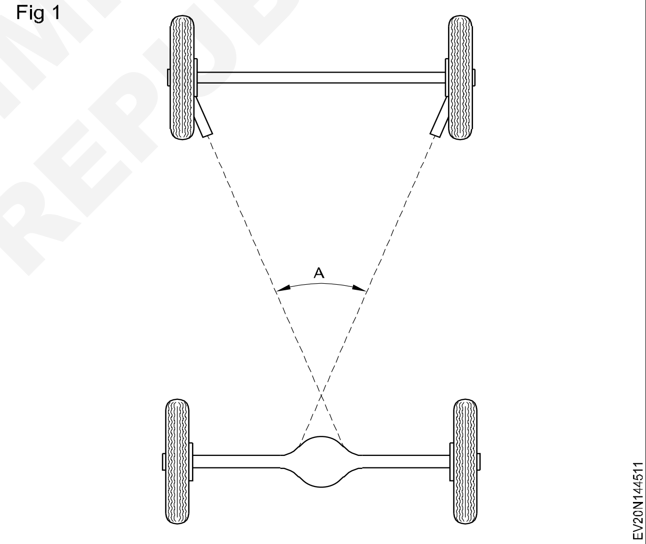
- Ackerman steering mechanism.
- Davis steering mechanism.

Only Ackermen steering mechanism is used in vehicles nowadays because of its simplicity and less wear of the parts.

Ackerman steering mechanism

To avoid skidding of tyres when the vehicle is negotiating a turn (Fig 2), it is necessary that all the wheels turn on an arc which has a common centre (4). The inner wheel turns at a larger angle (3) than that of (2) of the outer wheel. When the front wheels are in the straight ahead

Fig 1

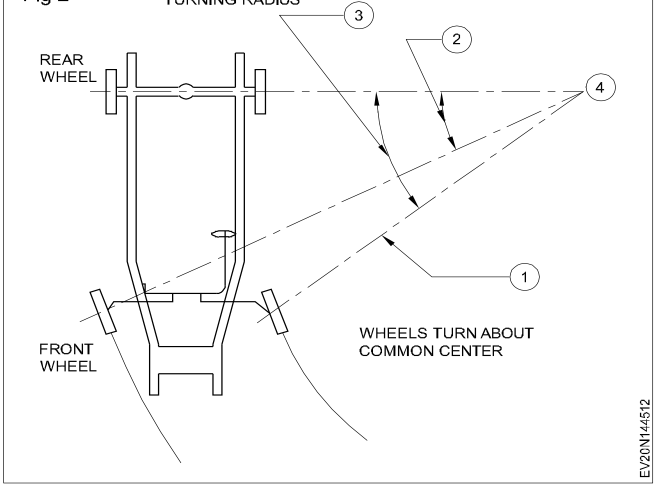


position and lines are drawn through the kingpin's centre and the steering arm's end, they will meet at a point at the centre of the rear axle just ahead of the differential. The included angle is called Ackermen angle (A) (Fig 1). The Ackermen steering results in different angles, through which the front wheels turn. This is achieved by setting the steering arms not exactly at right angle with the spindle body. Steering arms are slanted slightly towards the centre of the vehicle to get the Ackerman angle.

Principles of steering

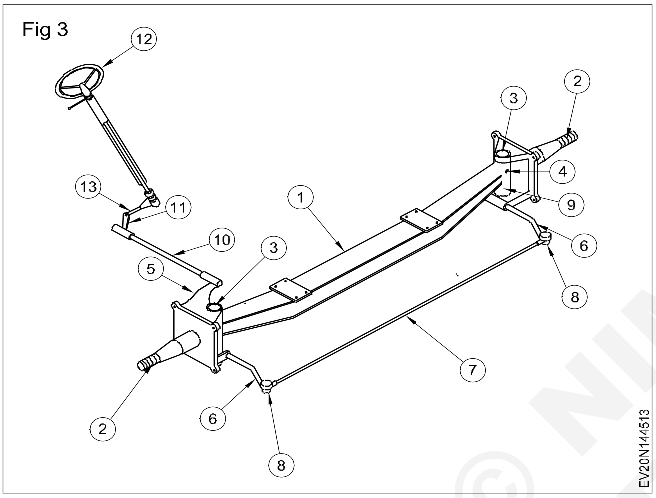
The steering system along with the suspension system, allow the driver to safely and easily control the vehicle's direction while driving/

Fig 2



Steering linkages (Fig 3)

Fig 3



When the steering wheel (12) is turned its motion is carried to the steering box through the steering cross-shaft (13). In the steering box this motion is converted into angular motion of the drop arm (11) which is connected to the drag link rod (10). The drag link rod's (10) other end is connected to the steering lever arm (5). The steering lever arm (5) is connected to the stub axle spindle(2). At the lower end of the stub axle, the spindle steering arm (6) is fitted. Both the steering arms (6) are connected by a track rod (7). When the steering wheel is rotated the drop arm (11) moves towards or away from the front wheel depending upon the direction of turn (right or left).

For example if the vehicle is to be turned to the right side the steering wheel is rotated clockwise. The drop arm (11) is pushed towards the front wheel, which forces the stub axle (2) spindle to turn right through the drag link rod (10) and the steering lever arm (5). The reverse will happen when the vehicle is turned left.

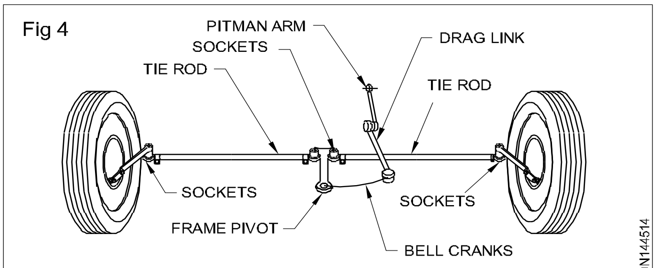
Different types of steering linkages (Figs 4-9)

Following types of steering linkages are used.

General arrangement of steering system

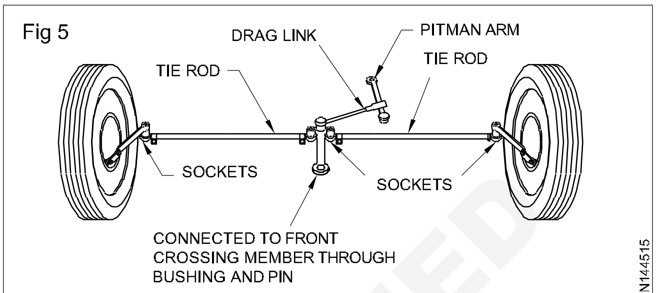
The arrangement of steering linkage depends upon the type of the vehicle and also with the location of the steering gear car in relation to the front wheels.

Fig 4



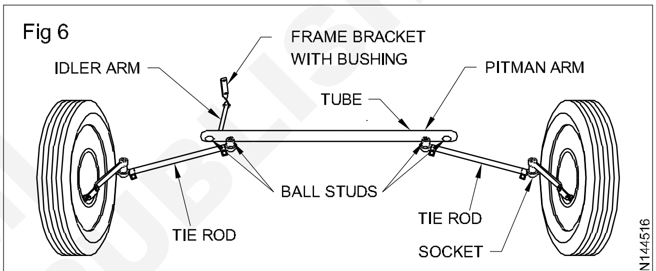
(a) CENTER-ARM STEERING WITH BELL CRANK INTERMEDIATE ARM

Fig 5



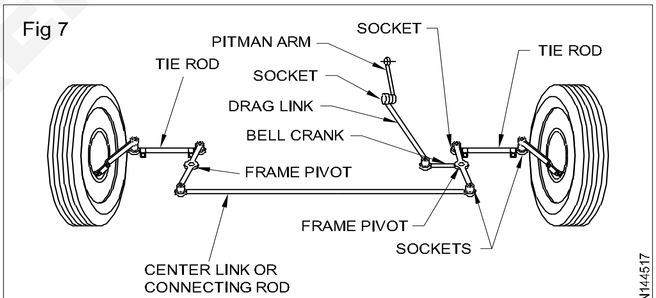
(b) CENTER-ARM STEERING WITH TRANSVERSE DRAG LINK

Fig 6



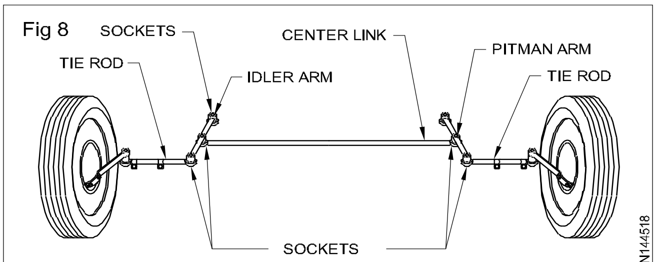
(c) PARALLELOGRAM LINKAGE WITH TUBULAR CENTRE LINK

Fig 7



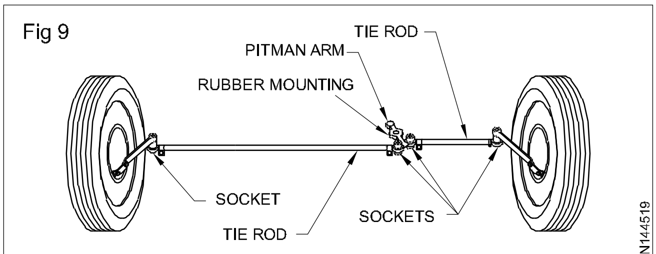
(d) PARALLELOGRAM LINKAGE WITH CENTER LINK AHEAD OF AXLE

Fig 8



(e) PARALLELOGRAM LINKAGE WITH CENTRE LINK BEHIND OF AXLE

Fig 9



(f) LONG-ARM, SHORT-ARM LINKAGE

Steering columns

The steering column is always at an inclination to vertical for comfort in driving. In fact, the driver comfort and the location of the steering gear bore on the classis frame. Due to this two factors, the inclination of column is about 20° in commercial vehicles and 50° in motor cars and upto 70° in sports car. The steering wheel is connected to the steering linkages to turn the front wheels with great effort.

Steering gear box

Objectives: At the end of this lesson you shall be able to
- **state the various types of steering gear boxes**
- **state the maintenance of the various steering gear box.**

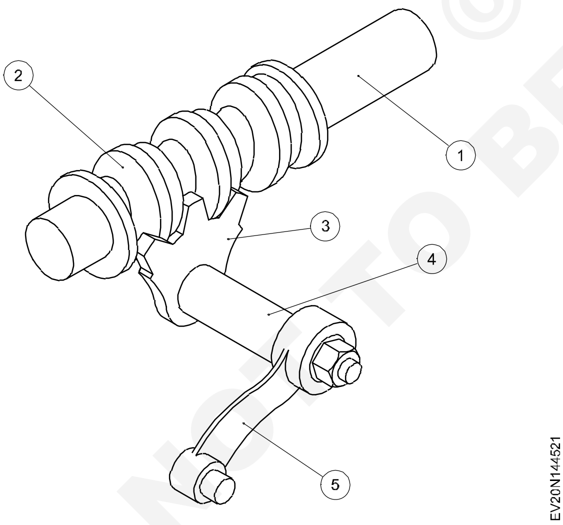
The following types of steering boxes are used.

- Worm and sector
- Worm and wheel
- Worm and nut
- Worm and roller
- Worm and recirculating ball and nut
- Rack and pinion

Worm and sector type (Fig 1)

The steering gearbox consists of the steering shaft (1) fitted with a worm (2) at one end. The worm (2) is in mesh with the sector (3). When the steering wheel is rotated, its motion is transmitted to the sector (3), through the worm (2). The sector (3) rotates at a certain angle. The sector shaft (3) in turn rotates a cross-shaft (4) which is connected to the drop arm (5). This angular movement is transmitted to the front wheels through the linkages to turn the vehicle.

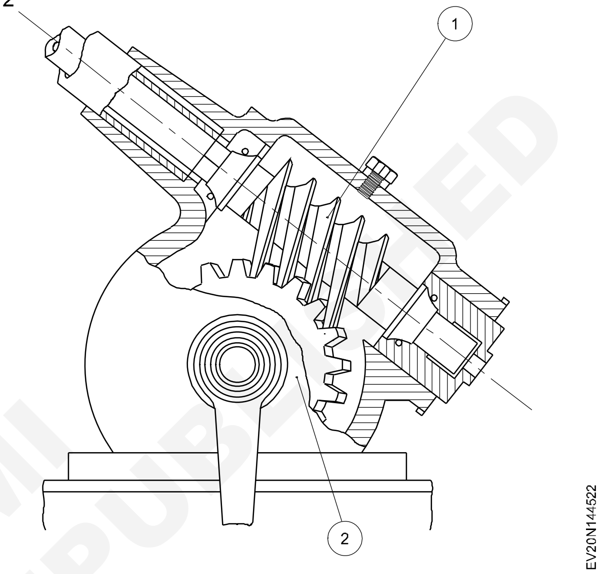
Fig 1



Worm and wheel type (Fig 2)

In this type a complete gear (2) is used instead of a sector. The worm (1) and gear (2) can be rotated to a new position as the sector portion wears out faster on use.

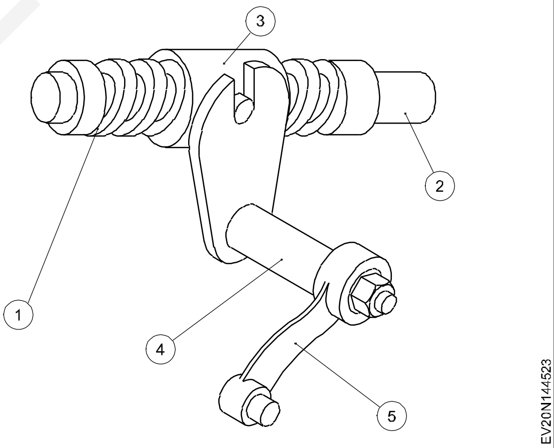
Fig 2



Worm and nut type (Fig 3)

In this type the worm (1) is an integral part of the steering column (2). When the steering column (2) rotates the worm (1) also rotates. The worm (1) is in mesh with the nut (3). When the worm rotates the nut (3) moves up and down on column (2). This enables the cross-shaft (4) to rotate in an arc. This in turn rotates the drop arm (5) in an arc. This movement is transmitted to the front wheels to turn the vehicle.

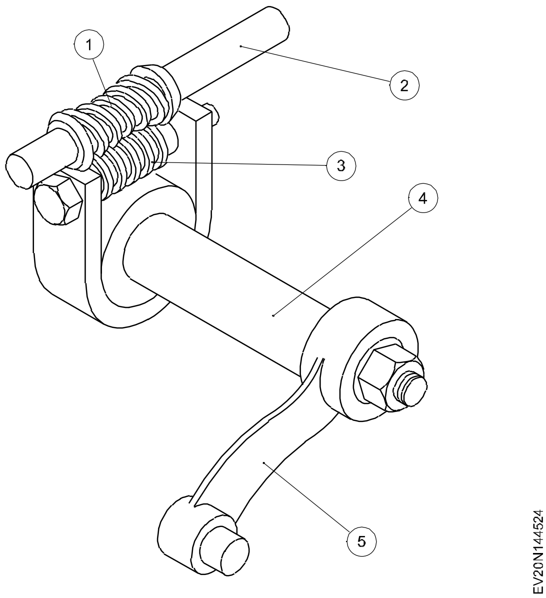
Fig 3



Worm and roller type (Fig 4)

The worm (1) is at the end of the steering column (2). The diameter of the worm (1) is more at its ends. Its diameter is gradually reduced at the centre. This enables the roller (3) to keep the contact with the worm (1) at all the positions. It also provides a variable ratio to permit faster and efficient steering. The roller (3) is mounted on the cross-shaft (4). The cross-shaft (4) is fitted to the drop arm (5). When the steering wheel is rotated, the column (2) also rotates along with the worm (1), which allows the roller (3) to rotate in an arc. This makes the cross-shaft (4) and drop arm (5) to move in an arc, which in turn moves the front wheels to the left or right through the linkages.

Fig 4



Worm and recirculating ball and nut type (Fig 5 & 6)

The worm (1) is at the end of the steering column (2). A ball nut (4) is fixed on the worm (1). Several balls (3) circulate in between the ball nut (4) and the worm (1). This reduces friction between the worm (1) and nut (4). A sector (5) is in mesh with the ball nut (4). When the steering wheel is rotated the steering column (2) also rotates and the ball nut (4) moves downward or upward on the worm (1). This makes the sector (5), cross-shaft (6) and drop arm (7) to move in an arc. This movement is transmitted to the front wheels to turn the vehicle.

Fig 5

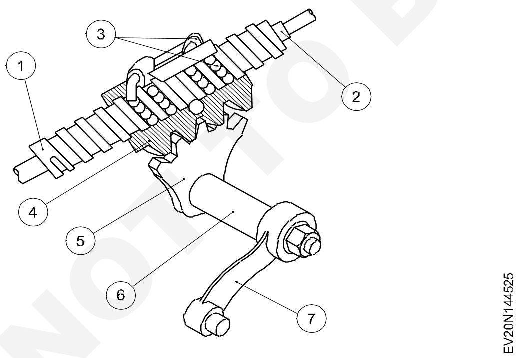
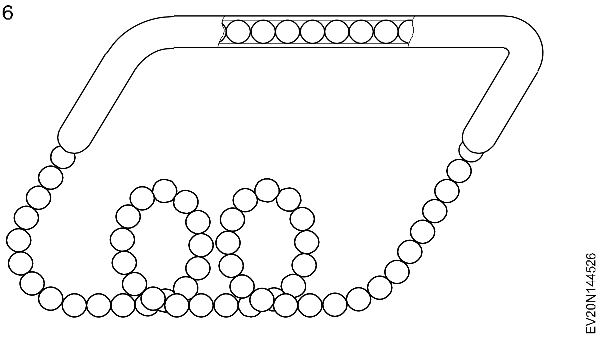


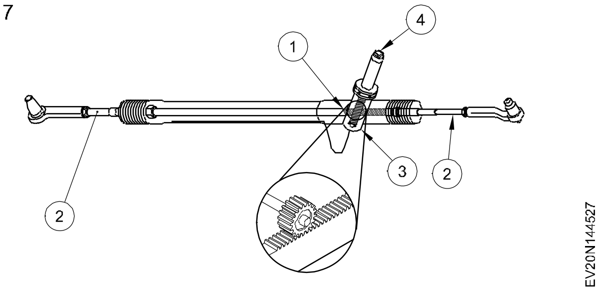
Fig 6



Arrangement of balls is shown in Fig 6. During overall always count the number of balls and ensure that the correct quantity is inserted. Lesser quantity of ball will affect the response from steering.

Rack and pinion type (Fig 7)

Fig 7



In this type a rack (1) is either connected or made part of a divided track-rod (2). The pinion (3) is attached to the steering column (4). The pinion (3) always remains in mesh with the rack (1). When the steering wheel is rotated the pinion (3) also rotates and the rack (1) moves left or right, causing the wheels to turn.

Helix gear

Helical gears are one type of cylindrical gears with slanted tooth face compared to spur gears, they have the larger contact area and excel in quiteness and less vibration and able to transmit large force a pair of helical gears has the same helix angle but the helix hand is opposite.

Maintenance of steering components

Fill oil upto the recommended level with the prescribed grade of lubricant. Remove the oil at prescribed intervals. Steering becomes hard in the absence of lubrication. After same run, the mating parts wear out, increasing the play this leads to steering noise & vibration.

The drop arm nut is to be tightened to a prescribed toque.

Drop arm and rocker shaft is to be fixed only at a prescribed position. It can be assembled only in one way. Otherwise make punch marks in both rocker shaft and drop arm at the time of removal.

'O' rings, seals, used in steering box are to be renewed during over haul or renewed in case of oil leaks.

Universal joints (single or double) are provided at the end of steering column, to provide

i Comfortable steering angle as per design

ii Absorb road shocks, which is not transmitted to drivers hand.

Backlash between mating gears are specified based on design. Rocker shaft end plays are specified by the supplier and the same is to be adjusted. Bearing preload is to be done during assembly of steering.

Helix's new steering box uses state of art CAD/CAM technology to ensure the quickest and smoothest steering on the market.

Power steering

Objectives: At the end of this lesson you shall be able to
- **state the need of power steering**
- **state the benefits of power steering**
- **state the types of power steering**
- **state the features of power steering**
- **state the construction of fully integral power steering**
- **state the operation of power steering**
- **state the shock absorption by power steering**
- **explain flow control valve of power steering**
- **briefly explain on pressure relief valve.**

Need for power steering

The need to achieve the greatest possible road safety under

- Increasing traffic density
- High axle loads
- Poor road conditions

Led to the development of power steering.

Benefits of power steering

- Effortless steering - reducing drivers fatigue
- Quick response - power assistance is immediate
- Positive road feel to the driver
- Absorbs road shocks
- Greater safety (in case of front tyre burst)
- Steering can be operated manually, in case of loss of power assistance
- Absolute control during driving
- Greater maneuverability

Types of power steering

There are three types of power steering system used in automobiles

1 Integral power steering
2 Linkage power steering
3 Electronic power steering

Fully integral power steering gear (Fig 1)

Salient features of power steering gear

Rotary valve

This device provides responsive steering control

Unloading valves

Furnish power steering pump protection and reduce pressure to unload steering linkage at the ends of steering gear travel.

Recirculating balls

Combines high mechanical efficiency with smooth operation.

Torsion bar

Provides positive valve centering with ultimate feel of the road.

Balanced area cylinder

Back pressures cannot affect steering stability.

Manual steering capability

Provides for steering control in the event of hydraulic failure

Construction

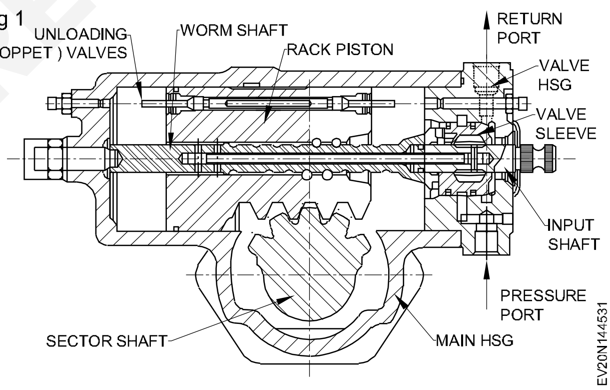
The fully integral power steering gear consists of

- A manual steering mechanism (Re circulating ball & nut type)
- Hydraulic power cylinder and piston
- A rotary control valve.

In a single compact package.

Normal operation (Fig 1)

Fig 1



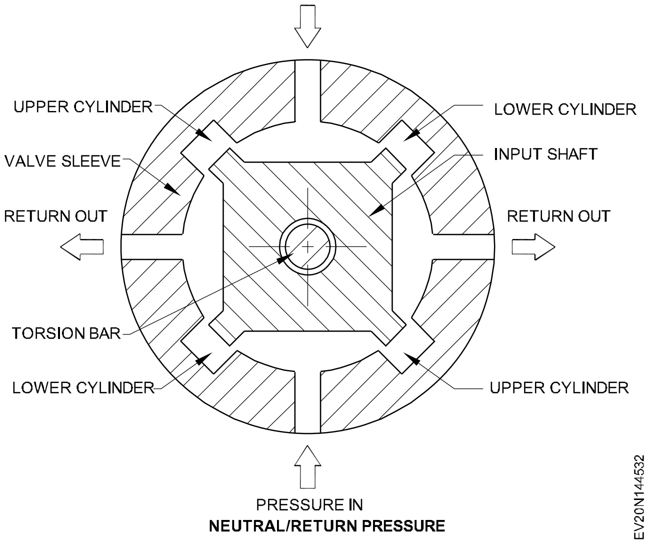
When the driver turns the steering wheel, he activates the steering gear input shaft. A torsion bar pinned at its one end to the input shaft and the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to this rotational force the worm shaft acting through the re-circulation ball mechanism, tries to move the rack piston axially through the gear housing cylinder bore.

Hydraulic power assistance

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is connected by linkage to the steered wheels. Because of this resistance, the torsion bar is twisted by the input shaft, thereby actuating the control valve. Pressurised fluid directed by the control valve assists in moving the rack piston axially through the cylinder bore. The rack piston then turns the sector shaft to steer the vehicle to the desired direction.

Neutral condition (Fig 2)

Fig 2

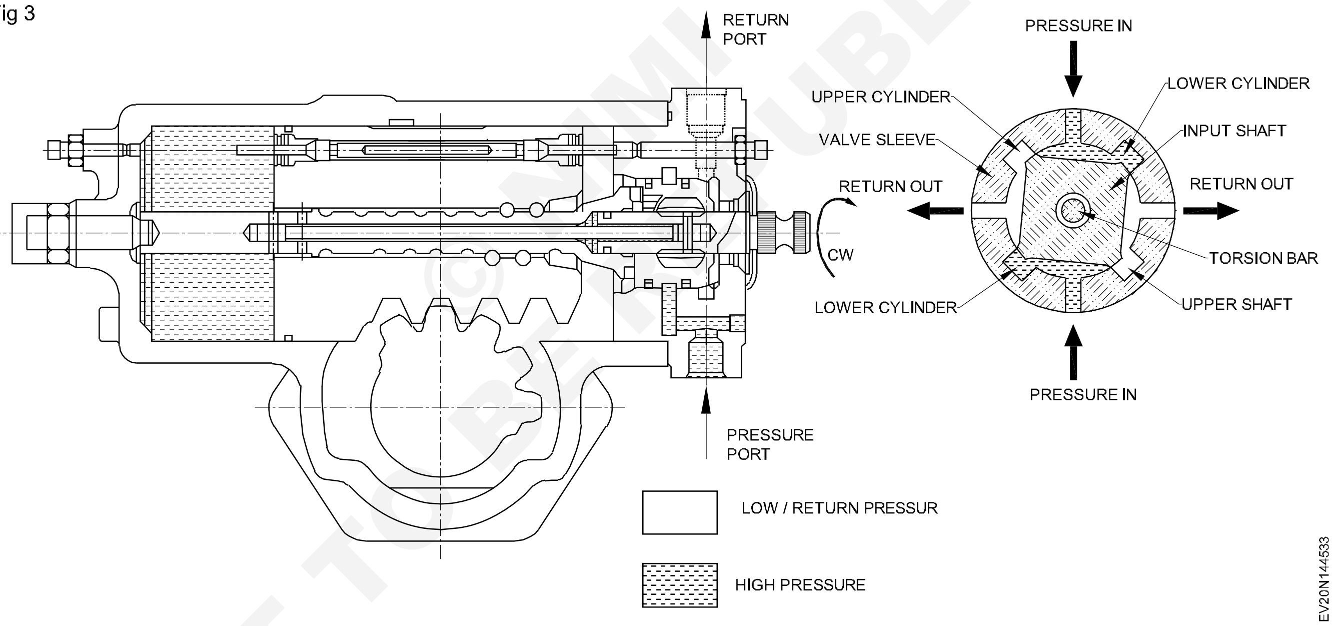


The rotary control valve mechanism, which is the heart of power steering system comprises of input shaft, worm shaft, torsion bar and valve sleeve. When all these components assembled together this becomes "valve assembly". The input shaft has four lands and the valve sleeve has four pockets assembled in neutral condition. The valve sleeve has keyed connection with the worm shaft. The diagonally opposite pockets connect the oil to the lower or upper cylinder. Always the valve will be in neutral condition. In this condition the oil flows to both sides of the cylinder and return back to the reservoir.

Right turn (Fig 3)

When the driver rotates the input shaft to the right through the steering wheel. Because of the road resistance the torsion bar gets twisted and the input shaft alone will twist to the right and disturbs the valve neutral position, thereby causing all the oil to flow to the lower cylinder and pushes the rack piston towards top. Once the driver stops rotating the steering wheel the torsion bar will gain its original position, as the worm shaft rotates and bring back the valve sleeve to the neutral position.

Fig 3



Left turn (Fig 4)

When the driver rotates the input shaft to the left through the steering wheel. Because of the road resistance the torsion bar gets twisted and the input shaft alone will rotate to the left and disturbs the valve neutral position, thereby causing all the oil to flow to the upper cylinder and pushes the rack piston towards bottom. Once the driver stops rotating the steering wheel the torsion bar gain its original position, as the worm shaft rotates and bring back the valve sleeve to the neutral position.

Shock absorption

Valve in shock absorption (Fig 4)

In general during the turns the driver disturbs the valve neutral position, causing the oil to flow to the respective cylinder. During shock absorption the road shocks force the worm shaft to rotate causing the valve sleeve to move from neutral condition, thereby causing the neutral condition disturbed and the oil flow on the opposite side resisting the Rack piston's movement, thus the oil absorbs all the road shocks and prevent shocks getting transmitted to the driver.

Flow control valve (Fig 5)

Function

The flow control valve controls the rate of flow within the power steering circuit. This is because, since the discharge rate per oil pump revolution (characteristic discharge rate) is constant, the discharge rate per unit time increases and decreases in proportion to the engine speed. To maintain uniform performance, the power steering requires a flow rate that remains within certain fixed range. The flow rate required by power steering is determined by the speed at which steering wheel is tuned, but must be such that power steering can respond at higher speeds. Consequently when the oil pump discharge rate exceeds a certain value in respective to the engine speed increase, the excess flow escapes to the interior of the pump or the reservoir so that the hydraulic fluid is always supplied to the system at the required rate.

Fig 4

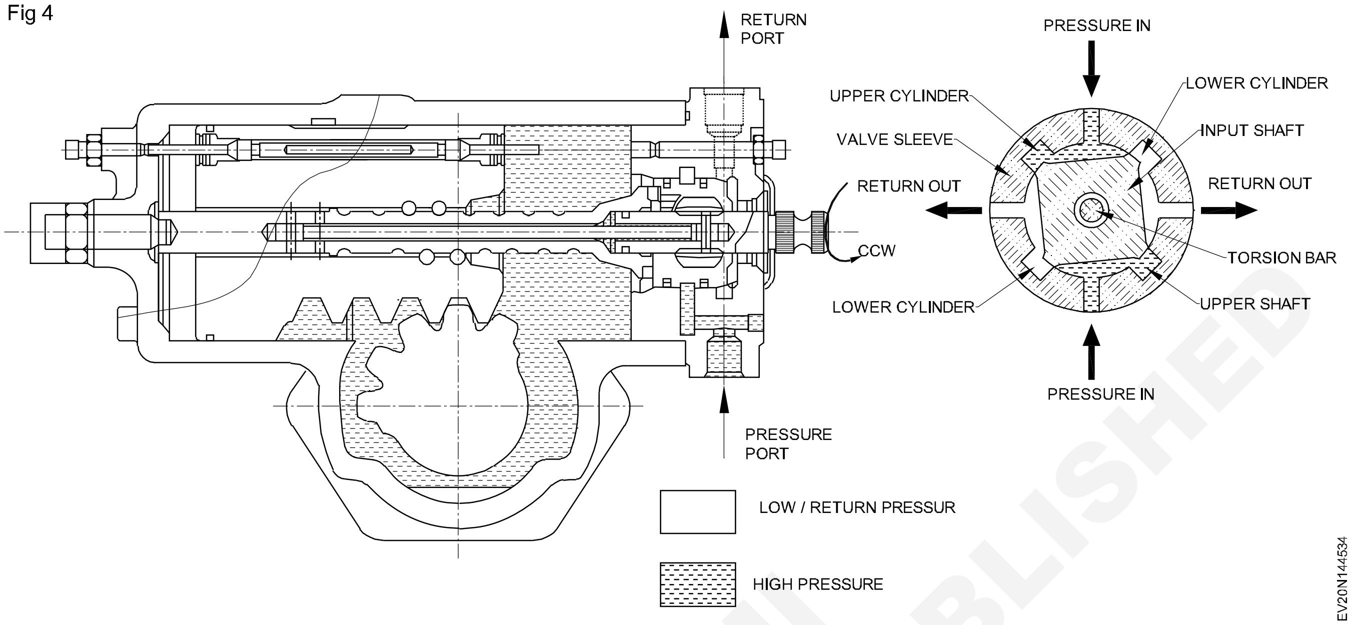
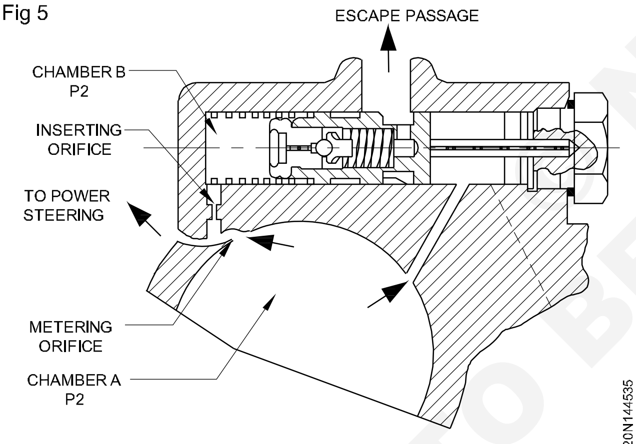
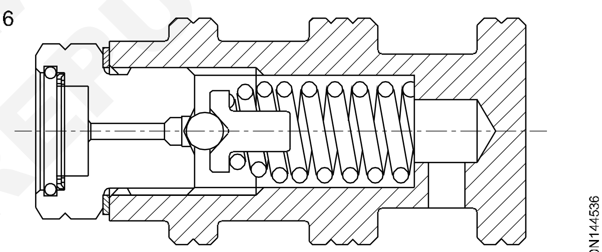


Fig 5



FLOW CONTROL VALVE

Fig 6



PRESSURE RELIEF VALVE

Operation

The hydraulic fluid discharged by the oil pump enters the pressure chamber, from it passes through the metering orifice to power steering chamber. When the pump discharge rate is lower than the adjustment flow rate, the fluid pressure differential between the chambers, movement of the flow control valve is prevented by the pressure of the spring and all of the fluid from the oil pump supplied to the power steering gear box.

The oil pump speed increases together with the engine speed, which increases the hydraulic fluid rate. When the discharge rate exceeds the adjustment flow rate (spring force) the spring is deformed from its original position and the flow control valve will move in and the excess oil will bypass to the suction line.

Pressure relief valve (Fig 6)

Function

The pressure relief valve controls the maximum pressure in the power steering circuit. That is the load on the oil pump is directly proportional to the steering wheel resistance. When steering wheel resistance is high, the hydraulic pressure required for power steering is also high and vice versa. Whenever the road wheels contact an obstacle or wheel stopper, which requires additional force to steer the wheel, the pressure will increase infinitely. Therefore a mechanism is required to prevent excessive force being applied and to protect the steering mechanism.

Operation

The pressure relief valve is built into the flow control valve. When the steering wheel is not being operated and during normal steering wheel operation the operating pressure will never raise above the adjustment pressure. Therefore the relief valve and the steel ball are seated by the force of the spring to close the passage.

The steering wheel is turned fully, therefore the power steering valve remains closed. In this state the hydraulic fluid from the oil pump is under pressure and the pressure exceeds the force of the spring, the relief valve and steel ball are lifted from its seat causing the oil to bypass to the suction side of the pump.

Trouble shooting

Noise in steering - Presence of air in the fluid will make it noisy and spongy (not responding) low fluid level also lead to noisy operation and unresponsive steering.

The remedy is to fill fluid upto the level and bleed the system to remove air.

Electronic power steering

Objectives: At the end of this lesson you shall be able to
- **state the working principle of electronic power steering.**

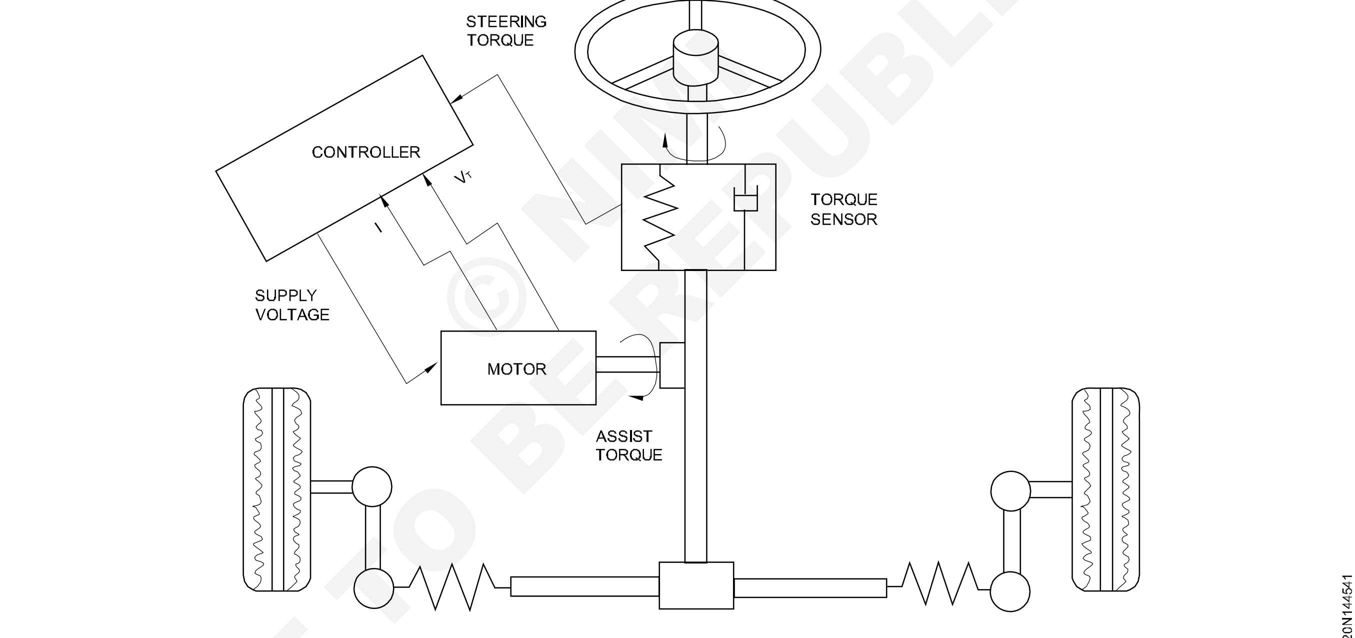
Electronic power steering (Fig 1)

There is a provision to protect the electric motor from being overloaded and also from the voltages surges from a faulty alternator or charging problem.

The electronic steering control unit is capable of self-diagnosing faults by monitoring the system's inputs and outputs and the driving current of the electric motor. In case of a problem, the control unit turns off the entire system by actuating a fail-safe relay in the power unit, the system reverts back to manual steering and warning light on the dashboard alerts the driver.

An electronic power steering has the following advantages over the hydraulic power steering, due to which it is being increasingly used in modern cars:

Fig 1

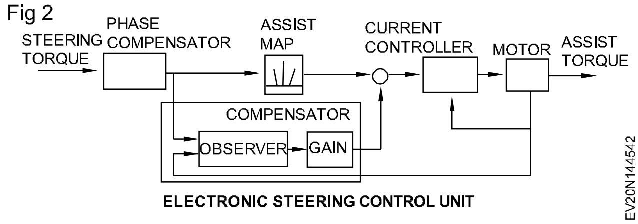


ELECTRONIC POWER STEERING SYSTEM

1 No problem of leakage of fluid.
2 Energy being consumed only while steering.
3 Steering assistance available even when the engine is not running.
4 While steering manually lesser force is required compared to a hydraulic system since there is no fluid to forced through valves.

In an electronic power steering system (Fig 2), steering sensor consisting of in fact two sensors, viz, a 'torque sensor' that converts the steering torque input and its direction into voltage signals, and a 'rotation sensor' that converts the rotation speed and direction into voltage signals, is located on the input shaft of the steering-gear box.

Fig 2



ELECTRONIC STEERING CONTROL UNIT

Inputs from the steering sensor and the vehicle speed sensor are fed to a microprocessor control unit where these are compared with a preprogrammed force assist map. The control unit then sends out the appropriate command signal to the current controller which supplies the appropriate current to the electric motor. The motor pushes the rack to the right or left depending on in which direction the current flows. Increasing the current to the motor increases the amount of power assist.

Wheel alignment (Wheel geometry)

Objectives: At the end of this lesson you shall be able to
- **state the purpose of wheel alignment**
- **state the camber and castor angle**
- **state the purpose of kingpin inclination and included angle**
- **state the purpose of the toe-in/toe-out**
- **state the steering ratio**
- **state the combined angles and scrub radius**
- **state the thrust angle.**

Purpose of wheel alignment

Wheel alignment is positioning of the front wheel and steering mechanism to

– minimize tyre wear

– reduce the driver's effort to turn the vehicle

– achieve self-centering after turning

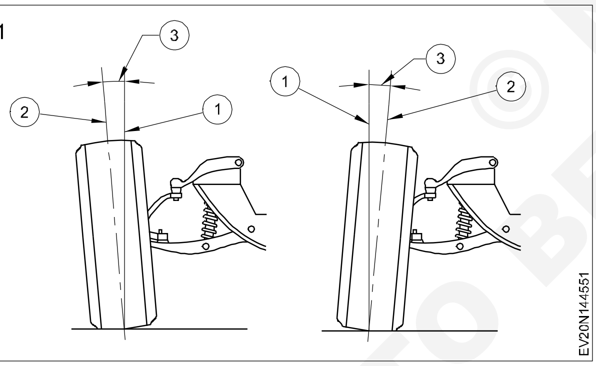
– achieve directional stability of the vehicle while running straight ahead.

Front wheel alignment depends upon the following.

- Camber
- Castor
- Kingpin inclination
- Toe-in and Toe-out

Camber (Fig 1)

Fig 1



The angle between the vertical line (1) from the central point of the tyre and the central line (2) of the tyre is known as camber angle (3). When the wheels are tilted outward at the top it is called positive camber, and if tilted inward at the top, it is called negative camber. Equal camber angle is provided on both the front wheels. With the positive camber wheels become vertical under load the tyre will have full contact with the road. If the positive camber is excessive then the tyre's outer edge will wear out faster. If the negative camber is excessive the tyre's inner edge will wear out faster. Unequal camber on both the front wheels will result in wheel shimming at low speed (abnormal vibration).

Factors affecting camber

- Hub bearing play
- Kingpin bush wear
- Kingpin end play
- Front axle bend/twist

Castor angle (Figs 2 & 3)

Fig 2

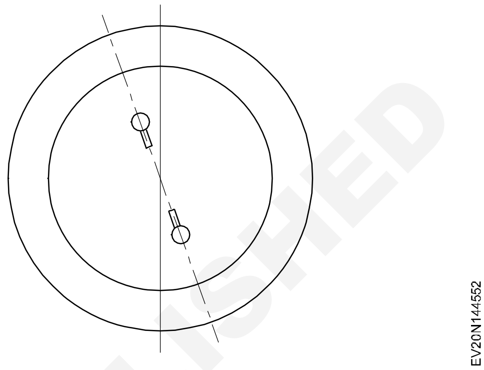
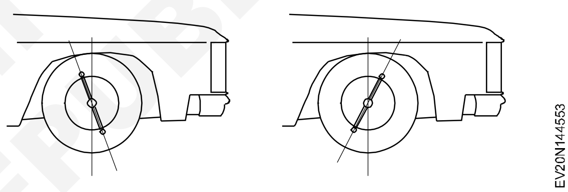


Fig 3



The castor angle is the angle formed by the forward or backward tilt of the steering axis from vertical, when viewed from the side of the wheel. A backward tilt is known as positive castor and a forward tilt is known as negative castor. If castor is not equal on both the sides it will cause the vehicle to pull to the side of the wheel having lesser castor angle.

Purpose of castor

- To maintain directional stability and control.
- To increase steering stability.
- To reduce the driver's effort to turn the vehicle.

Maintenance of steering components

Fill oil upto the recommended level with the prescribed grade of lubricant. Remove the oil at prescribed intervals. Steering becomes hard in the absence of lubrication. After same run, the mating parts wear out, increasing the play this leads to steering noise & vibration.

The drop arm nut is to be tightened to a prescribed torque.

Drop arm and rocker shaft is to be fixed only at a prescribed position. Many manufactures, make it 'idiot proofing'. so that it can be assembled only in one way. Otherwise make punch marks in both rocker shaft and drop arm at the time of removal.

'O' rings, seals, used in steering box are to be renewed during over haul or renewed incase of oil leaks.

Universal joints (single or double) are provided at the end of steering column, to provide

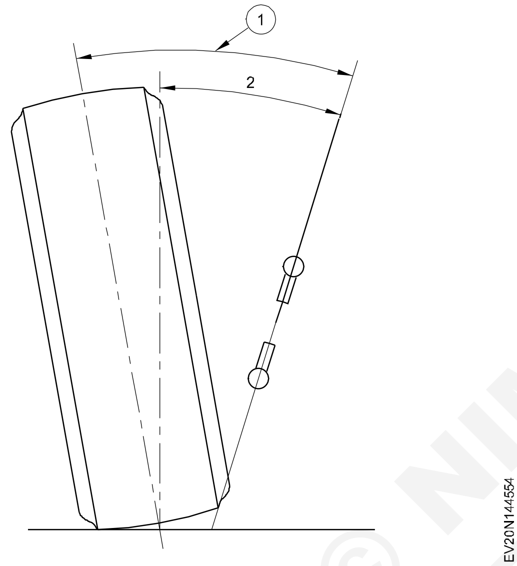
i comfortable steering angle as per design

ii absorb road shocks, which is not transmitted to drivers hand.

Backlash between mating gears are specified based on design. Cross shaft end plays are specified by the supplier and the same is to be adjusted. Bearing preload is to be done during assembly of steering.

Kingpin inclination (Fig 4)

Fig 4



King pins are mounted in such a way that they tilt inward. The angle between the centre line of the kingpin and the vertical line is called kingpin inclination (2) (Fig 4).

Purpose of kingpin inclination

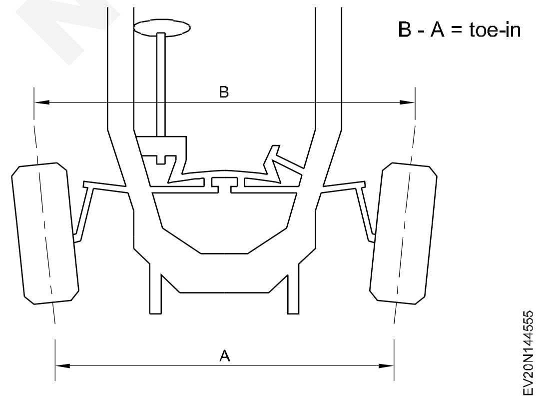
- It provides directional stability along with the castor angle.
- It helps in self-centering of wheels after negotiating a turn.

Included angle

It is the angle (1) in the vertical plane between the kingpin axis and the wheel centre line.

Toe-in and toe-out (Fig 5)

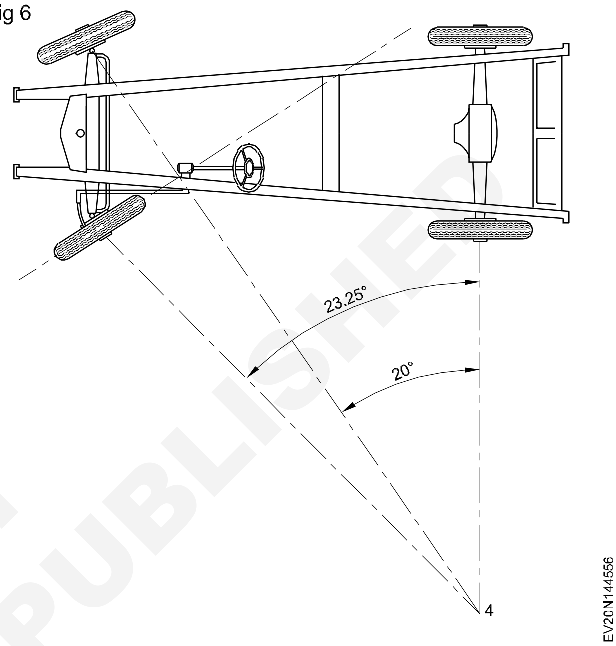
Fig 5



When viewed from the top, if the front wheels are inclined inward at the front it is called toe-in. When vehicle runs wheels tend to shift outward. An initial toe-in keeps the wheels straight ahead. If wheels are inclined outward at front it is called toe-out. Incorrect toe-in causes abnormal tyre wear, tyre slip and poor steering stability. The toe-in varies for different makes of vehicles. A few vehicles do not have any toe-in.

Toe-out on turns (Fig 6)

Fig 6



It is the difference between the two angles formed by the two front wheels on turn. The inner wheel follows the radius of a smaller circle than the outer wheel. Therefore the inner wheel must toe-out more to prevent tyre side slip and excessive wear. This is achieved by arranging linkages in such a way that the inner wheel toes-out more than the outer wheel on turns.

Steering ratio

It refers to the number of turns on the steering wheel required to produce one turn of the steering - gear cross shaft. It is done by the pitman arm. This steering ratio ranges from 11:1 to 24:1 in passenger cars having no power steering. A variable reduction ratio on steering gears is obtained by varying the pitch of the worm or cam. It is higher for the straight-ahead range and lower for the outer ranges.

The steering gear ratio is defined as the ratio between the number of degrees of rotation of the steering wheel and number of degrees through which the cross shaft is free to rotate at the same time. Higher steering gear ratio gives slow steering and fast steering is obtained by lower steering gear ratio. Vehicles connected with power steering have average steering gear ratios of 20 percent less than vehicles with manual steering.

Overall steering ratio

As the steering linkage gives a mechanical advantage or leverage, the front wheels will turn through a smaller angle than the cross or sector shaft. The number of degrees through which the steering wheel is turned is divided into the number of degrees that the front wheels turn. It is known as overall steering ratio. The ratio varies from 15 to 20 percent higher than the steering - gear ratio in both manual and power steering.

In other words, the ratio of the output force to the input force applied is known as steering ratio. A small applied force produces a much greater force at the other end of the device. Actual steering ratio varies mainly dependent on the type of vehicle and the type of operation. Many cars with manual steering use steering ratios as high as 28:1 with minimized steering effort.

Some lightweight sports cars use the steering ratios as low as 10:1. High steering ratios are called slow steering because the steering wheel has to be turned many degrees to obtain a small steering effect. Low steering ratios is called fast or quick steering because steering wheel has to be turned to obtain a large steering effect.

Steering ratio is determined by two factors:

1 Steering - linkage ratio, and

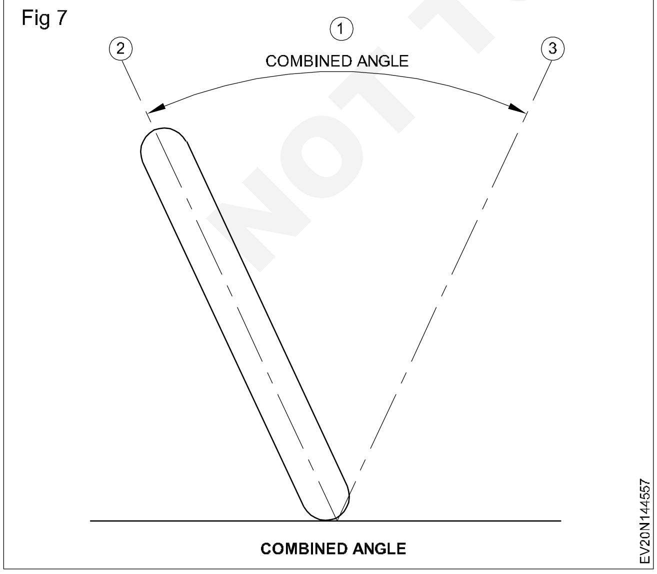
2 Gear ratio in the steering gear

The steering linkage ratio is determined by the relative length of the pitman arm and the steering arm. If the effective lengths of the pitman arm and the steering arm are equal, the linkage has a ratio of 1:1. If the pitman arm is shorter than the steering arm, the linkage ratio will be less than 1:1. For example, the pitman arm is about twice as long as the steering arm. This means that for every degree the pitman arm swings, the wheels will pivot about 2 degrees. Therefore, the steering-linkage ratio is about 1:2.

In the case of a rack-and pinion steering system, the steering ratio is determined largely by the diameter of the pinion gear. This steering ratio ranges from 14:1 to 24:1 in passenger cars without power steering.

Combined angle and scrub radius (Fig 7)

Fig 7



Combined angle or included angle (1) is the angle between the vertical plane of the wheel centre line (2) and the king pin centre line (3) called steering axis.

Combined angle is the sum of camber and king pin inclination called steering axis inclination. In a rear - wheel drive vehicle, the suspension cross member is pushed by the tractive force of the vehicle and the body is made to move forward during drive. The road resistance acts on the wheel at the contact point on the road. The distance acts on the wheel at the contact point on the road. The distance between the two points is known as scrub radius. When the tyre centre line lies outside the steering axis, this radius will be positive as shown in Fig 7.

It will be negative when the tyre centre line lies inside the steering axis. It is always referred in mm. This radius is mainly dependent upon the steering axis inclination, the wheel offset and suspension height. In the case of front wheel drive vehicle, the tractive force is acted on the front wheels at the contact point on the road. It is reversed in the case of rear-wheel drive.

Effect of combined angle

The effect of combined angle variation on the scrub radius. If the scrub radius is not equal to zero, a torque acted on the wheel turns away from the straight ahead position.

Effect of scrub radius

i When the scrub radius is negative, the wheel is caused to toe-in

ii When the scrub radius is positive, the wheel is caused to toe-out

iii When the scrub radius becomes zero, the wheel is kept in straight position without any toe-in or toe-out. This position is known as centre point steering. In case the centre point steering is implemented, any small change in the combined angle will cause to the point of intersection alternately above and below the ground. Thus, toe-in or toe-out is caused. A large scrub radius will cause greater torque required to turn the wheel. This means, higher loads on the steering linkage and suspension components act. It results in greater wear of steering linkage and unequal braking on the front wheels.

The scrub radius is the parameter to provide necessary road feel to the driver. The recommended value of combined angle is from 9-10° and the scrub radius should be upto about 12mm.

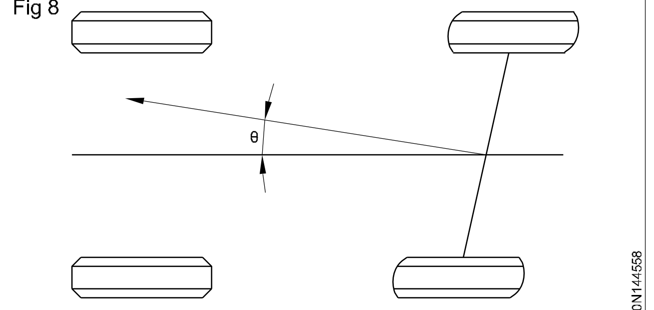
Thrust angle (Fig 8)

Thrust angle is the direction that the rear wheels are pointing in relation Fig 8 to the centerline of the vehicle. The vehicle will "dog track" (goes slightly outwards) down the road if the thrust angle is not zero and the steering wheel will not be centered.

Turning Radius

It is the radius of circle on which the out side wheel moves when the front wheels are turned to their extreme outer position. The radius is 5 to 7.5 meters for buses and trucks. The turning radius is usually proportional to the wheel base of the car, because the maximum rotation of the steering knucled is seldom more than 35 degrees.

Fig 8

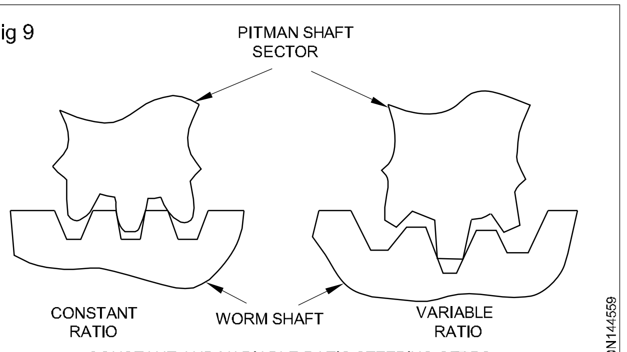


THRUST ANGLE

Variable steering ratio

The number of input turns per output turn of the steering gearbox is called the gearbox ratio. steering gears can have a constant or a variable ratio. The sector teeth in a constant ratio unit are identical in size and shape, while the sector of a variable ratio unit has larger center teeth Fig 9. This makes the steering faster in turns than in a straight direction. Variable ratio is normally used only in power-steering units.

Fig 9



CONSTANT AND VARIABLE RATIO STEERING GEARS

Electric Vehicle suspension, brake system and EV body engineering

Objectives:- At the end of this lesson you shall be able to
- **State the function of suspension system**
- **State the basic suspension movements**

Need of suspension system:- While vehicle moving on the road the wheels are thrown up and down due to the unevenness of the vehicle suspension is used to prevent the damage of working parts and also provide riding comfort of the vehicle. The following reason's vehicle suspension system is provided in a all types of vehicle

- For absorbing shocks and vibration caused due to road regularities
- For transmitting vehicle load to the wheels
- For maintaining the stability of the vehicle
- For providing cushioning and ride comfort to the passengers
- For preventing body shocks

Functions of suspension system:-

- it safe guard passengers and goods against road shocks
- it preserve the stability of vehicle while in motion (pitching or rolling)
- it provide the wheels always in contact with road while driving cornering and braking
- it helps to maintain proper steering geometry
- it allow rapid cornering without extreme body roll
- it prevent excessive body squat
- it helps to maintain body level
- it gives cushioning effects
- it transfers the braking torque to the chassis

Basic suspension movements: There are three types of suspension movements happen during vehicle movements. They are also as follow

1 Bouncing
2 Pitching
3 Rolling

Bouncing: There vertical movement of the complete body

Pitching: The rotating movement of all the parts between spring and road and portion of spring weight itself

Rolling: The movement about longitudinal axis produced by the centrifugal force during cornering the vehicle

Type of suspension systems

- **Independent suspension systems:** It allows one wheel to move up and down with minimal effects to the other
- **Non independent suspension system**: it has both right and left wheel attached to the same solid axle. When one wheel hit a bump on the road, its upward movement causes a slight tilt of the other wheel.

Unsprung weight and sprung weight

Unsprung weight is largely a function of the design of a vehicle's suspension and the a materials used in the construction of suspension components. Beam axle suspension, in which wheels on opposite sides are connected as a rigid unit, generally have greater unsprung weight than independent suspensions systems, in which the wheels are suspended and allowed to move separately. Heavy components such as the differential can be made part of the sprung weight by connecting them directly to the body Light-weight materials, such as aluminium, plastic, carbon fiber, and hollow components can provide further weight reductions at the expense of greater cost and fragility.

In a ground vehicle with a suspension, the unsprung weight is the mass of the suspension, wheels or tracks (as applicable) and other components directly connected to them rather than supported by the suspension. The mass of the body and other components supported by the suspension is the sprung weight includes the mass of components such as the wheel axles, wheel bearings, wheel hubs, tires and a portion of the weight of drive shafts, springs, shock absorbers, and suspension links. Even if the vehicle's brakes are mounted outboard (i.e., with the wheel), their weight is still considered part of the unsprung weight.

Scooter-type motorcycles use an integrated engine-gear-box-final drive system that pivots as part of the rear suspension and hence is partly unsprung. This arrangement is linked to the use of quite small wheels, further affecting the reputation for road - holding.

Driving uneven surface

If a vehicle is driven over a hump at high speed, the body initially remains balanced due to the large mass. The wheel, with its small mass in relation to the body, it is accelerated upwards very rapidly, and it is compresses the spring. Only the force corresponding to this spring travel is acting on the body.

On the other side of the hub, the wheel is accelerated downwards by the preloaded spring. Only the load relief of the spring corresponding to the bump acts on the body.

If the force the wheel is greater than the initial tension of the spring, the wheel loses adhesion on the road surface for a short time, as the initial spring tension is insufficient to move the wheel downwards quickly enough.

To achieve good driving safety and the best possible confort, the unsprung mass should be as small as possible.

Body vibration frequencies

These can be determined by the vibration at the front or rear of the vehicle. A complete vibration consists of the spring compression and rebound process. The number of vibrations per minute then gives the body-vibration frequency. Vibration dampers do not control the vibration frequency, the amplitude of oscillation is downrated by the greater resistance. In contrast, the mass plays a large part. The heavier the vehicle or the larger the payload, become the lower the vibration frequencies.

Frequency: This is the number of vibrations per second. Since a body does not vibrate very quickly, the number of vibrations is also given per minute (vibration frequency, body-vibration frequency).

A large mass and soft springs result in a low frequency (vibration frequency) and a large spring level.

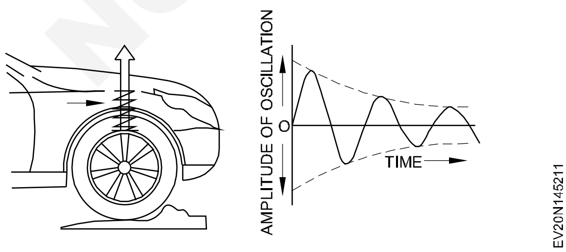
Damping vibration

If the wheel of a motor vehicle travels over an obstacle, both the body and the wheel start to vibrate. The upwards movement of the wheel causes the helical spring to be compressed, the spring force accelerates the body upwards. The spring force generated when the spring expands slows the body down again, the upper reversing point is reached. The body is accelerated downwards by the weight, beyond the rest position. The spring is compressed (tightened), the resulting spring force slows the movement of the body to the lower reversing point.

The travel from the upper to the lower reversing point of a vibration is known as the amplitude of oscillation.

This motion sequence is repeated until the kinetic energy is converted into heat by spring and air friction. (Fig 1)

Fig 1



Location of suspension system

The suspension system is provided in between the axles and chassis frame. There are two type of axles generally used in motor vehicles. They are:

1 **Solid Axle:** A solid axle (also called live axle or beam axle) houses the vehicle differential inside the axle itself connected to the wheels by rigid half shaft.

The entire axle moves as one, so if a left wheel drops into a pot hold, right wheel moves upto response.

2 **Dead Axle:** The axle shaft does not transmit power to the wheels and if it is provided for supporting the wheels and the suspension parts then it is called as dead axle.

suspension components

Leaf springs: Leaf springs were the first type of suspension spring used on automobiles, today they are generally found on light-duty & heavy trucks, vans, and some passenger cars. There are three basic types of leaf springs: multiple leaf, monoleaf and fiber composite.

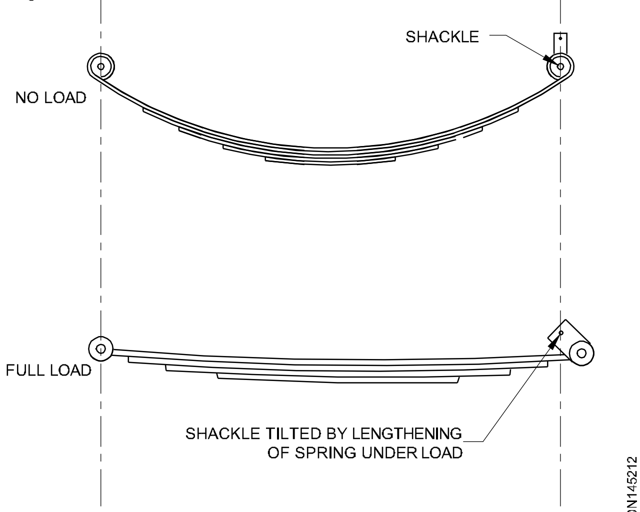
Multiple-Leaf springs: Multiple-leaf springs consist of a series of flat steel leaves that are bundled together and held with clips or by a bolt placed slightly ahead of the center of the bundle. One leaf called the main leaf, runs the entire length of the spring. The next leaf is a little shorter and attached of the main leaf. The next leaf is shorter yet and attaches to the second leaf, and so on. This system allows almost any number of leaves to be used to supported the vehicle's weight. (Fig 2)

Multiple-leaf springs have a curve in them. This curve, if doubled, forms an ellipse. Thus, leaf springs are sometimes called semielliptical or quarter elliptical. The semi or quarter refers to how much of the ellipse the spring actually describes. The vast majority of leaf springs are semielliptical.

Leaf springs are typically mounted at right angles to the axle.

Monoleaf springs: Monoleaf or single-leaf springs are usually the tempered plate type with a heavy or thick center section tapering off or both ends. This provides a variable spring rate for a smooth ride and good load-carrying ability. In addition, single-leaf springs do not have the noise and static friction characteristic of multiple-leaf springs.

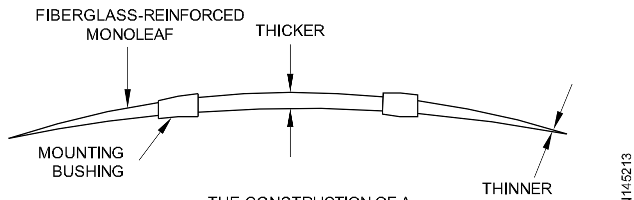
Fig 2



THE ACTION OF A LEAF SPRING AS IT COMPRESSES

Fiber composite springs: While most leaf springs are still made of steel, fiber composite types are increasing in popularity (Fig 3). Some automotive people call them plastic springs in spite of the fact that the springs contain no plastic at all. They are made of fiberglass, laminated and bonded together by tough polyester resins. The long strands of fiberglass are saturated with resin and bundled together by wrapping (a process called filament winding) or squeezed together under pressure (compression molding).

Fig 3



THE CONSTRUCTION OF A FIBERGLASS-REINFORCED MONOLEAF SPRING

Fiber composite leaf springs are incredibly lightweight and possess some unique ride control characteristics. Conventional monoleaf steel springs are heavy weights, tipping the scale at any where

Coil spring: These are mainly used as compression springs in passenger care. Generally open coil helical springs are used in vehicles.

Advantages: Low weight, low space requirements,

Disadvantages: Almost no damping, no transmission of wheel forces (longitudinal and transverse forces).

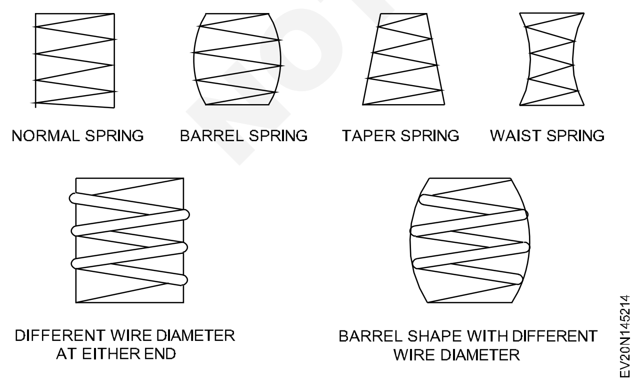
Helical springs usually have a linear spring characteristic. Soft helical springs differ from hard helical springs in that they have a:

- Smaller wire diameter
- Larger spring internal diameter
- More loosely would coil

Helical springs with a progressive characteristic must be fitted to allow a greater pay load and adequate comfort when the vehicle is unladen. This can be achieved with the following:

- Different sizes of the internal diameter, e.g. taper shape, barrel shape, waist shape
- Different wire diameters. (Fig 4)

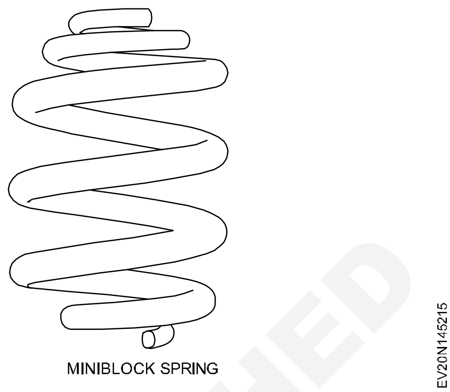
Fig 4



Types of helical springs

The barrel-shaped miniblock spring has the advantage over the cylindrical helical spring that the spring coils cannot touch when the spring is compressed while the vehicle is in motion because each coil lies inside the larger ones forming a spiral (Fig 5). This means that the spring can be shorter without sacrificing a long spring range for a high load-carrying capacity. The miniblock spring incorporates all the options for a progressive spring.

Fig 5



MINIBLOCK SPRING

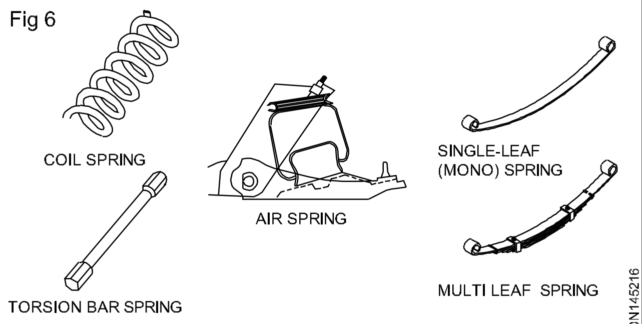
Helical springs cannot transfer wheel guidance forces.

They are therefore only used in axle designs in which the motive, braking and lateral forces are transferred by other elements (control arm, trailing arm McPherson-suspension strut). Vibration dampers are nowadays only rarely used inside the helical spring (Fig 5) because fitting and removal is taking more time.

Rubber spring

Natural and synthetic rubber are very elastic and have high interia damping characteristics. Hence it is used with vehicle springs. The high internal damping and elasticity of the rubber is used to intercept high-frequency vibrations, e.g. the control arm, are mounted in rubber cushions. This also improves the transverse suspension. (Fig 6)

Fig 6



VARIOUS TYPES OF AUTOMOTUVE SPRINGS

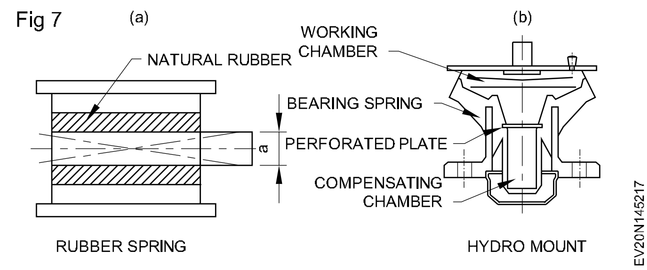
Rubber spring & Hydro mount

Hydraulically damped elastomer mountings & hydro mount, (Fig 7) are used instead of simple rubber springs to prevent vibrations of various frequencies from being transferred from the engine to the body. These consist of an elastic bearing spring made from natural rubber, which forms the mechanical connection between the engine and the body, and a hydraulic section, which consists of a working chamber and a compensating chamber and which is filled with hydraulic fluid. A perforated plate between the two chambers impedes the flow of fluid into the compensating chamber and damps any vibrations that have been transfered here.

Different types of suspensions system

The following types of suspensions are used in automotive vehicles.

Fig 7



TYPES OF SUSPENSION SYSTEM

SPRING

1 Steel springs
- Leaf spring Tapered leaf spring
- Coil spring
- Torsion bar

2 Rubber springs

Compression spring

Compression-shear spring

Steel - reinfoced spring

Progressive spring

Face-shear spring

Torsional shear spring

INDEPENDENT SUSPENSION

FRONT WHEEL (DEAD)
- Wishbone or parallel link type
- Mac-Pherson strut type
- Vertical guide type
- Trailing link type
- Swinging half-axle type

SHOCK ABSORBERS
- Telescopic
- Lever arm type

AIR OR PNEUMATIC SUSPENSION

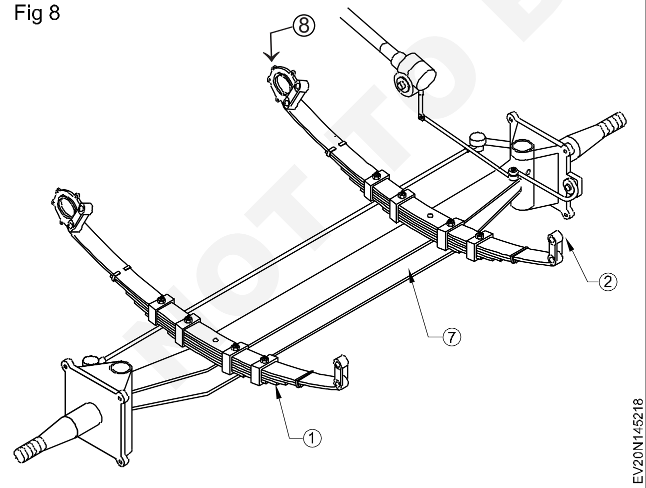
AIR SPRING
- Bellow type
- Piston type

STABILIZER OR ANTI-ROLL BAR

HYDROLASTIC SUSPENSION

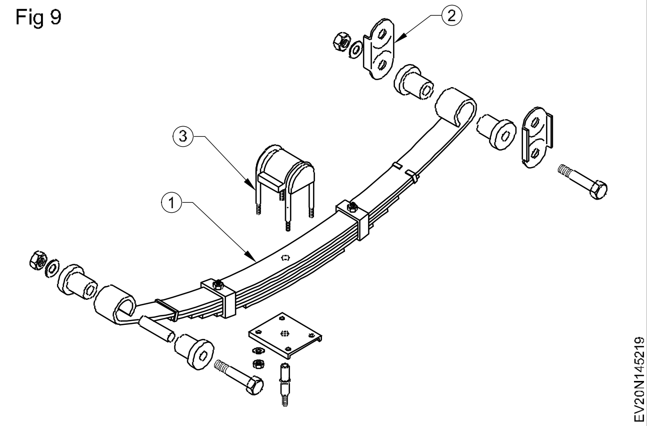
Conventional suspension system (leaf spring) (Fig 8)

Fig 8



In this system, a set of leaf springs (1) is used which connect the frame and axle (7). One end of the spring is fixed to the frame (8) and the other end is anchored by the shackle(2). The spring is mounted on the axle by ‘U’ bolts (3) (Figs 9 & 10). When the vehicle moves on bumps or ditch etc. the spring (1) elongates and the shackle (2) moves backward to accommodate the change in the spring length.

Fig 9



The following types of leaf springs are used.

- Semi-elliptical spring (Fig 11)
- Quarter elliptical spring (Fig 12)
- Three quarter elliptical spring (Fig 13)
- Transverse spring (Fig 14)
- Full elliptical spring (Fig 15)

In some vehicles a helper spring is used to relieve heavy load from the main spring assembly. The helper spring (4) is mounted on the top of the main spring assembly and its ends are kept loose. When the main spring deflects upward under heavy load, these loose ends rest against the brackets (5). A rubber buffer (6) is mounted on the frame so in the event of a heavy jerk spring does not hit the chassis frame. (Fig 16)

Non reactive suspension arrangement on multi-axle vehicles (Fig 17)

The suspension allows the load on the spring of one axle to be shared by the spring of the other, when an uneven road surface is encounted and result in minimal vertical movement of the frame.

Fig 10

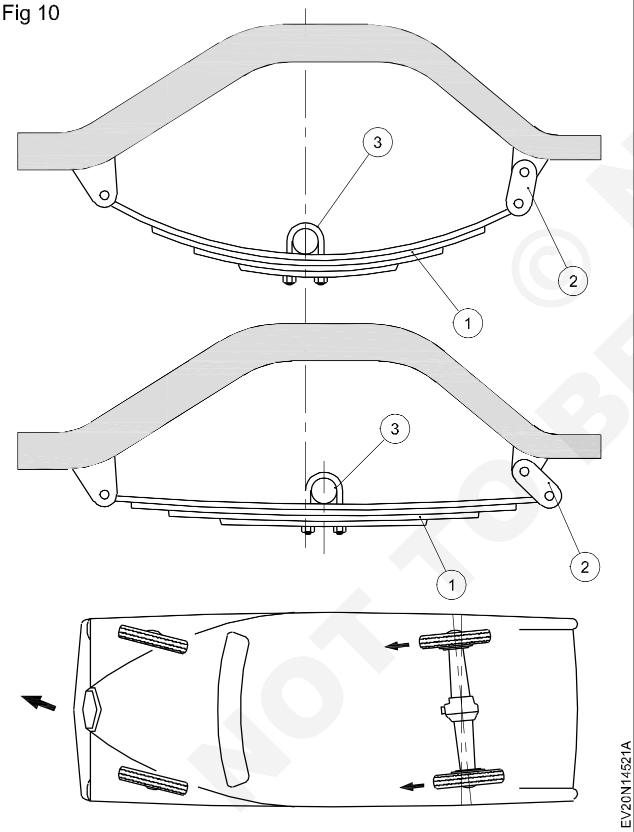


Fig 11

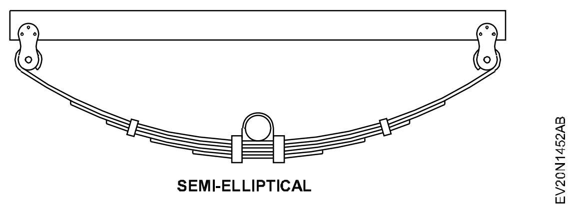


Fig 12

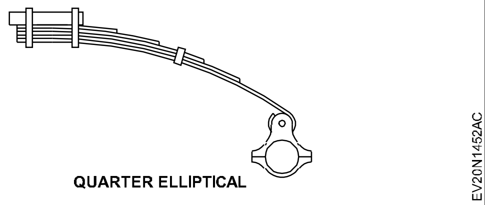


Fig 13

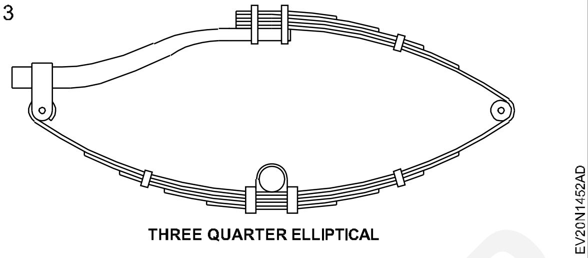


Fig 14

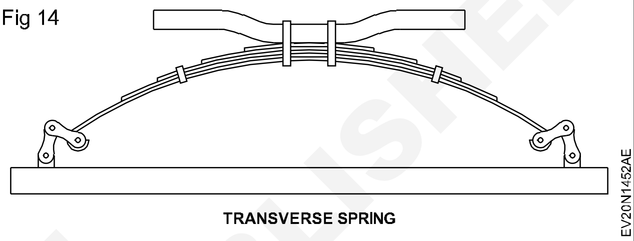


Fig 15

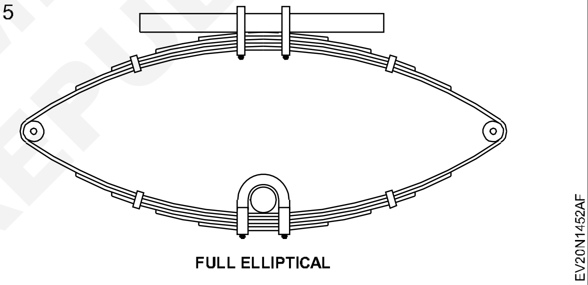
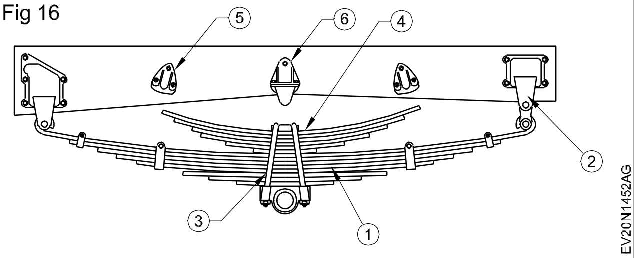


Fig 16



The braking efficiency in both the rear wheels are good, because of good road grip, due to balancing action of bell crank levers and connecting tie rod (3)

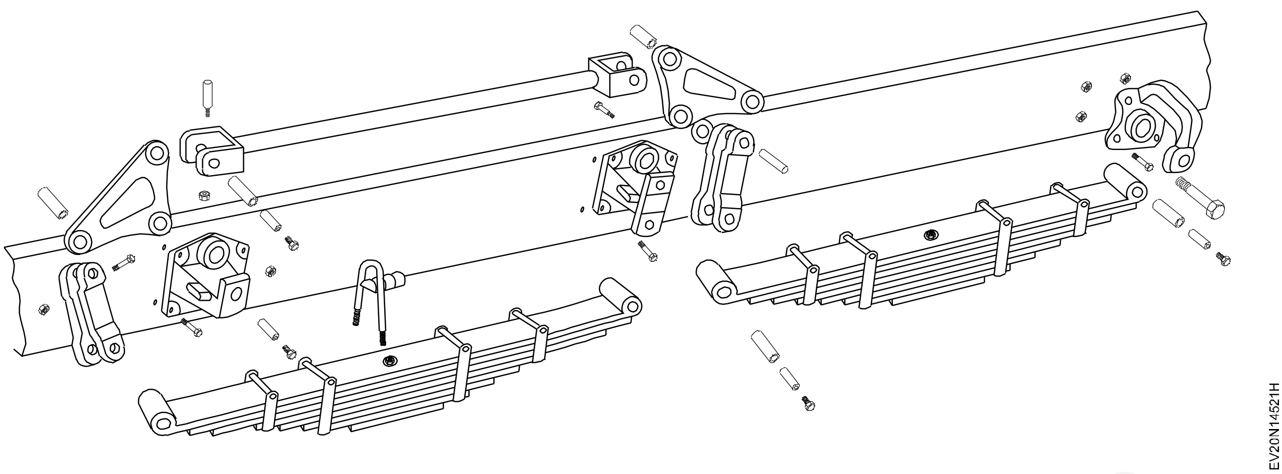
Weweller suspension

These suspension is mostly used for front springs in commercial passenger vehicle for better riding comfort and spring life.

The main purpose of rubber spring attachment is to prevent metal to metal contact between spring and chassis, by making use of rubber as a shock absorbing medium. Another advantage is prevention of rattles.

Rubbers in which the ends of springs are enclosed are fitted in the spring supports, attached to the chassis frame.

Fig 17

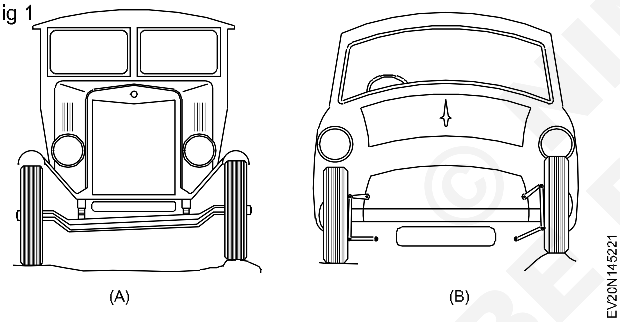


Independent suspension system

Objectives: At the end of this lesson you shall be able to
- **state the constructional features of the coil spring suspension**
- **state the constructional features of the torsion bar suspension system**
- **state the constructional features of the strut suspension system**
- **state the adaptive air suspension operation**
- **state the electronic air suspension system.**

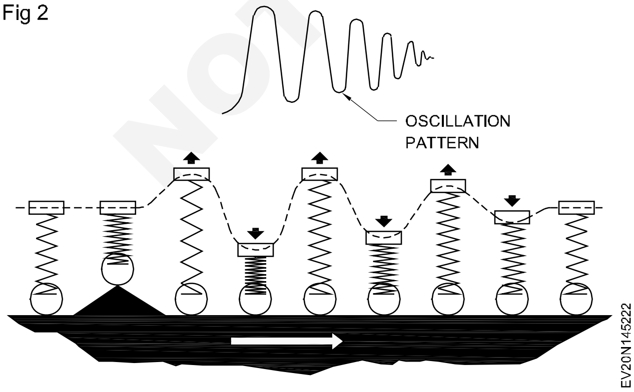
Independent suspension system (Figs 1 & 2)

Fig 1



In this type, the up or down movement of one wheel does not affect the other wheel (B). Each wheel moves independently on pot holes and bumps unlike in rigid suspension (A). The following types of independent suspension systems are used.

Fig 2



- Coil spring suspension
- Torsion bar suspension
- Macpherson street type suspension
- vertical guide suspension
- multi link rear axle suspension
- trailing link suspension
- Double wishbone arm

Coil spring suspension (Figs 3 & 4)

Fig 3

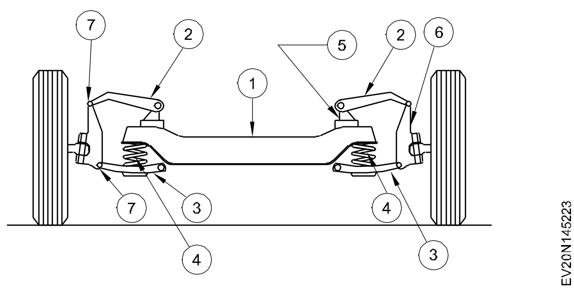
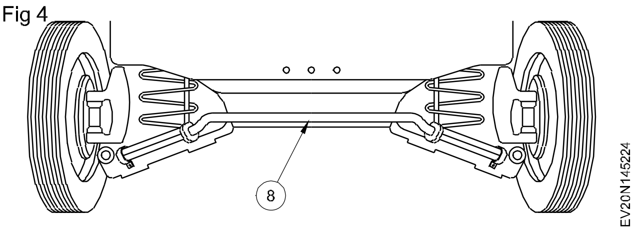


Fig 4



A leaf spring does not deflect quickly due to stiffness under light load. A coil spring responds quickly to road shocks. It can store more energy than a leaf spring and it is light in weight.

In the coil spring suspension, each wheel is independently supported by a coil spring. Shocks are sustained by each spring.

Construction

A double wishbone arm suspension system comprises a frame (1), an upper control arm (2), a lower control arm (3), a coil spring (4) and a shock absorber (5). The coil spring (4) is seated on rubber pads between the lower control arm (3) and the upper control arm (2) and the frame. A steering knuckle (6) is pivoted at each end of the upper and lower control arms through ball joints. (7) This allows for angular movement of linkages. This suspension is called wish-bone suspension.

A stabilizer bar (8) is used on the radius rods to guide the cushioning motion of the springs.

Torsion bar suspension (Figs 5 & 6)

Fig 5

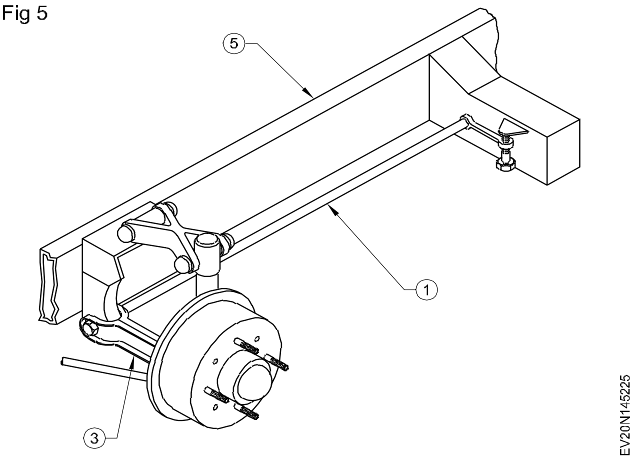
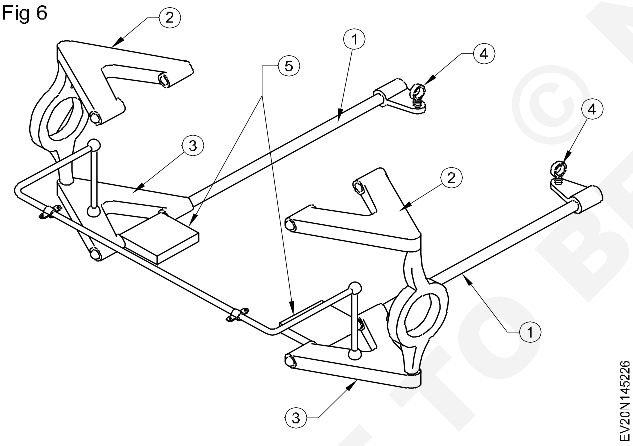


Fig 6



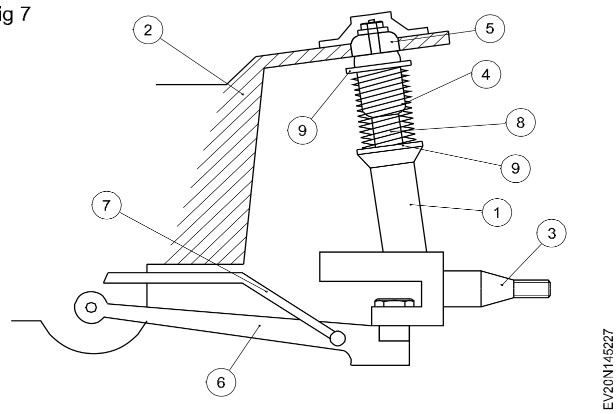
In this suspension, a torsion bar (1) is used as a spring between the upper (2) and lower (3) control arms. The torsion bar stores energy like a coil spring by twisting when the vehicle goes over a pot hole. When the wheel comes on plain surface the torsion bar untwists and comes to its normal position.

A torsion bar (1) is fixed on each side of the frame (5). One end of this is connected to the wheel hub spindle and the other end is connected to the frame cross-member. As the wheel moves on a pothole the lower wish-bone (3) tries to rotate the torsion bar (1). The torsion bar (1) twists and tries to keep the lower control arm (3) in a straight position.

In this system an eye bolt adjuster (4) is provided to adjust the height of the lower control arm (3). This system is used in Ambassador cars.

Mac - pherson Strut type suspension (Fig 7)

Fig 7

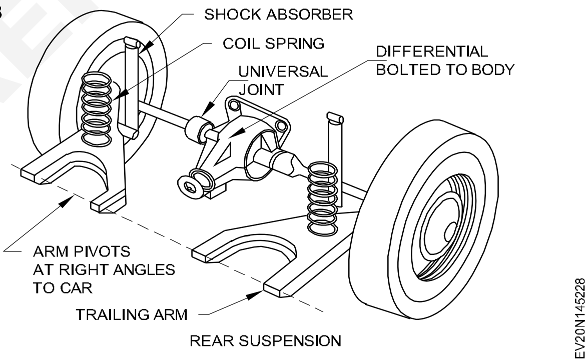


In this type a strut (1) is mounted between the frame (2) and the stub axle (3). A shock absorber (8) is fixed inside the strut (1). A coil spring (4) is mounted on two collars (9). A rubber pad (5) is used between the upper end of the strut (1) and the frame (2). A transverse link (7) is attached to the frame (2) and stub axle (3) by a ball joint or rubber pad. It controls the wheel path. A stabilizer bar (6) connects the two lower transverse members.

This suspension system is known as MCPHERSON strut type suspension. It is simple in construction and light in weight. It allows more deflection of the front wheel without any effect on the steering.

Rear independent trailing link suspension (Fig 8)

Fig 8



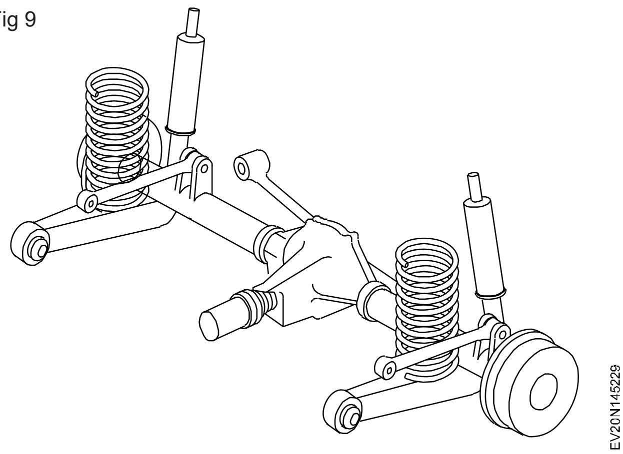
Indepedent coil-spring rear suspensions can have several control arm arrangements. For example, A-shaped control arms are sometimes employed. When the wide bottom of a control arim is toward the front of the car and the point turns in to meet the upright, they are called trailing arms. When the entrure A-shaped control arms are mounted at an angle, they are known as semi trailing control arms or multilink suspensions. Coil springs are used between the control arm and the vehicle body. The control arms pivot on a cross member and are attached at the other end to a spindle. A shock absorber is attached to the spindle or control arm.

Some vehicles use a rear-suspension system that used a lower control arm and open driving axles. A cross member supports the control arms, while the tops of the shock absorbers are mounted to the body. The springs are set in seats at the bottom and tops of the cross member.

Multi link rear axle suspension (Fig 9)

A multilink rear suspension uses several control arms to guide the wheel. Different models feature different types of multilink rear suspensions that satisfy the varying demands of vehicle dynamics, ride comfort, and space requirements. These include the double-whishbone rear suspension, trailing-link double-wishbone rear suspension, and trapezoidal-link rear suspension.

Fig 9



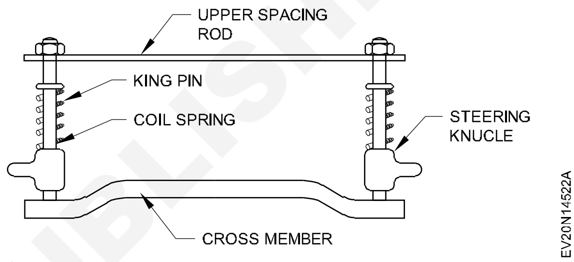
In the double-wishbone suspension, the wheel is guided by two triangulated laterla control arms (the wishboes) and a tie rod. The suspension strut is attached to the lower wishbone to provide vertical support.

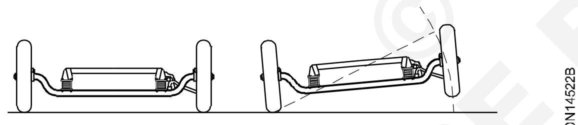
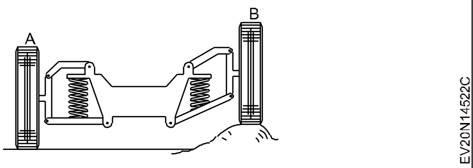
The trailing-link double-wishbone suspension has a trailing link that also carries the wheel and upper and lower wish bones. The spring is located on the trailing link ahead of the center of the wheel; the shock absorber is behind it.

The trapezoidal-link rear suspension permits excellent performance, handling, and comfort. The rear wheel is fixed by an upper lateral control arm and a trapezoidal lower link with a tie rod behind it. For reduced weight, the trapezoidal link and upper control are hollow aluminium castings.

Vertical guide suspension: In this suspension system kingpin is directly attached to the cross member of the frame it can slide up and down as corresponding to the vehicle wheel motion and there by compressing the spring.. In this type of suspension the wheel track, wheel base and wheel altitude remain unchanged Fig 10

Fig 10

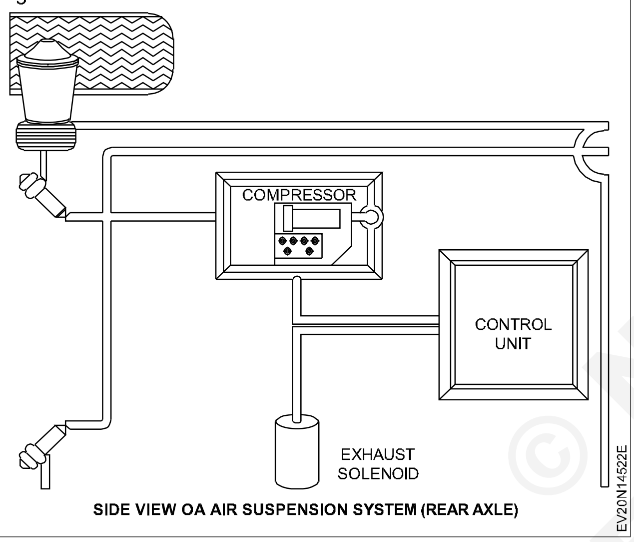


Comparison between rigid and independent suspension	
Rigid axle suspension system (Fig 11)	**Independent suspension system (Fig 12)**
 TRIPPING EFFECT OF SOLID FRONT AXLE	
1 This is a simple arrangement. 2 In this system leaf springs are used. The wheels swivel on each end by a pivot arrangement between the axle and the wheel spindle. 3 The up and down movement of either of the front wheels causes a vertical tipping effect on the other wheel as these wheels rotate on a common axle. 4 Shocks are transmitted from one wheel to the other wheel. 5 This system does not allow more deflection of the front wheels and have some effect on steering. 6 In this system the spring weight is more. 7 Vibration damping is less effective. 8 Because of its simplicity, it requires less maintenance, and, therefore, the maintenance cost is less.	1 This is complicated as compared to the rigid axle suspension. 2 In this system a coil spring is used on each side. 3 In the independent suspension system each front wheel is free to move up and down with minimum effect on the other wheel. 4 Shocks are not transmitted from one wheel to another. 5 This system allows more deflection of the front wheels without any effect on the steering. 6 Spring weight is less. 7 Vibration damping is more effective. 8 Because of its complexity, it requires more maintenance, thereby, the maintenance cost is more.

Adaptive air suspension operation (Fig 13 & 14)

Fig 13

Fig 14



Additionally, the air suspension allows the speed-dependent lowering of the body-this change in ride height means a low center of gravity and significantly increased directional stability as a result. The vehicle's handling characteristics are improved at the same time. Some European vehicles have air suspension struts at all four wheels.

The information obtained from sensors on the axles and acceleration sensors on the body is evaluated in the adaptive air suspensions central control unit. This computer can control the adjustment of the individual shock absorbers in milliseconds, depending on driving situation.

Provided no higher damping forces are required - for instance when driving straight ahead on good rods - the damper setting remain comfortably soft.

Specific adjustments to the damping force at individual wheels eliminates body movement, which could affect occupant comfort.

The height sensor uses the induction principle to constantly monitor the distance between the vehicle's axle and its chassis.

When the ignition is switched on, when the vehicle's door is opened before ignition, the control system is activated. The height sensor uses the induction principle to constantly monitor the distance between the vehicle's axle and its chassis.

When the vehicle is being loaded, unloaded, or lowered due to driver command or vehicle speed, the electronic readings from the height sensor monitor the change. This is picked up by the electronic control unit and compared to the stored reference values.

The ECU either activates the electric motor of the compressor, or the exhaust solenoid vale. This also requires the solenoid valve block to be actuated, in order to maintain the required level. The corner solenoid valves are subject to stringent leakage requirements to maintain the vehicle's height even without system operation.

When the vehicle is being loaded, the compressor delivers air into the four air suspension bellows, until the normal level has once again been reached. For additional air delivery or rapid response, the reservoir solenoid valve is opened and air flows directly from the reservoir.

When the vehicle is being unloaded, the solenoid valve block is activated. This results in airflow from the air suspension bellows being removed via the air dryer solenoid valve in the compressor, then via the relay valve. The air is then exhausted into the atmosphere.

Any dynamic air spring movement while the vehicle is in motion is ignored and does not cause the control system to respond.

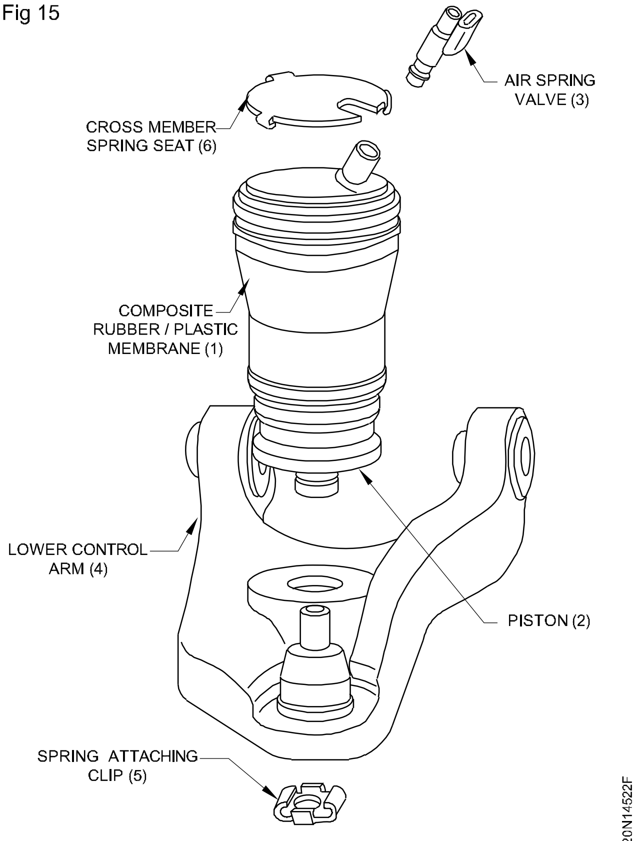
Aaptive air suspension system (Fig 15)

In an air suspension system, the air springs replace the coil springs in a conventional suspension system. These air springs have a composite rubber and plastic membrane (1) that is clamped t a piston(2) located in the lower end of the spring. An end cap is clamped to the top of the membrane and air spring valve(3) is positioned in the end cap. The air springs are inflated or deflated to provide a constant vehicle trim height. Front air springs are mounted between the control arms(4) and the cross member (Fig.15). The lower end of these air springs is retained in the control arm with a clip (5) and the upper end is positioned in a cross member spring seat (6).

The rear air springs are the same as the front air springs except for their mounting. The lower ends of the rear springs are bolted to the rear suspension arms and the upper ends of these springs are attached to the frame.

An air spring valve(3) is mounted in the top of each air spring. These valves are an electric solenoid - type valve that is normally closed. When the valve wining is energized, plunger movement opens the air passage to the air spring. Under this condition, air may enter or be exhausted from the air spring. Two O-ring seals are located on the end of the valves to seal them into the air spring cap. The valves are installed in the air spring

Fig 15



FRONT AIR SPRING SUSPENSION

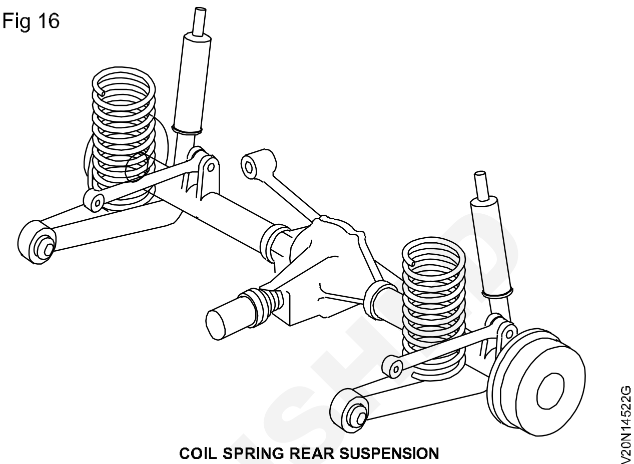
cap with a two stage rotating action similar to a radiator pressure cap.

Never rotate an air spring solenoid valve to the release slot in the cap fitting until all the air is released from the spring. If one of these solenoid valves are loosened with air pressure in the spring, the air pressure drives the solenoid out the spring with extreme force. This action may result in personal injury.

Coil spring rear suspension

Some rear - wheel drive vehicles have a coil spring rear suspension. Upper and lower suspension arms with insulating bushings are connected between the differential housing and the frame (Fig 16). The upper arms control lateral movement and the lower trailing control arms absorb differential torque. In some rear suspension systems, the upper arms are replaced with strut rods. The front of the upper and lower arms contain large rubber bushings. When strut roads are used in place of the upper arms, both ends of these rods contain large rubber bushings to prevent noise and vibration transfer from the suspension to the chassis. The coil springs are usually mounted between the lower suspension arms and the frame, while the shock absorbers are mounted between the back of the suspension arms and the frame.

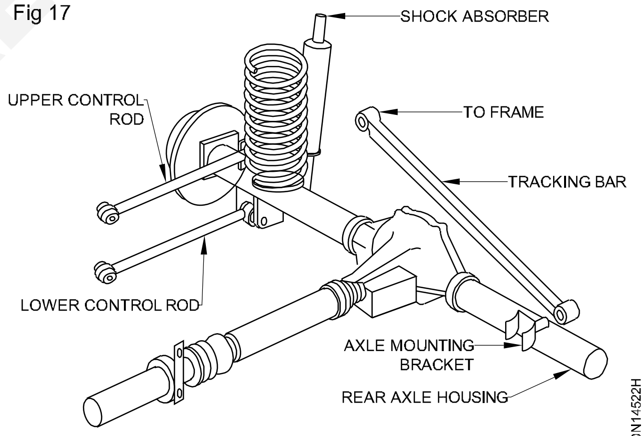
Fig 16



COIL SPRING REAR SUSPENSION

Some rear suspension systems have a tracking bar connected from one side of the differential housing to the chassis to prevent lateral chassis movement (Fig 17). Large rubber insulating bushing are positioned in each end of the tracking bar. A tracking bar may be referred to as a panhard or Watts rod.

Fig 17



COIL SPRING REAR SUSPENSION

Air suspension

Objectives: At the end of this lesson you shall be able to
- **state air suspension**
- **state the major parts of air suspension**
- **explain the function of the air supply system**
- **explain the construction of air bag**
- **describe the construction of height control valve (HCV)**
- **describe the functions of air suspension.**

Air suspension

An air suspension supports the vehicle on the axles with an arrangement of air bags instead of some type of steel spring, leaf o r coil, or some type of torsion spring arrangement. The air bags are sometimes referred to as air springs or bellows. Suspensions that have steel or torsion springs that are supplemented by the use of air bags are not considered air suspensions. There are combination systems that have both air and steel springs. Usually the air suspension components are used on the rear of the vehicle. Depending on the situation, this type of air suspension will probably have to be dealt with for leveling purposes.

Normally, the air suspension is just one part of the air system on the vehicle. Most vehicles with an air suspension also have air brakes along with other equipment that may be operated with air.

Major components of air suspension

An air suspension has three basic components

i Air supply system

ii Air bag (bellows)

iii Height control valve (HCV)

Air supply system

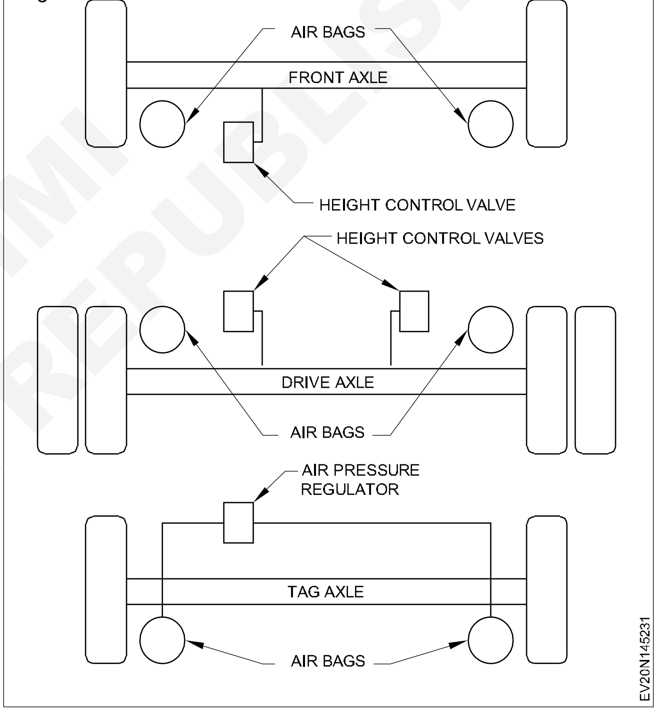
The air supply: The air supply is engine air compressor, the air tanks, air valves and air lines. The engine air compressor supplies air for every piece of air equipment on the vehicle. The maximum pressure supplied by the compressor varies. For many years, the air supply was maintained around 120 to 125 psi but on some newer, larger vehicles this has been increased to 135 psi.

Air bags (bellows) (Figs 1 & 2): Air bags are simply a rubber baldder that holds air. Air bags are also referred to as air springs or bellows. The air bags are located between the frame of the vehicle and the vehicle axles. Air bags are rated for weight and pressure capacities.

Air bags placement and arrangements very amongst chassis manufacturers. At the very least, there will be one air bag for each side of each axle in the vehicle. There can be two air bags for each side of the axles. Some manufacturers use two air bags for each side fo the drive axle and some use two air bags for each side of the drive and front axles. Space between air bags for side to side placement also varies. Some place the air bags outboard as far as they can and some have the bags closer together. When two bags per side are used, one will be in front of the axle and the other behind the axle. Again, spacing can vey.

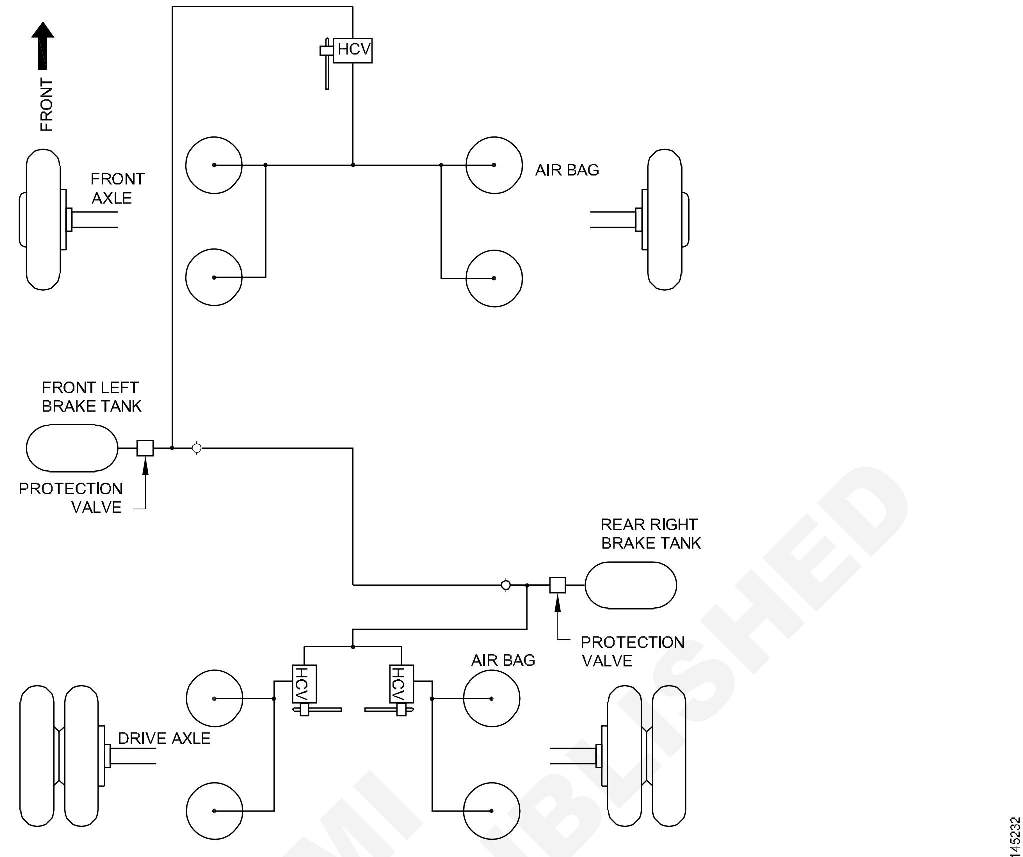
Most air bags will have some device such as a cone that keeps that air bag from being crushed or damged when fully deflated. Inflating air bags is limited to the available air pressure to the suspension system. How much lift the air bags will have various with vehicles and air bags, but the average lift the air bags will supply, when maximum available system air pressure is used, is between 51/2 and 61/2 inches from a totally deflated state.

Fig 1



Construction of height control valves: The height control valves (HCV from now on) (Fig 3) are kind of the brains of the system. They dictate how much air is in the air bags. This dictates the height the vehicle sits at, thus Height Control Valve. Most HCVs are mechanical valves but electronic height control mechanisms are available. The HCV is mounted to the frame of eth vehicle. An L shaped linkage attaches the HCV to the axle. As the axle moves up and down in relationship to the frame, the linkage moves the valve or electronic mechanism. With mechanical valves, there is an air line from the air supply to the HCV. There is an air line from the HCV to the air bag or bags+that it controls. The HCV also has an exhaust port. When the connecting linkage moves up, the HCV connects the air supply to the air bag(s) to the exhaust port, deflating the bag(s). This controls the height of the vehicle. If the Height Control

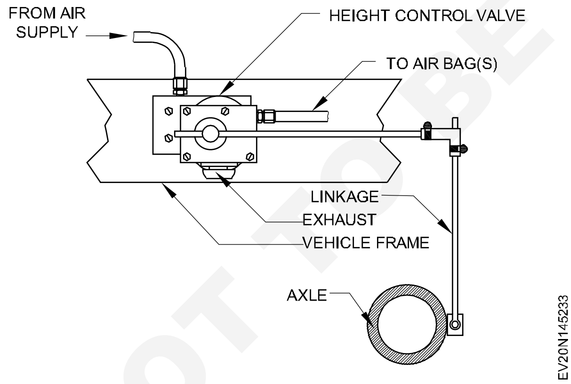
Fig 2



DUAL AIR BAG ARRANGEMENT WITH ONE HCV FRONT AND TWO HCV REAR

is electronic, as the control linkage moves up or down, an electronic sensor sends information to an electronic control. These controls will open or close air solenoid valves as needed to inflate or deflate the bags.

Fig 3



Typical height control valve mounting and connection to axle

There are two basic styles of mechanical HCVs, the instant response valve (IR valve) and the delay valve. These names are accurate descriptions of how the valves react. The IR valve will start to inflate or deflate the air bags as soon as the valve activating lever moves.

The delay valve has a slight delay when the activating lever moves before inflating or deflating the air bags.

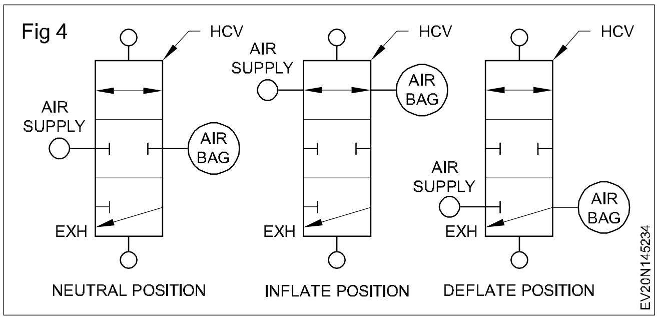
The number and arrangement of HCVs used on a suspension varies a little. There are normally three HCVs used on a suspension. Either there is one for the front axle and two for the rear, (most common arrangement) or some use two on the front axle and one on the rear. A few chassis have been done with one HCV for each side of the front and rear axles, a total of four, but this would not be very common. Vehicle with a tag axle use regulated air or tie the tag air bags to the driver air bags to control the tag air bags. Although it may be done, no one using HCVs to control the tag axle air bags.

The following diagrams show the basic mounting of a HCV and several air bag and HCV arrangements.

Functions of air suspensions: The vehicle is supported on the frame with an arrangement of air bags. The vehicle air system, engine air compressor, tanks, lines, etc. supplies air to the height control valves (HCV) mounted to the frame of the vehicle. The height control valves are connected to the air bags with an air line. The linkage which connects the HCVs to the axles rotates the HCV valving as it moves up and down. When weight is added to the vehicle or transferred through the suspension of the vehicle, the air in the air bag(s) is compressed, the frame moves closer to the axle. This forces the HCV linkage up. As the linkage moves up, the valving of the HCV connects the air supply to the air bag(s). The added pressure and volume inflates the air bag(s), causing the frame to move away from the axle. As the frame moves back to the proper ride height, the HCV linkage moves to the neutral position. This moves the valving away from the air supply and locks the air in the air bag to maintain the proper ride height. As weight is removed from the vehicle or the suspension shifts weight away, the existing pressure in the air bag(s) can push the frame away from the axle. The HCV linkage is pulled down. This connects the air bag(s) to the HCV exhaust port. As air is exhausted from the air bag(s), the frame lowers back down towards the axle. As the linkage moves up to the neutral position, the exhaust port is closed and the air is again locked in the air bag(s), maintaining proper ride height.

These three drawings (Fig 4) show as schematic example of the height control valve in he neutral position, inflate position and deflate or exhaust position.

Fig 4



Shock absorbers

Objectives: At the end of this lesson you shall be able to
- **State the function of the shock absorber**
- **State the different types of shock absorbers**
- **State the construction of a shock absorber**
- **Explain the function of a shock absorber**
- **State the effect of weak suspension system**
- **State gas pressurized shock absorber**
- **State the load adjustable shock absorber**
- **State the electronic adjustable shock absorber**
- **State the automatic load adjustable shock absorber.**

Function and location of shock absorber

When the vehicle is running on a rough road, or a stone gets below the wheels or the wheel falls into a pit, heavy shocks are experienced. A bouncing wheel makes it difficult to control the vehicle and it is to avoid such bouncing of the wheels, a suspension system is provided in the vehicles. Vibration of higher amplitude and lower frequency are absorbed by suspension spring. Vibration of low amplitude and high frequency are absorbed by the shock absorber. The shock absorber is connected between the chassis cross- member and the spring axle or suspension control arm. It is also called as Dampers.

Different types of shock absorbers

Shock absorbers are mainly classified into two types.

Mechanical type

This is called a dry or friction type. It absorbs shocks with the help of friction discs and spring.

Hydraulic type

These shock absorbers absorb shock by the resistance of a fluid. There are three types.

- Vane type
- Piston type
- Telescopic type

Nowadays the telescopic shock absorber is most popular and is in use because of easy replacement and handling.

Construction of a shock absorber

Mechanical shock absorber

It consists of two discs with a small clutch, spring and centre bolt. One disc is fixed to the chassis and the other to the axle. A friction disc works between these two discs.

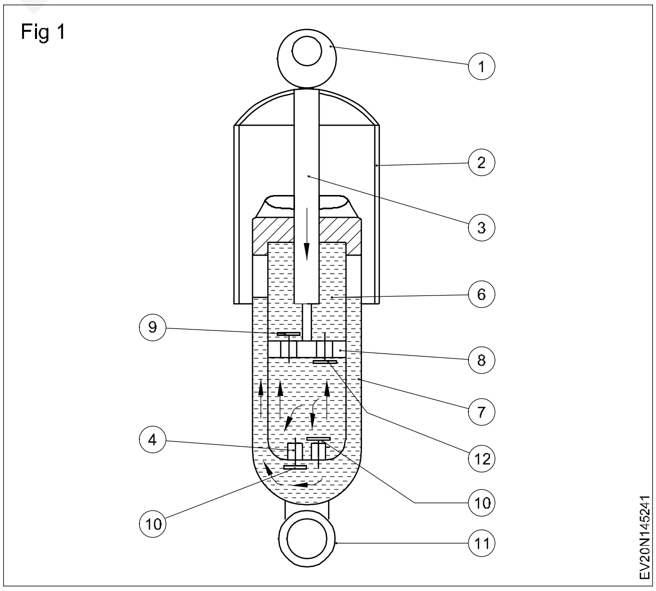
All discs are assembled with the spring and centre bolt.

When the axle is lifted up the friction produced in between the discs due to the spring pressure, absorbs the vibration.

Telescopic shock absorber (Fig 1)

It is widely used in a vehicles nowadays.

Fig 1



Construction

The telescopic shock absorber is made of two thin steel tubes, the inner forms the cylinder (6) and the outer (7) forms the reservoir. It is called telescopic because the tubes are concentric. The outer tube (7) is connected to the axle or suspension member by an eye (11). A block (4) is welded in the bottom of the inner tube. The block

(4) has two non-return valves (10). One valve allows oil from the reservoir (7) to the lower cylinder (6) and the other from the lower cylinder (6) to the reservoir (7). At the upper end of the shock absorber a dust excluder (2) is provided. The piston (8) has a rebound valve (12) and pump valve (9). The piston rod's (3) upper end is welded to an eye (1). This eye (1) is attached to the frame. The cylinder (6) is fully filled with hydraulic fluid and the reservoir is partly filled.

During the rebound/functioning of shock absorber stroke the eye (1) moves away from each other. The piston (8) moves upward. The rebound valve (12) opens and the fluid passes to lower the portion of the cylinder from the upper portion. Since the upper portion does not have enough fluid to fill the lower portion completely, a vacuum is created in the lower portion. Now the extra fluid flows into the lower portion from the reservoir (7) through the foot valve (10). This passage of fluid provides necessary damping during rebounding.

This way, the shock absorber controls the quick bouncing of the wheels on the road. This provides stability to the vehicle. It also controls the slow balancing of the body to provide comfort to the passenger and avoid damage of other parts.

Factors affecting suspension

The following factors affect suspension in any vehicle.

- Irregularities of road surface
- Bumps and holes
- Heavy load or unequal weight distribution
- Tyre traction and pressure
- Side forces while negotiating corners.

Effects of weak suspension

- Directional unstability of the vehicle
- Excessive/abnormal tyre wear
- Damaging of chassis frame and other parts
- More shocks and uncomfortable riding

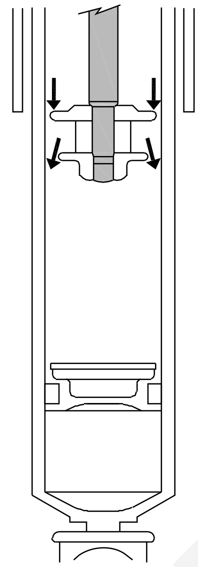
Gas pressurized shock absorbers (Fig 2)

Shock absorber 'dissolve' can be reduced by pressurizing the fluid with nitrogen.

In a hydraulic shock absorber, the oil heats up as the energy of motion of the suspension is dampened. The rapid piston movement as the vehicle moves over the road causes the hydraulic fluid to aerate. This reduces the dampening effect, and the shock absorbers performance very quickly deteriorates. This condition is called shock absorber dissolve. It can be reduced substantially by pressurizing the fluid with gas, usually nitrogen.

In this mono-tube design, fluid fills the chambers above and below the piston. As the piston moves in the cylinder, valves control the movement of oil from one chamber to the other.

Fig 2



COIL SPRING REAR SUSPENSION

EV20N145242

Pressure on the oil is provided by nitrogen gas at the base of the cylinder, acting on a free floating separation piston which separates the gas from the oil.

Pressure on the oil is provided by nitrogen gas at the base of the cylinder, acting on a free floating separation piston which separates the gas from the oil.

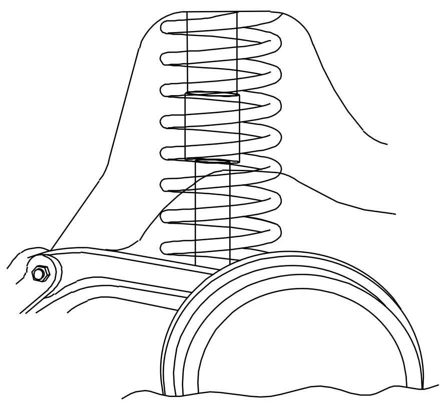
On bump, the piston moves downwards, and the penetration of the piston rod displaces a quantity of oil equal to its volume. The separation piston is displaced accordingly, and gas pressure increases.

On rebound, the piston and rod move upwards, and gas pressure reduces as the separation piston follows the movement.

Pressure on the oil is maintained, even when the piston and rod are at the top of their stroke.

Load-adjustable shock absorbers (Fig 3)

Fig 3



LOAD - ADJUSTABLE SHOCK ABSORBERS

EV20N145243

The rubber air cylinder in the load-adjustable shock absorber can be pressurized to assist suspension springs that are under load. Changing the pressure in the cylinder can alter ride height, and the stiffness of the suspension.

When vehicles carry heavy loads, their suspension is compressed, causing the rear of the vehicle to be lower than normal.

As a result, steering becomes lighter, the alignment of the headlights becomes too high, and the compression length of travel of the suspension over bumps is reduced, causing discomfort to passengers.

To reduce these effects, a manually adjustable air spring can be incorporated into each rear shock absorber. The air spring consists of a flexible rubber cylinder which seals the outside of the upper and lower halves of the shock absorber.

The shock absorber is a standard hydraulic type, providing normal dampening action, but when a heavy load is placed on the rear of the vehicle, the rubber air cylinder can be pressurized to assist the suspension springs.

By changing the air pressure in the cylinder, the ride height can be adjusted, as well as the stiffness of the suspension.

Compressed air in the pneumatic cylinder can absorb smaller road shocks, and provide better ride characteristics than just stiff springs alone.

The rubber air cylinder is connected to a filling valve by a flexible plastic hose. Air from a tire pump or a hand unit forces more air into the rubber cylinder, allowing the suspension to support more weight.

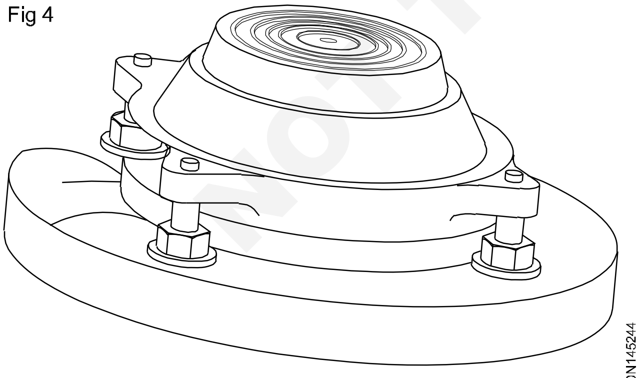
The maximum air pressure setting must not be exceeded as this can damage the shock absorber and its mounting points on the vehicle frame.

When the load is removed, the extra air is released through a filling valve, which allows the suspension to return to its original settings.

A minimum air pressure must be maintained in the cylinder to prevent tearing of the rubber as it collapses internally with shock absorber action.

Electronic adjustable - shock absorbers (Fig 4)

Fig 4



COIL SPRING REAR SUSPENSION

The electronic adjustable - shock absorber has a rotary solenoid that can alter dampening rate by changing the number of restrictions the oil must pass through, and varying the force needed to open the valves.

Adjustable shock absorbers provide a means of changing their rate of dampening of the spring oscillations, to suit road conditions. Electronic controls let the changes occur either automatically, or as the driver prefers.

Each shock absorber has a rotary solenoid that can alter the dampening rate by changing the number of restrictions the oil must pass through.

In this position, all orifices are open. Oil can flow more easily through the passageways in the piston. Only a small dampening effect is applied to the oil.

This provides a dampening force that emphasizes ride comfort when traveling at low speeds.

Closing some orifices makes it harder for fluid to flow through the piston. This increases the dampening effect of the shock absorber, providing a firmer ride, more suitable for higher speeds, and faster cornering.

The solenoid is operated by an electrical signal from the electronic control unit or ECU.

The ECU allows different modes of operation, according to a selector switch on the dash-board. In the Auto position, the dampening effect at the front wheels is increased at road speeds above 80 kilometers per hour.

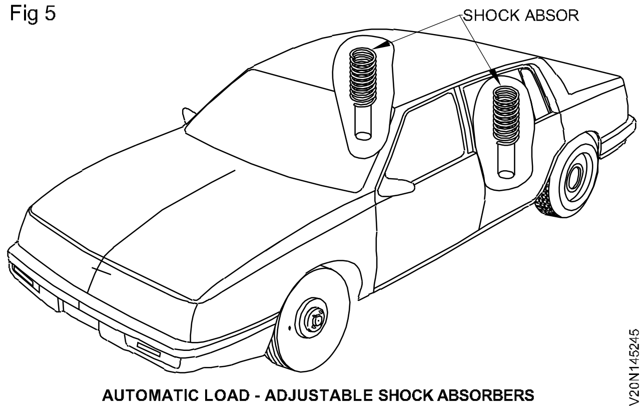
This improves vehicle stability at high speeds. The rear shock absorbers stay at their normal setting.

The manual position has two setting - normal or sport. In normal setting, all shock absorbers remain at a rate suited to ride comfort. There is no change to the settings at high speeds.

The sport setting increases the dampening rate of all the shock absorbers. This is more suited to brisk driving, with heavy acceleration and cornering.

Automatic load - adjustable shock absorbers (Fig 5)

Fig 5



AUTOMATIC LOAD - ADJUSTABLE SHOCK ABSORBERS

Automatic load-adjustable shock absorbers maintain vehicle ride at a pre-set level, according to the load placed over the rear axle.

The section examines automatic load -adjustable shock absorbers. They are also called self-leveling.

When vehicles carry heavy loads, their suspension is compressed, causing the rear of the vehicle to be lower than normal.

As a result, steering becomes lighter, the alignment of the headlights becomes too high, and the compression length of travel of the suspension over bumps is reduced, causing discomfort to passengers.

A lower vehicle handles better on smooth roads, but on a rough road, reduced suspension travel can let harsh road shocks be transmitted to the passenger compartment, and cause discomfort.

An automatic load adjustable suspension system controls the vehicle ride height automatically, according to the load placed over the rear axle.

It consists of air-adjustable shock absorbers fitted to the rear suspension, an electrically driven compressor and air-dryer assembly, and an electronic control unit, and associated wiring and tubing.

The ECU is mounted to the cross-member over the rear axle and a moveable link connects it to a rear suspension member.

As the vehicle is loaded, the normal suspension springs are compressed, which lowers the height of the vehicle.

When the ignition is switched on, the ECU senses the lowered ride height and switches on the air compressor. Air is directed to the shock absorbers, causing the airbag around them to expand the raise the suspension to the normal trim height.

If the load is removed, the suspension springs expand, raising the height of the vehicle.

The ECU senses the raised ride height, and air is exhausted from the shock absorbers, causing the airbag to deflate, and lower the suspension to the normal trim height.

During normal suspension operation, continual adjustment of vehicle ride height is prevented by a time delay, in the ECU.

This allows the trim height to be adjusted only when the ECU reads an out-of-trim signal for 5 to 15 seconds. The compressor run-time or exhaust-time is limited to 2 minutes. This prevent it continuing to operate, if the system develops an air leak, or if an exhaust vent remains open.

Hydraulic shock absorbers	The dampening action of a hydraulic shock absorber comes from transferring oil, under pressure, through valves that restrict the oil flow. Resistance to motion is low when the piston moves slowly, and high when its velocity is high.
Gas pressurized shock absorber	Shock absorber 'dissolve' can be reduced by pressuring the fluid with nitrogen.
Load - adjustable shock absorbers	The rubber air cylinder in the load - adjustable shock absorber can be pressurized to assist suspension springs that are under load. Changing the pressure in the cylinder can alter ride height, and the stiffness of the suspension.
Manual adjustable rate in shock absorbers	In a manual adjustable -rate shock absorber, the position of the valves the piston can be changed to vary the number of restrictions the oil has to pass through and to vary the force needed to open the valves.
Electronic adjustable - rate shock absorbers	The electronic adjustable - rate shock absorber has a rotary solenoid that can alter dampening rate by changing the number of restrictions the oil must pass through, and varying the force needed to open the valves.
Automatic load - adjustable shock absorbers	Automatic load - adjustable shock absorbers maintain vehicle ride at a pre-set level, according to the load placed over the rear axle.

Brake system

Objectives: At the end of this lesson you shall be able to
- **state the principle of brake**
- **state the various types of brake systems**
- **state the function and operation of mechanical brakes.**

Principle

- To stop the vehicle.
- To slow down the vehicle.
- To park the vehicle.

Types

According to application

- Foot brakes
- Hand brakes

According to operation

- Drum type
- Disc type
- Mechanical brake
- Hydraulic brake
- Air brake
- Air-assisted brake
- Vacuum-assisted brake

Foot brake

The brake which is applied by foot is called the foot brake.

Hand brake

The brake which is applied by hand is called the hand brake, e.g. a scooter's front brake and a commercial vehicle's and car's parking brake.

Drum brake (Figs 1 & 2)

In this type of brakes, the brake shoes (1) & (2) are placed inside the brake drum (3). When the brake is applied, the brake shoes expand through linkages, come in contact with the brake drum and stop the wheels.

Fig 1

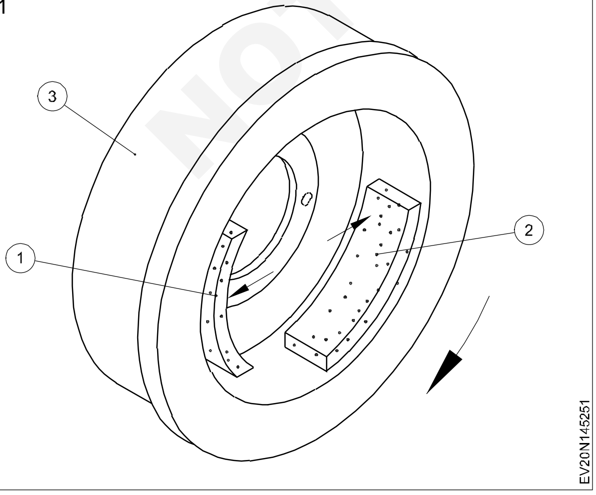
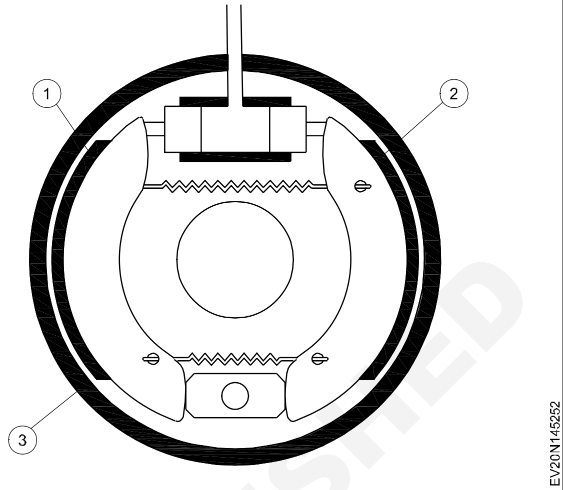


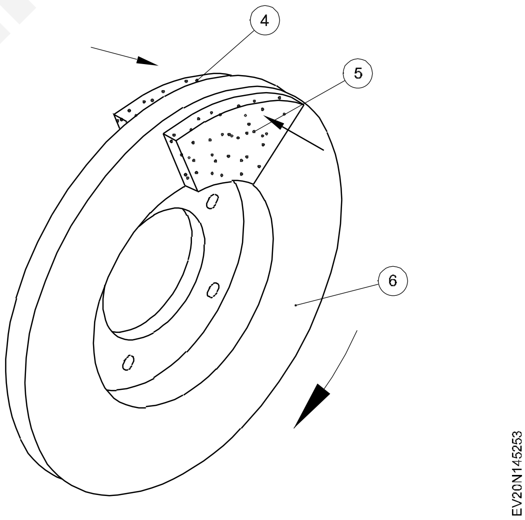
Fig 2



Disc brakes (Fig 3)

In this type the brake pads (4 & 5) are arranged at both the sides of the disc (6) which is connected with the wheel hub. When the brake is applied the pads (4 & 5) move towards the disc (6) and stop the wheels. The following types of disc brakes are used.

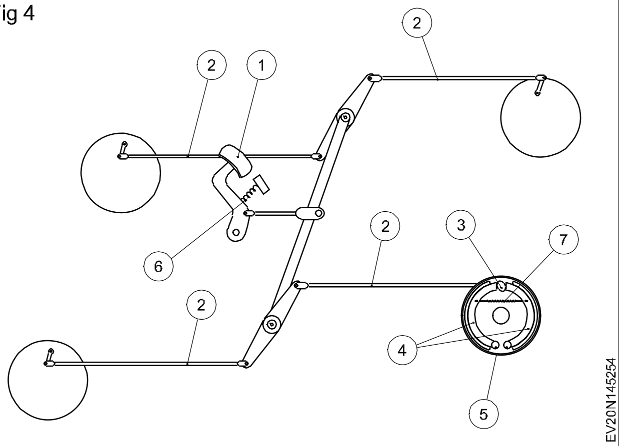
Fig 3



Mechanical brakes (Fig 4)

When the brake pedal (1) is pressed, the linkage (2) operates the cam (3) and expands the brake shoes (4). The brake shoe comes in contact with the brake drum (5) and stops the brake drum. When the brake is released the brake pedal goes back to its original position with the help of the pedal- return spring (6). The brake shoe comes to its original position with the help of the brake shoe rectracting spring (7), and allows the brake drum to rotate. The mechanical brakes are used in two wheelers, three wheelers and the parking brakes of the commercial vehicles.

Fig 4



Mechanical advantage

Mechanical advantage is the ratio of force produced by a machine to the form applied to it. A simple mahcine that exhibits mechanical advantage is called as lever.

In brake system, the multiplied and applied on the wheel by means of mechanical linkage, hydraulic power, pneumatic power or vaccum power.

Hydraulic brakes

Objectives: At the end of this lesson you shall be able to
- **state the principle of a hydraulic brake**
- **state the function of the master cylinder.**

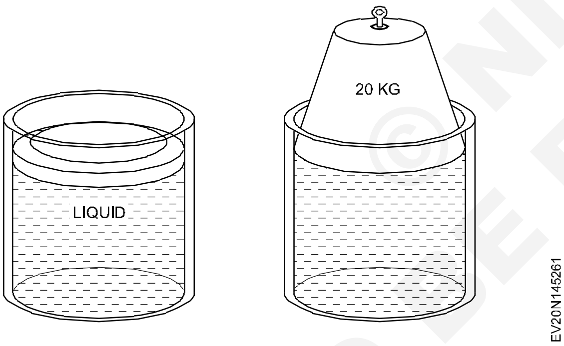
Principle

Hydraulic brakes work under the principle of Pascal's law.

Pascal's law

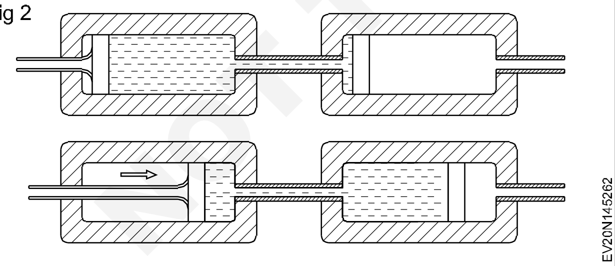
- Liquid cannot be compressed. (Fig 1)

Fig 1



- Motion can be transmitted through a liquid. (Fig 2)

Fig 2

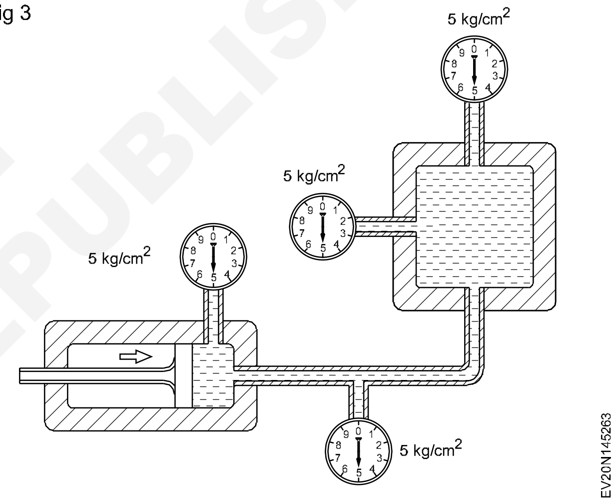


- Liquid pressure is transmitted equally in all directions. (Fig 3)

Operation (Fig 4)

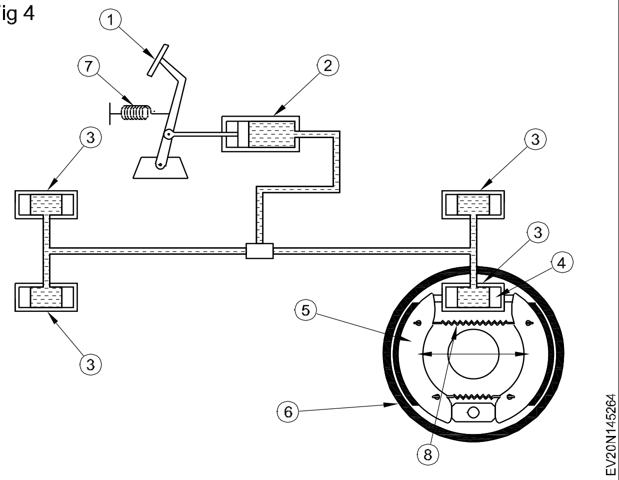
When the brake pedal (1) is pressed the fluid inside the master cylinder (2) is pressurized and supplied to the wheel cylinders (3). The wheel cylinder pistons (4) push the brake shoes (5) towards the brake drum (6). The friction between the brake shoe lining and the brake drum stops the rotation of the brake drum (6).

Fig 3



When the brake is released the brake pedal comes to its original position with the help of the pedal return spring (7). The brake shoes come to their original position with the help of the brake shoe retracting spring (8). When the brake shoe returns to its position, it pushes the wheel cylinder pistons inside, and the pressurized fluid is sent back to the master cylinder.

Fig 4



Components of hydraulic brakes they are

Master cylinder

Wheel cylinder

Connecting pipes

Brake fluid

Brake fluid reservoir

Master cylinder

It serves as a pump to build up hydraulic pressure to operate the brakes. It maintains the level of the fluid in the system.

Types

- Single barrel master cylinder
- Tandem master cylinder
- Centre feed master cylinder
- Tank type master cylinder

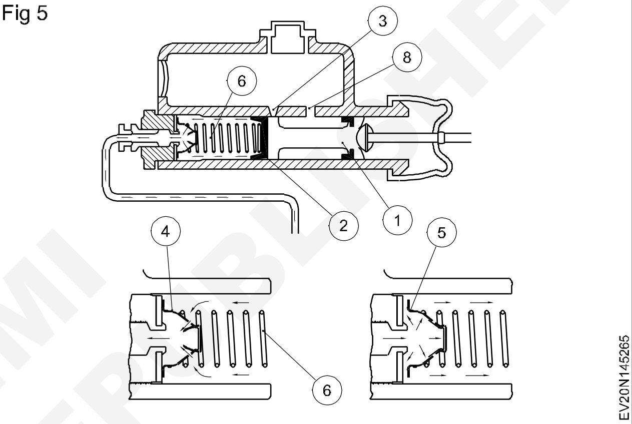
Single barrel master cylinder (Fig 5)

When the master cylinder reservoir is filled, the fluid reaches only on the back side of the primary cup.(2) When the pedal is pumped (pumping action) the master cylinder piston returns quickly, and a partial vacuum is created in front of the piston (1). Due to the partial vacuum in the front side of the primary cup, the fluid from the back side of the primary cup reaches the front side of the primary cup via the transfer port (8) by the folding edges of the primary cup. When the brake pedal is pressed the master cylinder piston (1) moves forward and the primary cup (2) covers the compensating port (3). The fluid inside the master cylinder is pressurized and supplied to the wheel cylinders through the non-return check- valve (4).

When the brake is released the pressurized fluid is sent back to the master cylinder by lifting the check-valve (4) from its seat (5) against the master cylinder spring (6) tension.

When the brakes are in a fully released position the master cylinder piston spring keeps the check-valve assembly to its seat trapping some pressure in the wheel cylinders and lines, normally about 15 to 17 lbs. This pressure is to keep the wheel cylinder cups and lines from leaking and avoid the possibility of air entering the system.

Fig 5



Master cylinder (Types)

Objectives: At the end of this lesson you shall be able to
- **state the different types of master cylinders**
- **state the advantage of a tandem master cylinder**
- **state the function of a tandem master cylinder**
- **state the function of the centre feed master cylinder**
- **state the function of the tank type master cylinder.**

The other three types of master cylinders are

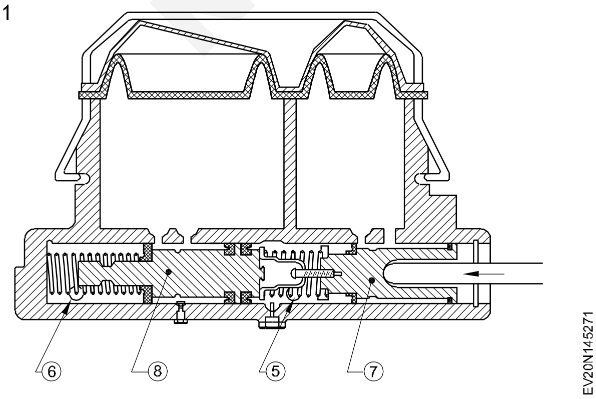
– tandem master cylinder

– centre feed master system

– tank type master cylinder.

Tandem master cylinder (Fig 1)

Fig 1



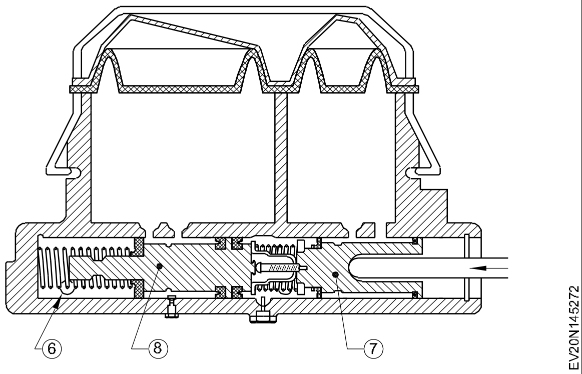
In a tandem master cylinder two separate cylinders and reservoirs are provided in the same body. There are two check-valves, one each for the front and rear brakes. In this type,in the event of failure of one brake line (front or rear), the other continues to work and stops the vehicle. This is also called dual line brake. This is compulsory as per current motor vehicle act in India in all heavy vehicles.

Operation

When the brake pedal is pressed, the primary piston (7) is forced in the cylinder. Fluid is forced to go to the pipelines passing through the check-valve (5) to the front brakes. Further pressing of the brake pedal forces the primary piston (7). The fluid pressure forces the secondary piston (8) into the cylinder. The fluid is forced through the check-valve (6) to the rear brakes. Further pressure on the brake pedal exerts equal pressure on the shoes of all the four wheels.

Failure of brakes (Fig 2)

Fig 2

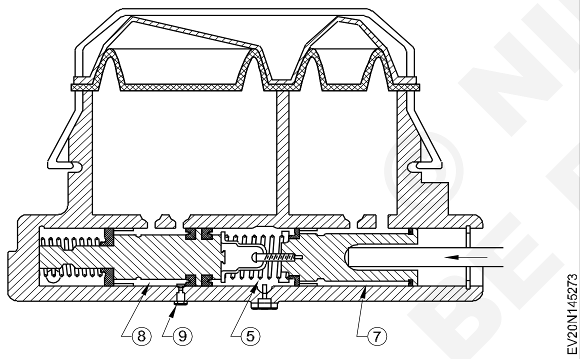


When the front brake fails the primary piston (7) is forced forward till it contacts the secondary piston (8). Now, both the pistons move together.

Pressure is created on the secondary side and this forces the fluid through the check-valve (6) to the rear brakes and the vehicle is stopped.

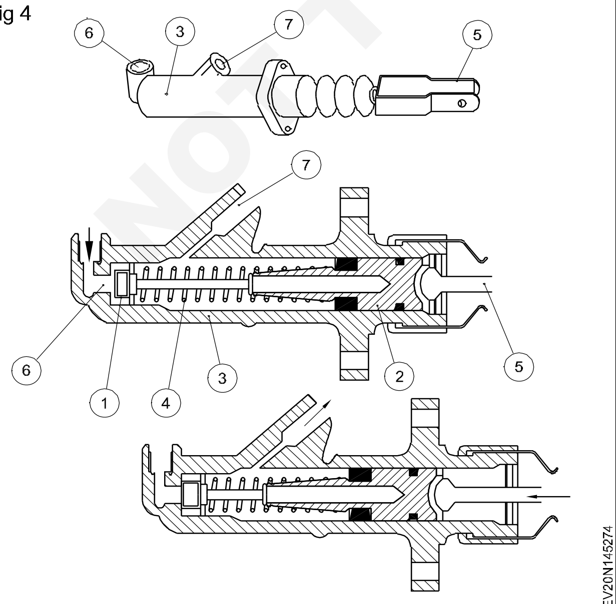
When the rear brake fails (Fig 3) there is no pressure on the secondary side. The pedal effort pushes the primary piston (7) which forces the secondary piston (8) to stop (9). Further movement of the piston (7) builds up the fluid pressure which is transmitted to the front wheel cylinders through the check-valve (5) and the vehicle is stopped.

Fig 3



Centre feed master cylinder (Fig 4)

Fig 4

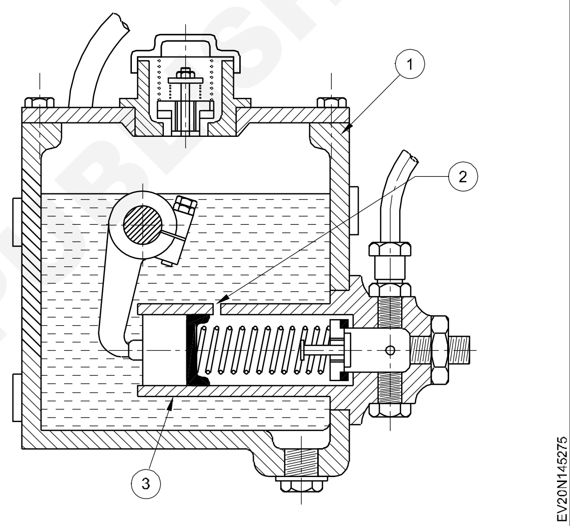


In this type of a master cylinder a non-return valve (1) is provided on the piston's (2) head. When the brake is released, a vacuum created by the rapid return of the piston causes the fluid to flow into the cylinder (3) by lifting the light coil spring (4) and opening the non-return valve (1). When the system is at rest, the non-return valve sits on its seat and thus full compensating is effected through the bypass port. When the brake pedal is pressed the push-rod (5) moves inside the cylinder. The non-return centre valve (1) seals the inlet (6). The pressurized liquid is sent to the wheel cylinders through the outlet passage (7) to apply the brake.

Tank type master cylinder (Fig 5)

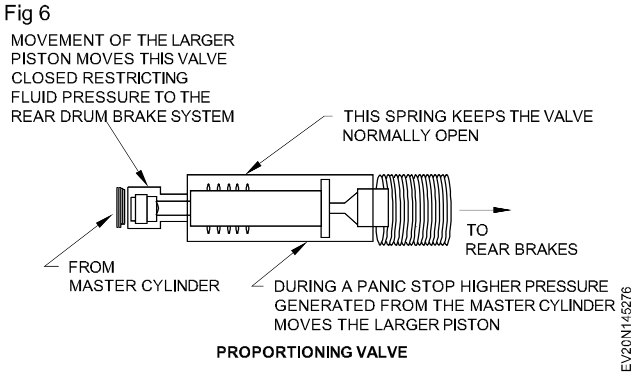
It is also called a submerged type master cylinder. In this type the master cylinder (3) is mounted in a reservoir (1) and a by-pass port (2) is provided on the top of the master cylinder to supply fluid to the master cylinder (3) from the reservoir (1). The operation of this type is the same as that of the ordinary barrel type master cylinder.

Fig 5



Brake proportioning valves (Fig 6)

Fig 6



The proportioning valve is installed on vehicle's with front disc, rear drum brake systems. They provide balanced braking during sudden, hard braking by restricting fluid pressure to the rear brakes. This helps prevent rear wheel lock up as the vehicle's weight is shifted toward the front wheels.

The typical inline proportioning valve remains open until a panic brake situation occurs. During a sudden braking situation, high pressure from the master cylinder moves the larger piston, closing the valve restricting fluid pressure. In late model vehicles these valves have been incorporated into the combination valve along with the metering valve and failure warning light switch. Many proportioning valves are mounted directly in the master cylinder outlet to the rear brakes. It is providing highly effective and well balanced braking of all the wheels.

A height sensing proportioning valve is installed in the hydraulic line leading to the rear drums. They are found on many light trucks, located between the vehicle's chassis and the rear axle. When a driver brakes hard, the rear lifts up and forward. This lightens the load on the rear tires increasing the chance of lock up. It incorporates a lever attached to a spring that moves a valve to restrict fluid pressure as the vehicle's chassis raises up and away from the axle.

An electronic brake proportioning EBP has replaced the conventional proportioning valve in many late model vehicles. This system monitors the speed difference between the front and rear wheels and utilizes the ABS system to prevent rear wheel lock-up. (Fig 7)

Fig 7

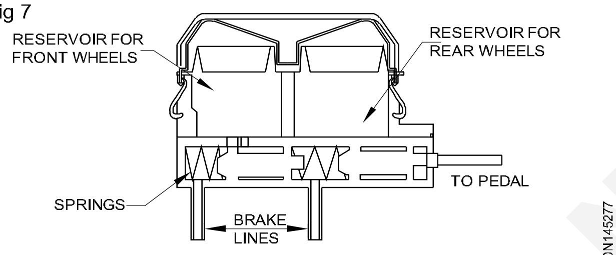


DIAGRAM OF MASTER CYLINDER

When the brake pedal is depressed, it pushes on the first (primary piston) through a linkage. The pressure builds in the cylinder and lines as the brake pedal is depressed further. The pressure between the primary and secondary piston forces the secondary piston to compress the fluid in its circuit. When the brakes are operating correctly, the pressure will be the same in both circuits.

A proportioning valve is required on vehicles that have disc brakes on the front wheels and drum brakes on the rear wheels. Disc brake pads are normally contact with the disc, while the drum brake shoes are normally not in contact wtih the drum. If the pressure was not proportioned the disc brakes would engage before the drum brakes when you depress the brake pedal.

The proportionaling valve compensates for this, allowing the drum brakes to engage first before the disc brakes. The proportioning valve does not allow any pressure determined pressure is low when compared to the maximum pressure in the braking system, this allows the drum brakes to engage before the disc brakes egage. Having the rear brakes engage first provides the control and stability needed to stop our vehicle safety.

Electro hydraulic brake (EHP) system

In an electro-hydraulic set-up, the required brake pressure is instead typically generated by a hydraulic pump and accumulator assembly. The distribution of brake pressure around the car is controlled by a hydraulic unit, feed with presssurised fluid from the accumulator and motor, while a brake ECU interprets various inputs and generates the approporiate control signals. This system is also a hydraulic brake by wire system.

When the driver press on the pedal. sensors monitor the pressure applied and the travel of the pedal itself. The ECU interprets these signals., along with other key inputs such as vehicle speed and steering angle and generates command signals for the hydraulic control unit.

Pressurised brake fluid is then discharged from the accumulator, travelling through solenoid-operated valves in the hydraulic control unit to the individual brakes, slowing the car. This approach has many advantages, such as the system being able to continue to increase braking pressure if an emergency situations detected -whereas a driver might otherwise let off slightly. In the EPB systems the master cylinder will feature a pressure simulator which generates increased pressure as the pedal in depressed in order to ensure suitable brake pedal feel. The master cylinder is also hydraulically linked to the braking system. In some cases just the prompt wheels, in order to provide emergency stopping. (Power element of the EPB fail)

Power assisted servo brakes

Objectives: At the end of this lesson you shall be able to
- **state the need of power-assisted hydraulic brakes**
- **draw the layout of a vacuum-assisted hydraulic brake**
- **list out the various types and their functions in the vacuum-assisted hydraulic brake.**

Power assisted servo brakes

It reduces the brake pedal effort without affecting the braking efficiency. Two types of power-assisted servo brakes are used.

- Vacuum-assisted power brakes
- Air-assisted power brakes

Vacuum-assisted power brakes (Fig 1)

The power brake unit uses the vacuum produced in an engine.

A booster cylinder (1) is a closed cylinder with a piston or diaphragm (2) inside. One side of the piston is connected to the master cylinder (3) through a push-rod (4). The other side is connected to the brake pedal (5) through a linkage (7). A vacuum control valve (6) is placed between the brake pedal linkage (7) and the piston (2).

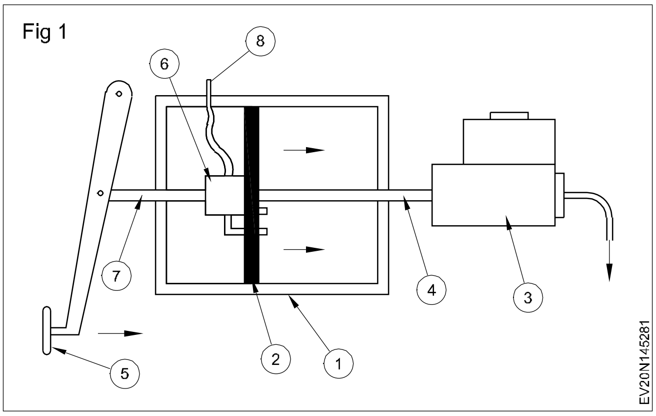


Fig 1

The vacuum control valve (6) admits vacuum or atmospheric pressure to reach both sides of the piston (2). When a driver presses down the brake pedal (5), the vacuum control valve (6) cuts off the atmospheric pressure and opens the vacuum inlet passage (8) to the brake cylinder side. The atmospheric pressure acts on the piston to push the push-rod. This reduces pedal effort.

Vaccum-assisted power brakes are divided into two types.

Vacuum suspended power brakes (Fig 2)

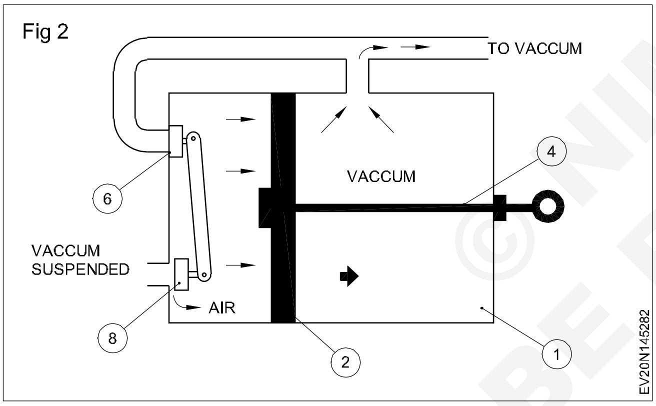


Fig 2

A booster (1) has a vacuum existing on both sides of the diaphragm or piston (2) when the booster is in a released position. When the brake is applied, the atmospheric pressure is admitted to one side of the piston by closing the vacuum valve (6) and opening the air valve (8). The difference in pressure on both sides of the piston causes the necessary movement of the piston along with the push-rod (4).

Atmospheric air-suspended power brakes (Fig 3)

The booster (1) has atmospheric pressure on both sides of the piston (2) when it is in the released position. When the brake is applied a vacuum is created on one side by closing the air valve (8) and opening the vacuum valve (6) to cause the piston to move along with the push-rod.(4)

This type of power-assisted brakes will not operate if the engine is not running. A small vacuum tank is included to provide enough vacuum for several brake applications after the engine has stopped.

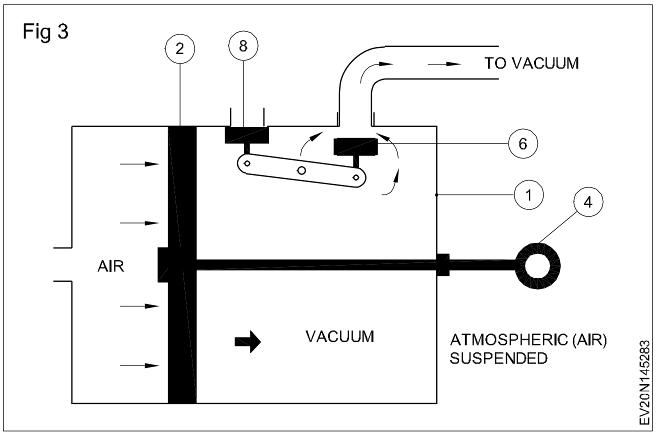


Fig 3

Types of brakes

- Integral type brake
- Multiplier type brake
- Pedal-assisted type brake

Integral type (Fig 4)

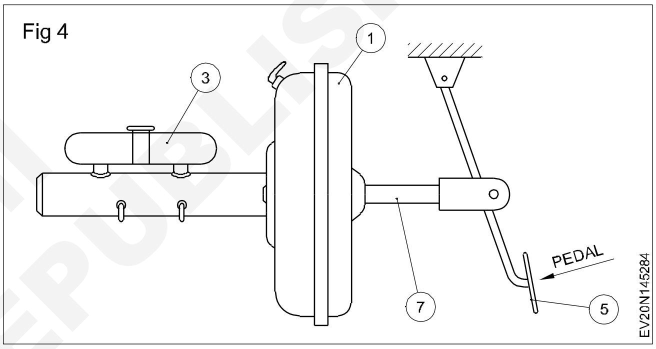


Fig 4

In this type the brake master cylinder (3) is an integral part of the power brake assembly (1). The booster assembly (1) is fitted between the brake pedal (5) and the master cylinder (3). When the brake pedal is operated the linkage (7) actuates a brake valve in the power brake assembly. An atmospheric pressure is applied to one side of the piston or diaphragm and the vacuum to the other side. The difference in pressure causes the piston/diaphragm to move. This movement forces the master cylinder piston inside for effective braking. Most cars and light vehicles use this type of system.

Multiplier type (Fig 5)

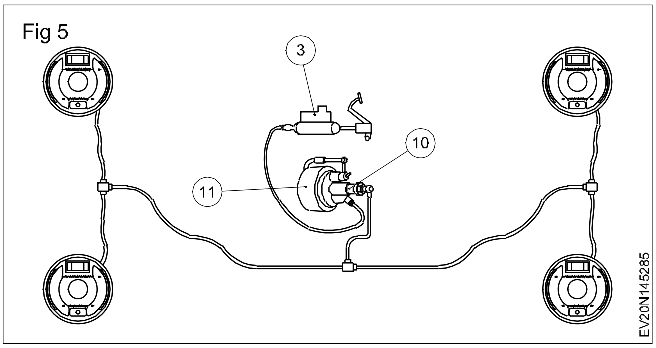
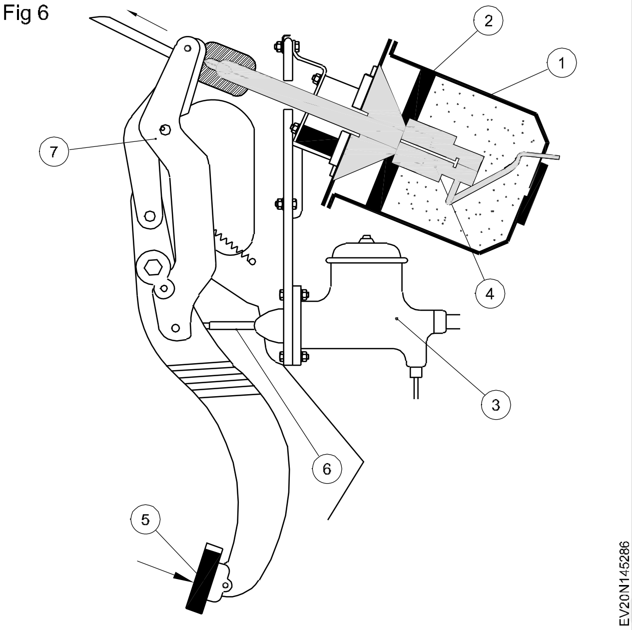


Fig 5

This type multiplies the pressure produced by the hydraulic cylinder (10) . When the brake is applied, the hydraulic pressure from the master cylinder (3) actuates a control valve in the multiplier unit (11). This causes to admit atmospheric pressure to enter at one side of the diaphragm. The other side of the diaphragm has a vacuum. Due to the difference in pressure the diaphragm is forced to move. This produces high hydraulic pressure which is transmitted to the wheel cylinders. A very light pedal pressure multiples several times and produces heavy braking action.

Pedal-assisted type (Fig 6)

Fig 6

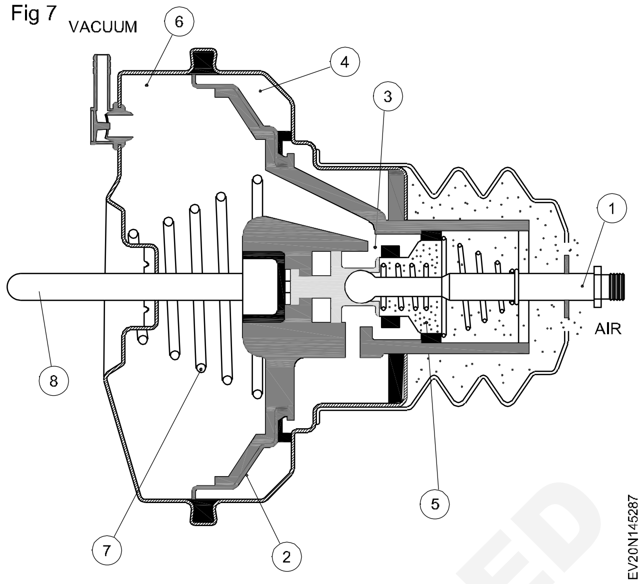


This system has a power cylinder assembly (1). It assists in applying the brakes through a mechanical linkage (7). When the brake pedal (5) is pressed the linkage to the power cylinder is actuated. It causes the valve (4) to open and moves the diaphragm (2) within the power cylinder (1). This movement is carried through the linkages (6) to the master cylinder (3) and increases the total force applied for the braking action. This set up applies the booster pressure to the brake pedal instead of directly to the master cylinder.

Vaccum booster (Fig 7)

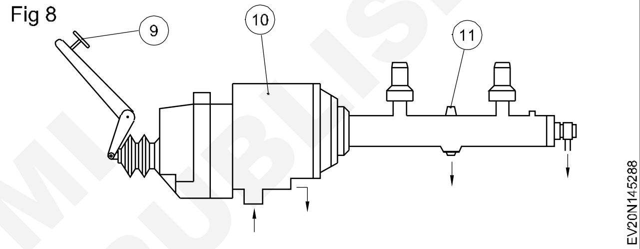
A vaccum booster helps in reducing pedal effort. Inside the booster, vacuum is created when the engine is running and the brake is not applied. In this position the vacuum port (3) of the rear chamber (4) remains open and the atmospheric port (5) remains closed. Thereby vacuum exists in both the front (6) and rear chambers (4). When the brake pedal is pressed its push-rod (1) pushes the diaphragm assembly (2). This causes the vacuum port (3) to close and the atmospheric port (5) to open. Now,vacuum exists only in the front chamber (6) and air at the atmospheric pressure exerts in the rear chamber (4). This forces the diaphragm assembly (2) to move towards the front chamber and pushes the master cylinder push-rod (8) to apply the brakes. When the brake is released the diaphragm assembly (2) comes back to its original position by the return spring (7), closing the atmospheric port (5) and opening the vacuum port (3).

Fig 7



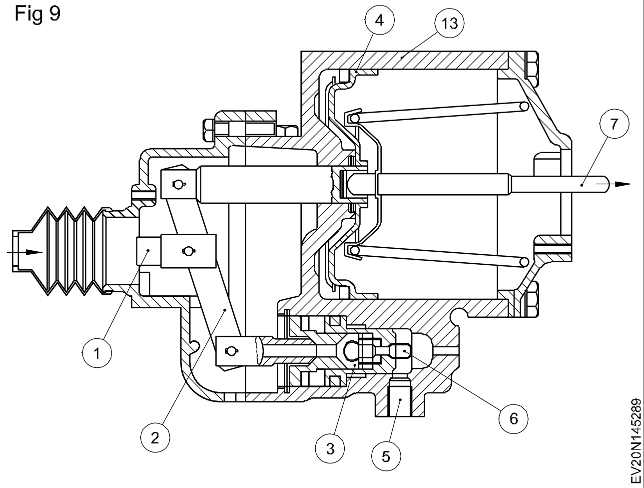
Air-assisted power brakes (Fig 8)

Fig 8



In this system instead of a vacuum, air pressure is used to assist in the application of brakes. It is a lever type servo-fitted (10) on the chassis. The front end is linked to the brake pedal (9) and the rear to the master cylinder (11). This will boost the force applied on the master cylinder at the time of application of the brakes. Details of servo unit 10 shown in Fig 9.

Fig 9



Operation

When the brake pedal is pressed, the fork rod (1) which is linked to the brake pedal presses the lever (2). The lever (2) is linked with the air control valve (3). The air control inlet valve (6) opens and allows high pressure air from the air compressor to reach into the cylinder (13) behind the piston (4) through the air inlet port (5). The piston (4) moves forward pushing the master cylinder piston rod (7). The brake fluid under high pressure goes to the wheel cylinders to actuate the brakes.

The functions of the other units in this system like the air compressor, unloader valve, flick valve etc, are the same as in the air brake system.

The piston rod (7) is linked to the brake pedal rod (9) in such a way that in the event of air pressure failure, the pedal rod (9) can press the master cylinder rod (7) and the vehicle can be stopped.

Drum brake

Objectives: At the end of this lesson you shall be able to
- **state the various components of drum brake**
- **state the functions and operation of drum brake.**

Types of brakes

There are two types of brakes

1 Drum brake

2 Disc brake

  a fixed - caliper disc brakes

  b floating - caliper disc brake

1 Drum brake

A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum.

Components of drum brake (Fig 1)

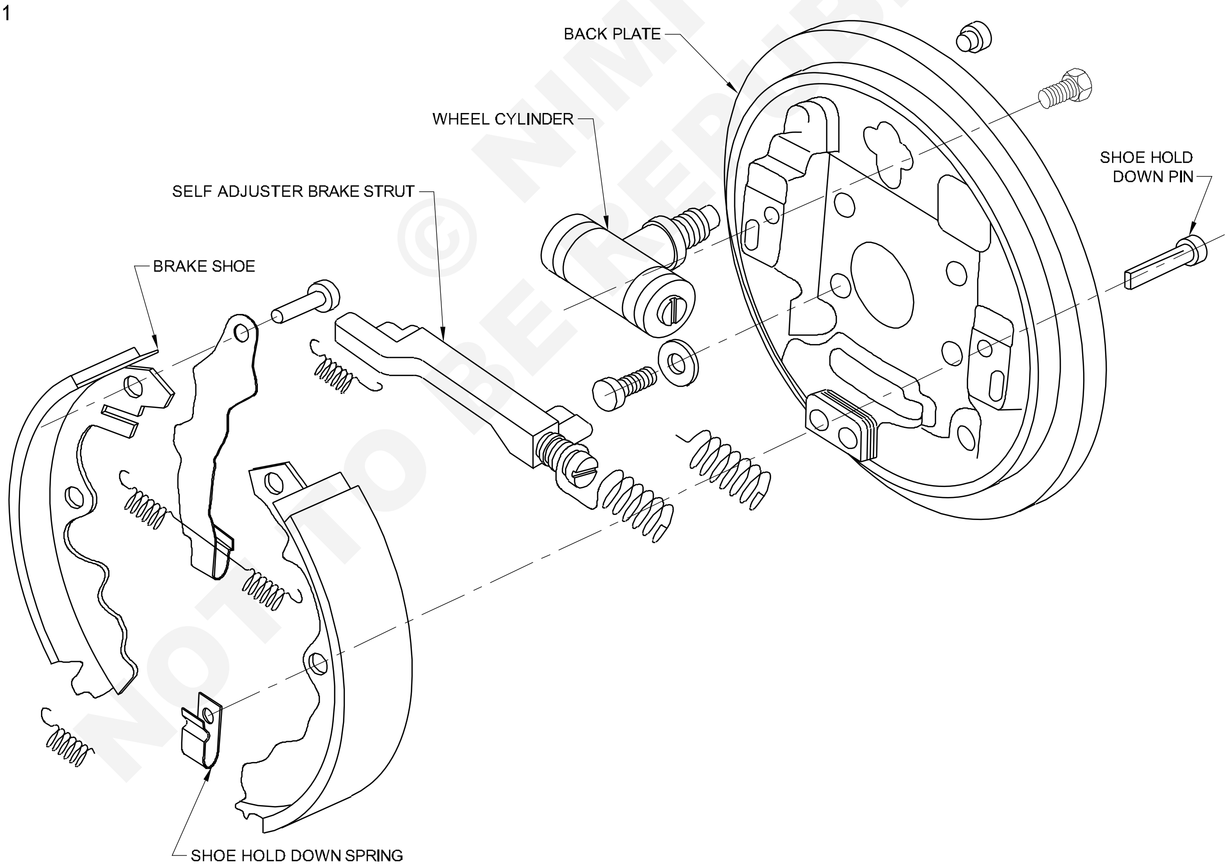
Back plate

The back plate provides a base for the other components. It attaches to the axle and forms a solid surface for the wheel cylinder, brake shoes, and assorted hardware. Since all braking operations exert pressure on the back plate, it must be strong and wear resistant.

Brake drum

It is positioned close to the brake shoe without touching it, and rotates with the wheel and axle. When a driver applies the brakes, the lining pushes against the inner surface of the drum which generates friction heat of high amount. So, the brake drum is generally made of a special type of cast iron that is heat conductive and wear resistant.

Fig 1



COMPONENTS OF A DRUM BRAKE

Wheel cylinder

The wheel cylinder consists of a cylinder that has two pistons, one on each side. Each piston has a rubber seal and a shaft that connects the piston with a brake shoe. When brake pressure is applied, the piston are forced out pushing the shoes into contact with the drum. One wheel cylinder operates the brake on each wheel. Hydraulic pressure from the master cylinder acts on the piston cup, pushing the pistons toward the shoes, forcing them against the drum. When the driver releases the brakes, the force of the brake shoe retract spring returns the piston to its original position.

Brake shoe

Brake shoes are typically made of two pieces of sheet steel welded together. The friction material is either riveted to the lining table or attached with adhesive. The crescent - shaped piece is called the web and contains holes and slots in different shapes for return springs, hold down hardware, parking brake linkage and self adjusting components. All the application force of the wheel cylinder is applied through the web to the lining table and brake lining. Each brake assembly has two shoes a primary and secondary. The edge of the lining table generally has three "V" shaped notches or tabs on each side called nibs. The nibs rest against the support pads of the backing plate to which the shoes are installed.

Self adjuster brake strut

The self - adjuster is used to adjust the distance between the brake shoe and the drum automatically as brake shoes wear.

Operation

When brake pedal is pressed, either through Mechanical / hydraulic / pneumatic means, brake shoes expands against the drum. Many drum brakes are self-actuating. The brake shoes contact the drum, there is a kind of blocking action, which has the effect of pressing the shoes into the drum with more force. Because of this action, the shoes must be pulled away from the drum when the brakes are released. For which springs are provided to hold the brake shoes in place and return the adjuster arm after it actuates.

Advantages

Self reinforcement , Dirt-proof design, Parking brake easier to use.

Disadvantages

Maintenance is costly; Pad replacement is time consuming, Poor heat dissipation Tendency towards fading.

Disc brake

Objectives: At the end of this lesson you shall be able to
- **state the various components of disc brake**
- **state the function and operation of different types of disc brake.**

Disc brake

Disc brake also works on the principles of the drum brake, disc which rotates along with the vehicle wheel and is partially held by a brake caliper assembly mounted on the suspension. When the brake pedal is depressed, the brake pads mounted on the inside and outside of the housing are pressed hydraulically against the rotating disc.

Major components of disc brake are

Disc, Piston, Brake pads and piston housing bracket.

Types of disc brakes

Disc brakes are categorized into

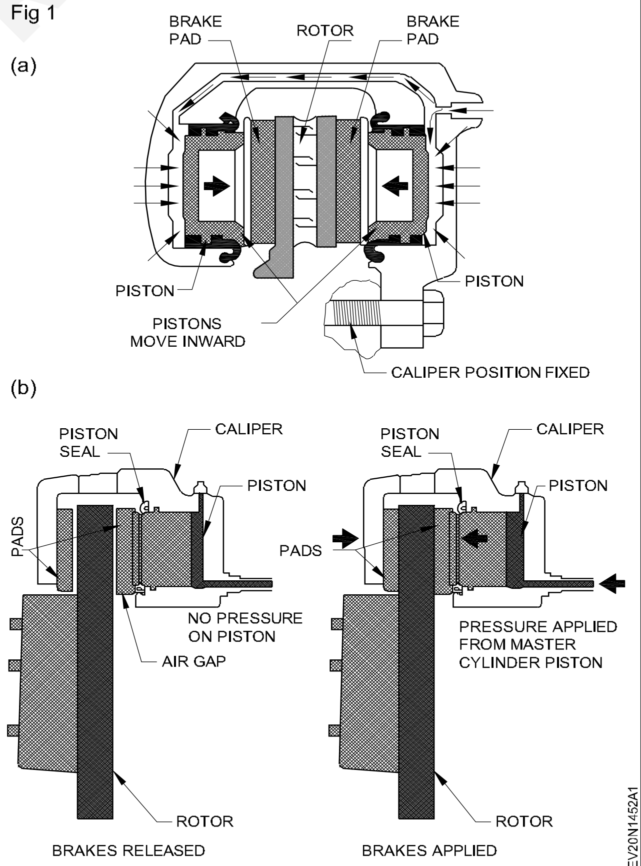
a Fixed caliper disc brake (Fig 1a)

It contains two pistons in housing and brake pads on the piston. On applying force over brake pedal, the hydraulic fluid passes through piston housing bracket and makes the two pistons move against the brake pads located in the housing and after closing the air cap these are pressed against the rotating brake disc. Nowadays, this type is rarely used.

b Floating caliper disc brake (Fig 1b)

When the brakes are applied, the piston moves in the housing and recesses the inner pad against the rotating brake disc. The hydraulic pressure in the cylinder of the piston housing acts both on the surface of the piston and on the bottom of the piston housing. As result, the piston housing slides on the locating studs in the opposite direction and the outer brake pad is drawn against the brake disc with same force from the wheel side. when the brake release, the air gap between the pads and the brake disc is restored force of the piston sealing ring.

Fig 1



Wheel cylinder

Objectives: At the end of this lesson you shall be able to
- **state the function of a double piston wheel cylinder**
- **state the function of a stepped wheel cylinder**
- **state the function of a single piston wheel cylinder**
- **state the function of the baffle type wheel cylinder.**

The fluid pressure of a pipeline is increased in the wheel cylinder by using a bigger diameter piston. This increased fluid pressure is applied on the brake shoes by the pistons, and braking action is achieved.

Operation of wheel cylinder

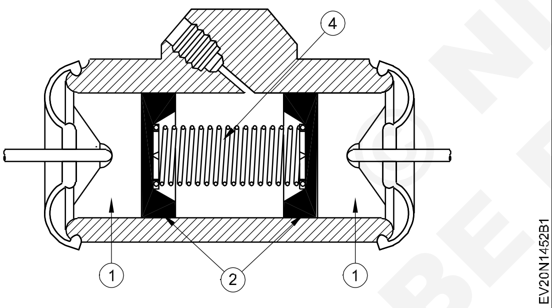
The space in the cylinder bore between the cups (2) always remains filled with fluid. When the brake pedal is pressed, additional brake fluid is forced into the cylinder bore under pressure. Due to this pressurized fluid, the cups (2) and pistons (1) move outward and expand the brake shoes. The expanded brake shoes come in contact with the brake drum and stop the vehicle.

There are four types of wheel cylinders used with drum brakes.

Double piston with straight bore (Fig 1)

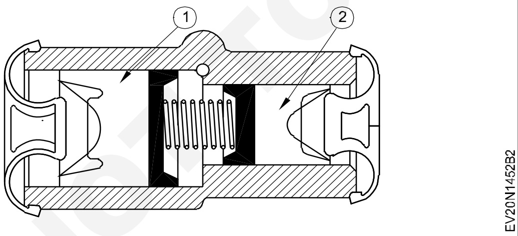
In this type two pistons (1) are used in a single bore. These pistons are separated by a spring (3). Each piston is connected to one brake shoe.

Fig 1



Double piston with step bore (Fig 2)

Fig 2



This type of wheel cylinder is similar to the double piston with a straight bore with the difference that a stepped bore is used instead of a straight bore. Both the pistons (1) & (2) have different diameters, so the pressure on each brake shoe is different.

Single piston wheel cylinder (Figs 3 & 4)

There are two wheel cylinders each of which will operate one shoe independently. In this type one piston (1) is used in one cylinder. One end of the wheel cylinder (5) is pivoted and the other end is connected to the brake shoe and actuates the brake shoe (6) when the pedal is pressed.

Fig 3

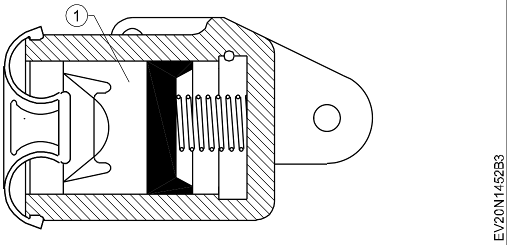
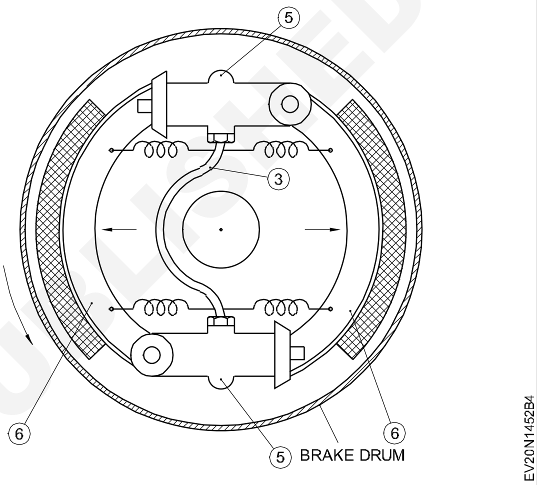


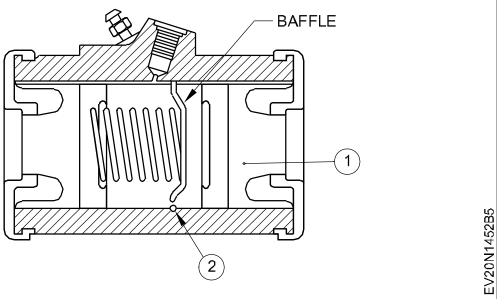
Fig 4



The two wheel cylinders are connected by a pipe line (3). Both the wheel cylinders have equal diameter; so equal pressure is exerted on both the brake shoes. In this type both shoes becomes leading shoes in the forward direction. This allows equal wear on both the brake shoes.

Baffle type piston wheel cylinder (Fig 5)

Fig 5



This type is used to avoid clinking noise during braking while the vehicle is moving in reverse. In this type an orifice (2) is drilled on the base of the cylinder. The orifice (2) reduces the flow of fluid from the front half to the rear half, thereby causing the primary shoe to operate first and the secondary shoe expands a little later. So the noise is avoided.

Brake fluid

Objectives: At the end of this lesson you shall be able to
- **state the necessity of bleeding the brake system**
- **state method of brake pedal adjustment**
- **state the characteristics of brake fluid**
- **state the advantages and disadvantages of a hydraulic brake.**

Bleeding of hydraulic brake system

The hydraulic brake system must be bleed whenever the fluid line has been disconnected or air gets into the system. A leak in the system may sometimes be indicated by a spongy brake pedal. Air trapped in the system is compressible and does not permit pedal effort to be transmitted to the brakes. The system must be absolutely free from air at all times.

Brake pedal adjustment

There should be always at least 12.7mm (1/2") free pedal travel, before the push rod engages the master cylinder piston. This adjustment is accomplished by shortening or lengthening of the brake master cylinder eye-bolt. This is done so that the primary cup will clear the bypass port when the piston is in the off position. This will prevent the compensating action of the master cylinder against temperature changes of the brake fluid.

Brake fluids

Characteristics of brake fluid

- It should be able to flow freely at extremely high and low temperatures.
- It should be able to serve as a lubricant.
- It should be anti-corrosive and anti-rust.
- It should show resistance to evaporation.
- It should not damage or swell the rubber parts.

Use only approved brake fluids in a brake system. Any other fluid such as power steering fluid, automatic transmission fluid, or engine oil, which has a petroleum base, must never be used in the brake system. Petroleum based fluids will damage the rubber components in the brake system, like the piston cups and seals, and cause them to swell and disintegrate.

Advantages of a hydraulic brake

- Simple in construction.
- Equal braking at all the wheels.
- Wear of the parts is less.
- Little maintenance is required.

Disadvantages

- Any leakage of fluid in the line will lead to brake failure.
- Chances of the brake fluid reaching the brake shoes are very high. This will damage the brake shoes.
- If fluid enters the lining it reduces the braking efficiency.

Brake lining

Objectives: At the end of this lesson you shall be able to
- **state the material required for the brake lining.**

Two types of brake linings are used.

- Organic brake lining
- Semi-metallic brake lining

Organic brake lining

These linings are moulded from a mixture of asbestos, fibre glass, asbestos fibres etc. Resin is used as a binding material.

The blend of raw materials for our friction materials (brake pads, brake linings)

Disc brake pads and drum brake linings are made from a blend of 10 to 20 kinds of raw materials. Depending on their specific roles, the raw materials are divided into three categroes; “blending material”, “stiffener: and “friction adjustment material”.

The bonding material hardens raw materials and gives the materials their intensity. Mainly phenol resin is used currently.

The stiffener gives the friction materials further intensity. Various kinds of organic and inorganaic, fibers, such as aramid fibers and metal fibers are used.

The friction adjustment material mainly adjusts the effectiveness of friction materials. It is used for strengthening the effectiveness or stabilizing a lubricants, organic, fillers, inorganic fillers, abrasive material and metal powder are blended as necessary.

- 1 Sintered alloy

The phenomena where the particles of powder material join together and turns into a solid substance by pressurizing and fabricating the powder matetial and heating it at temperature below the melting point. Material that is not made by melting metal, but instead by sintering metal powders is called sintered alloy.

- 2 C/C composite

Carbon fiber reinforced carbon composite. Carbon composite material has been strengthened with carbon fiber. It is extremely thermally stable and light-weight.

- Friction materials
  - Organic type
    - Asbestos
    - Non-asbestos
  - Metallic type — Sintered alloy*1 Main material copper, brass and steel
  - Inorganic type — C/C composite*2

This material is often used for brake rotors and brake pads for aircraft and racing cars.

Performance requirements for friction materials (brake pad, brake lining)

Further more, friction materials are required to exercise stable effectiveness (minimum fluctuation of effectiveness) under varying conditions, such as vehicle speed, laden weight or temperature change from brake, usage as well as under different environment influences including humidy, water and mud. Strength to withstand thermal disturbances and mechanical strength are also important design criteria.

Durability is another important property of friction materials as they wear with use. Moreover, when brakes are applied, squeal, noise and vibrations must be minimized. Further more, the friction materials should not cause damage to the material they get into contact, such as the disc rotos. Friction materials also require to have low thermal conductivity to prevent temperature buildup of the brakes themselves or brake oil.

Main performance requirements for friction materials are:

- Optimum effectiveness, i.e. appropriate friction coefficient (μ).
- Stable effectiveness under various usage and/or environmental conditions.
- Strength to withstand thermal disturbances and mechanical strength.
- High level of durability.
- Minimized brake squel, noise and vibrations.
- Low damage to the contact material, such as the disc rotor.
- Low thermal conductivity.

Semi-metallic brake linings

These linings are mostly used for front disc brakes in front wheel drive vehicles. It is made of fine polished steel wool. It also includes iron powder and graphite. Plastic resin is used as a binder. The mixture is heated and pressed to form the lining. Semi-metallic linings are more wear and heat resistant than organic linings. Semi- metallic linings can retain their coefficient of friction when operating at very high temperatures.

Brake adjuster

Objectives: At the end of this lesson you shall be able to
- **list out the different types of brake adjusters**
- **state the operation of the different types of brake adjusters**
- **list out materials required for the brake drum**
- **state the need of the turning brake drum.**

The following types of brake adjusters are used.

1 Serrated wheel brake adjuster

2 Slack adjuster for ‘S’ Cam brake

3 Wedge type brake adjuster

4 Snail and cam type adjuster.

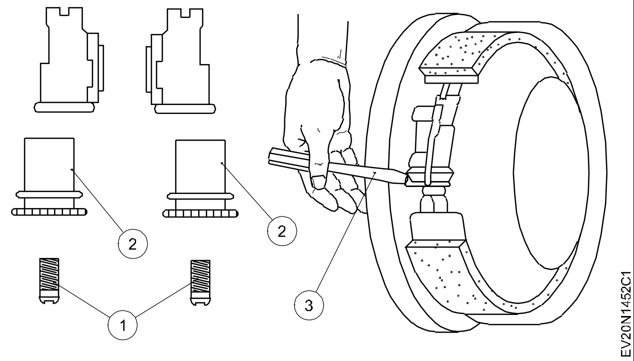
Serrated wheel brake adjuster (Fig 1)

In this type an adjusting screw head (1) fixed with the serrated wheel (2) is screwed in the head of the wheel cylinder end covers. This adjusting screw (1) can be screwed in or out by moving the serrated wheel with a screwdriver (3) through an opening at the back of the end plate (4) .

Slack adjuster for ‘S’ Cam brake (Fig 2)

Slack adjuster adjusting nut is rotated to move the cam to set the required brake lining to drum clearance. Thereafter adjusting nut is locked.

Fig 1

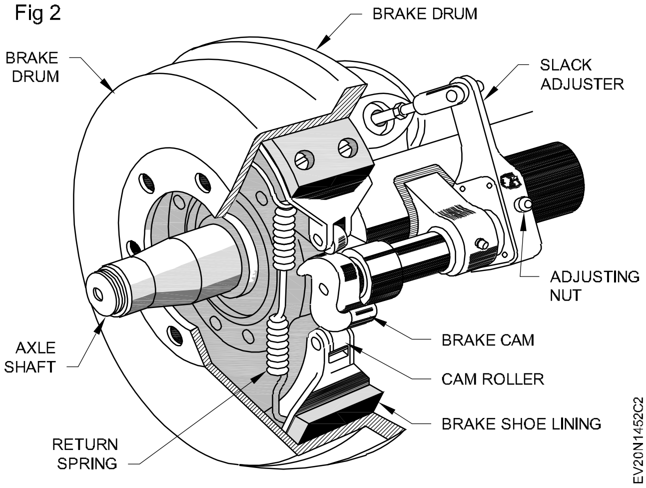


Automatic brake adjusting slack adjuster have already been introduced and being fitted in commercial vehicles now a days. (Fig 3)

Wedge type adjuster (Fig 4)

In this type a bolt (1) called wedge is used. The wedge (1) has a tapper end on which two links (2) rest. The links (2) are connected to the brake shoe. When the

Fig 2



wedge (1) is screwed in, the links (2) move apart and expand the brake shoes.

Snail and cam type adjuster

In this type one end of the brake shoes rests on a cam (1). The cam's outer end is square or hexagonal. The cam can be rotated by a spanner. When it is rotated the brake shoes expand. It is simple and is widely used in small vehicles.

Brake drum

The brake drum is made of the following materials.

- Cast iron
- Steel
- Steel-backed with cast iron lining
- Aluminium alloy

Need of the turning brake drum

Brake drums gets scored due to mainly two reasons

1 Brake liner wearing nut upto the rivet which score the drum.

2 Entry of dust & foreign practical entering brake liner and drum. In the event of score, brake drum is to be turned in a lathe upto the prescribed limit of the manufacturers. Check taper and ovality of drum before and after the turning.

manifold, and in the cylinder. Since the exhaust is being compressed and there is no fuel being applied, the engine works backwards, slowing down the vehicle. The amount of negative torque generated is usually directly proportional to the back pressure of the engine.

An exhaust brake is a device that essentially creates a major restriction in the exhaust system and creates sunstantial exhaust back pressure to retard engine speed and offer some supplemental braking. In most cases, an exhaust brake is so effective that it can slow a heavily loaded vehicle on a down grade without ever applying the vehicle's service brakes. More advanced exhaust brakes have exhaust pressure modulation (EPM) that controls the back pressure which in turn improves the braking performances across a range of engine speeds.

There are several ways of stopping a vehicle such as using the normal brakes, the engine brake or for diesel powered vehicles; drivers can also use an exhaust brake. Exhaust brakes can be very efficient in the long run and it can considerably slow down a vehicle, regardless of its size or weight. It prevent over heating and completely silent.

Anti lock brake system

Objectives: At the end of this lesson you shall be able to
- **state the advantages of ABS**
- **list out the different types**
- **state wheel lock up condition**
- **state hold mode**
- **state normal braking**
- **state electronic brake distribution advantage**
- **Traction control system.**

Anti lock brake sysem

Advantages of ABS

Anti-lock brake systems are designed to prevent wheel lockup under severe braking conditions irrespective of any type of road conditions.

The result is that, during heavy braking ABS:

– retains directional stability (vehicle stability)

– stops faster (shortened stopping distance)

– retains max. control of vehicle (steerability)

– If front wheels lock-up it is no longer possible to steer the vehicle.

– If rear wheels lock-up the car can become unstable and can start to skid sideways.

Split suface braking: When brakes are applied on a combination of slippery and high friction surfaces, the wheels on the slipper surface easily locks-up and the vehicle loose stability and will be dragged towards the high friction side, which may lead to accidents through the oncoming vehicle. But ABS prevent this and offers stability until the vehicle comes to a complete halt.

Types of ABS systems

4-Sensor 4-Channel type: This type is generally used for FF (Front engine Front driving) car. This type has four wheel sensors and four hydraulic control channels and controls each wheel independently.

4-Sensor 3-Channel type: This type is generally used for FR (Front engine Rear driving) car. This type has 2 channels for front wheels and the other one is for rear wheel control.

3-Sensor 3-Channel type: In this type the front wheels are controlled independently but rear wheels are controlled together by one wheel speed sensor (ex. On differential ring gear)

1-Sensor 1-Channel type: In this type only the rear wheels pressure are controlled by one sensor.

How ABS Detects wheel lock up condition

ABSS has got wheel speed sensors on all the four wheels. It continuously calculates the slip ratio of all the four wheels.

Slip ratio: It is the percentage ratio between difference of vehicle speed and wheel speed to vehicle speed.

$$\text{Slip ratio} = \frac{(\text{Vehicle speed} - \text{Wheel speed})}{\text{Velocity speed}} \times 100$$

While wheel speed information is directly taken from wheel speed sensor, vehicle speed information is not attained directly from vehicle speed sensor. There is no vehicle speed sensor information to ABS. It is attained with some logic using wheel speed sensor information only. The reason being exact vehicle speed cannot be attained from sensor, when the wheel is locked and vehicle skidding.

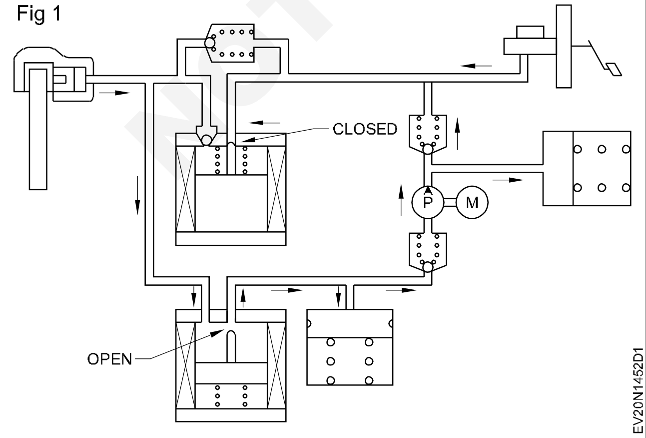
How ABS calculates vehicle speed

At the time of braking the speed of individual wheels differ hence slip ratio also differs. Two wheel drive vehicles uses the maximum wheel speed as vehicle speed at the time of wheel lockup. This gives a fairly correct information above vehicle speed, because the vehicle will tend to propel at that speed.

For ex: At braking if the wheel speed information from all the four wheels in car are 20, 30, 20, 20 Kmph. Then vehicle speed is taken as 30 Kmph for calculating slip ratio of individual wheels.

Dump mode (Fig 1)

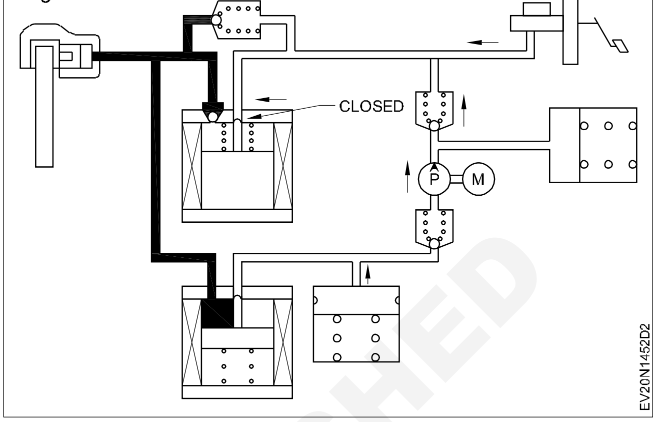
Fig 1



When ABS unit detects a wheel lock up condition it tries to avoid wheel lockup by releasing pressure from wheel cylinder. In this case Solenoid Valve - In, Solenoid valve - Out and motor is ON. Solenoid Valve - In closes the passage from master cylinder. Solenoid Valve - Out opens the passage to pump, which pumps the fluid out reducing the pressure at wheel cylinder.

Hold mode (Fig 2)

Fig 2



Once the pressure is released to some extent to avoid wheel lock up condition, pressure is locked inside wheel cylinder by switching off the Solenoid Valve - Out alone i.e. Solenoid Valve - Out closes the passage from wheel cylinder to pump locking the pressure inside wheel cylinder.

In four wheel drive vehicles since torque is transmitted to all four wheels the chances of four wheel lockup in low friction surfaces are more. Calculation of vehicle speed from wheel speed gives wrong result. Hence four wheel drive vehicle use additional “G” sensor to calculate vehicle speed.

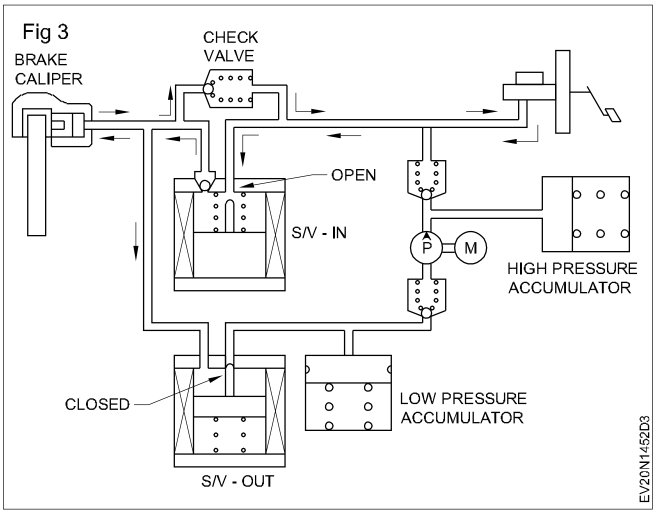
G-Sensor (Acceleration sensor)

G-Sensor is used by the ABS for measuring the deceleration rate of the vehicle whenever brakes are applied. G-Sensor signal output is directly proportional to the Acceleration/Deceleration of the vehicle. Using wheel speed sensor logic has its own disadvantages as there are chances of all the four wheels getting locked up during braking on very low friction surfaces like on ice or slippery surfaces. Under these conditions, it is impossible to calculate the deceleration rate of the vehicle from the wheel speed sensors. In this case, ABS cannot perform efficiently.

Normal Braking (Fig 3)

In normal braking Solenoid Valve - In, Solenoid Valve - Out and motor is off. Brake pressure applied to the master cylinder goes to wheel cylinder through Solenoid valve - In Solenoid valve - IN is normally open type (NO) i.e. it is open when it is off. Solenoid Valve - OUT is normally closed type (NC) i.e. it is closed when it is off. Brake fluid return to master cylinder through check valve in Solenoid valve - IN. This is like conventional braking. ABS operates in normal mode till lockup condition is detected. Once wheel lockup condition is detected ABS

Fig 3



comes into operation i.e. Dump, Hold and Increase mode are executed.

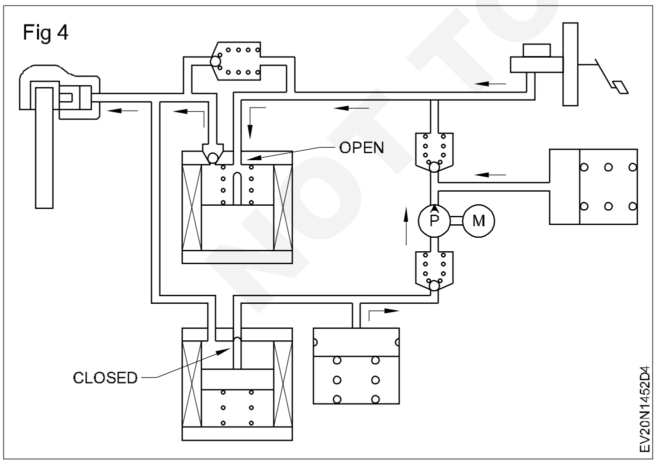
Dump mode

When ABS unit detects a wheel lock up condition it tries to avoid wheel lock up by releasing pressure from wheel cylinder. In this case Solenoid Valve - In, Solenoid Valve - Out and motor is ON. Solenoid Valve - In closes the passage from master cylinder. Solenoid valve - Out opens the passage to pump, which pumps the fluid out reducing the pressure at wheel cylinder.

Increase mode (Fig 4)

In this mode pressure is increased to compensate for the released pressure. The Solenoid Valve condition is similar to normal mode except motor is ON. The pump pushes brake fluid into master cylinder circuit to increase the brake pressure applied to wheel cylinder. The pedal pressure applied by the driver and the motor pressure together from the pressure applied to wheel cylinder. Once the ABS unit does the dumping operator (pressure release) the pressure increase is done in steps of hold and increase for better steering control, stability and better stopping distance.

Fig 4



EBD (Electronic Brake-force Distribution)

The EBD system is a sub-system of the ABS system, it is very effective in controlling the effective adhesion utilization by the rear wheels. It controls the slip of the rear wheels in the partial braking range. The brake force is moved even closer to the optimum range, thus dispensing with the need for a mechanical proportioning valve.

The mechanical proportioning valve has its limitations when speaking about achieving the idea brake force distribution to both the front and rear wheels.

EBD doesn't have any new components in face the same ABS components like wheel speed sensor, electronic unit are used. It is only a logical extension of ABS logic in ECU memory. EBO system provide the solenoid valves to reduce the brake pressure to the rear wheels when the slip ratio of rear wheels ar emore than that of front wheels. EBD failure is indicated by glowing the parking lamp.

EBD advantage (Fig 5)

– Function improvement of the base-brake system
– Appropriate brake force distribution to front and rear wheels with respect to load variations
– Possible to achieve ideal brake force distribution with EBD
– Compensation for the different friction coefficients
– Elimination of the mechanical proportions valve
– Failure indication through warning lamp in cluster.

Maintenance of ABS Brake Systems

The following table should only act as a guide; the manufacturer's recommendations should always be followed.

Traction control system (TCS) (Fig 6)

The TCS system prevents the drive wheels spinning when pulling away and accelerating.

This stabilises the vehicle in the longitudinal direction, the cornering stability is maintained and the vehicle is prevented from breaking away at the powered axle.

The TCS is an enhancement of ABS. Both systems use common sensors and actuators and often have a common ECU where the data exchange is usually carried out via a CAN bus. When the vehicle is being driven with snow chains, the TCS can be deactivated. A distinction can be made between:

- TCS systems with engine intervention.
- TCS systemswith brake intervention, otherwise known as ELSD Electronic Limited Slip Differential.
- TCS systems with engine and brake intervention.

TCS/ELSD brake circuit of a wheel

Advantages

- Improvement of traction when pulling away or accelerating.
- Increase of dirving safely at high motive forces.
- Automatic adjustment of engine torque to the grip rates.
- Driver information about reaching dynamic limits.

TCS with brake intervention/electronic limited slip differential ELSD

An electro-hydraulic system is used as a starting off aid. The lock effect is created as a result of brake intervention on the spinning wheel in order to achieve better traction.

Structure

Hydraulic system

This is composed of a hydraulic pump with suction and delivery valves inter and outlet valves, a hydraulic changeover valve and a check valve with pressure limiter.

Electrical system

This is composed of ABS/TCS (ELSD) ECU and wheel speed sensors.

Operating principle

Pressure build-up

If a driven wheel spins, this is detected by the ECU with a speed sensor. It activates the hydraulic pump and the check valve. The check valve (CV) closes and the pressure generated by hydraulic pump P brakes the spinning wheel.

Pressure holding The inlet valve (IV) is closed.

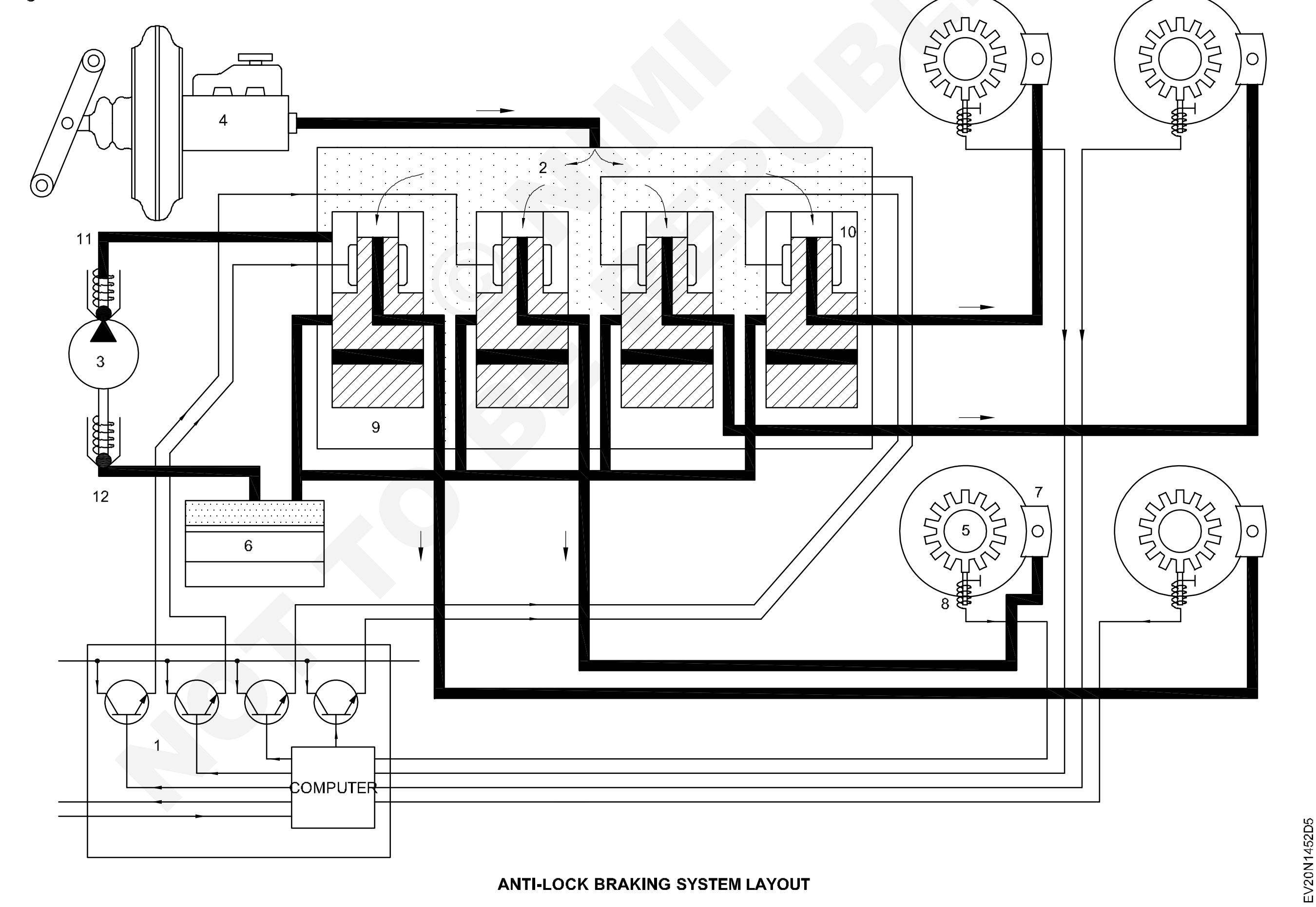
Pressure reduction

If the wheel has stopped spinning, then the inlet and check valves are opened and the pressure is relieved to the expansion tank via the master cylinder.

TCS with engine and brake intervention (Fig 7)

The system works with engine or brake intervention, according to the driving situation. The block collaboration of engine and brake intervention for preventing unreliable wheel slip when pulling away. (TCS operation/ELSD operation) or in overrun mode. (EDTC operation)

Fig 5



ANTI-LOCK BRAKING SYSTEM LAYOUT

Fig 6

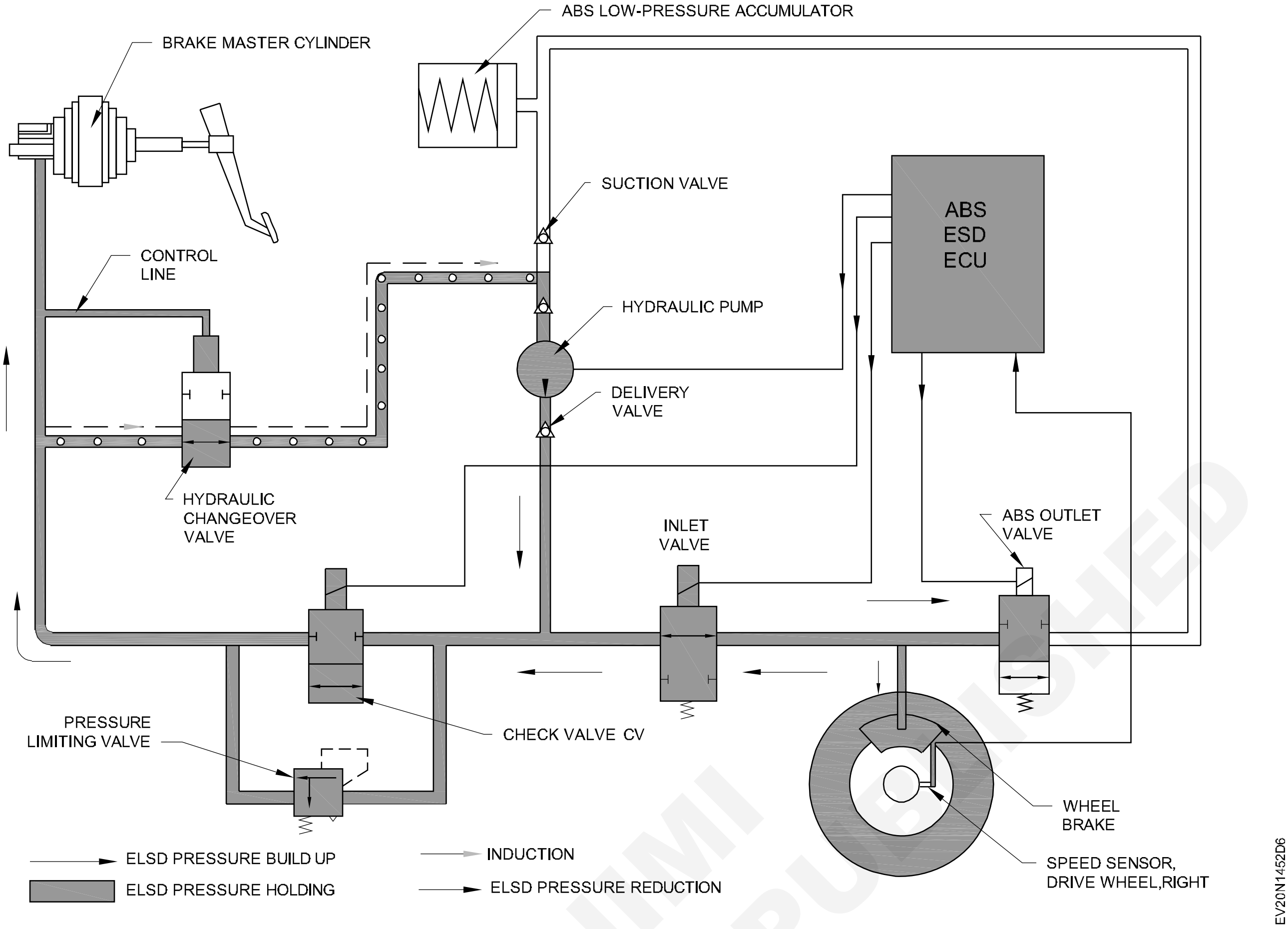
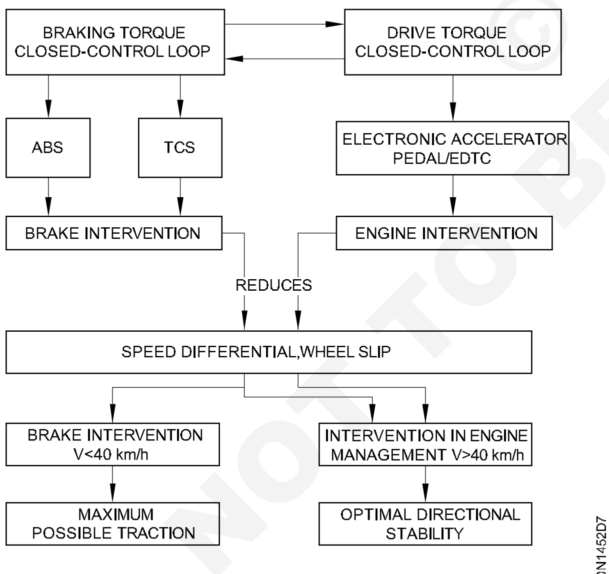


Fig 7



TCS BLOCK DIAGRAM

Tyres

Objectives: At the end of this lesson you shall be able to
- **state the functions of tyre**
- **state the types of tyres**
- **state the construction of tyres**
- **state the tyre specification**
- **state the tyre inflation**
- **state the run flat tyres**
- **state the need of tyre valves**
- **state the tyre ratings**
- **state the tyre pressure monitoring system**
- **state tyre traction rating**
- **state the tyre temperature rating**
- **state the concept of compact spare tyres.**

Function of tyres

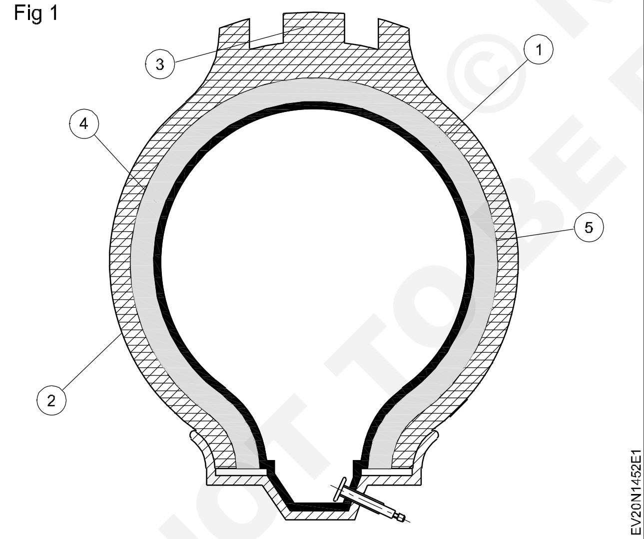
Tyres should be able to:
- absorb shock
- grip the road surface in both wet and dry condition
- withstand vehicle load.

Types of tyres

- Tube tyre
- Tubeless tyre

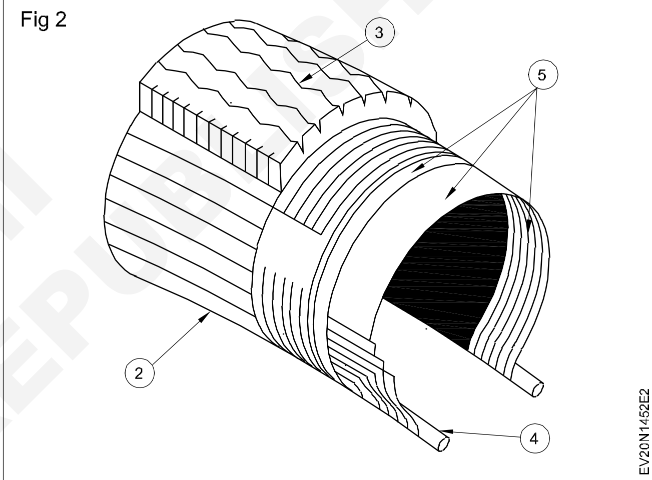
Tube tyre (Figs 1 & 2)

Fig 1



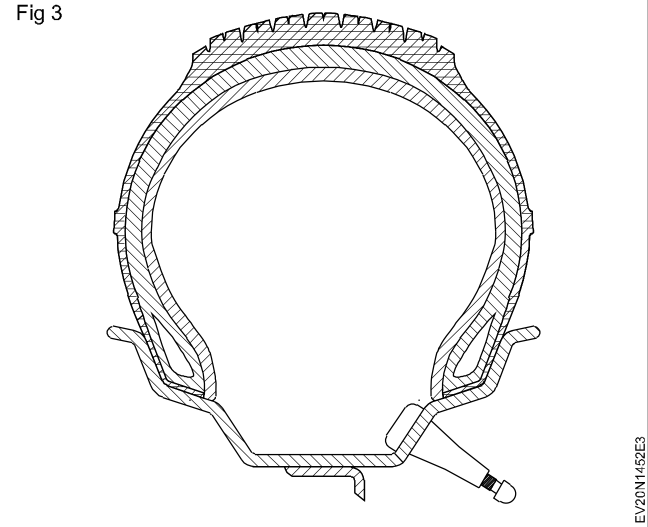
It is the most commonly used tyre. A tube (1) is used inside the tyre (2). The tube is inflated with air at a pressure recommended by the manufacturer. It provides cushioning. The outer portion of the tyre which keeps contact on the road is made of synthetic rubber. This portion is called tread (3). Steel beads (4) are provided at the inner edge. A number of plys (5) of rayon cord are provided to give strength to the tyre. The beads (4) and plys (5) provide strength to the tyre.

Fig 2



Tubeless tyre (Fig 3)

Fig 3



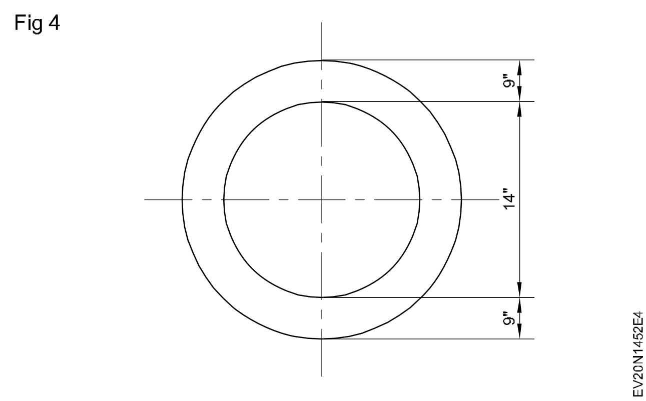
Its construction is similar to that of the tube tyre except that it does not have a tube and air is directly inflated in the tyre. The tubeless tyre can retain air for a longer period than the tube type tyre after puncture. This tyre need not be removed from the wheel to set right a puncture.

Material of tyre

- Rubber - for tread
- Nylon/rayon - for cord
- High tensile steel wire - for bead.

Tyre specification (Fig 4)

Fig 4



Tyre is specified in terms of the shoulder width, bead circle diameter and ply rating (PR).

Eg. 9”x14” - 14 PR

Here the shoulder width is 9”. The bead circle diameter is 14” and the No. of plies (Ply rating PR) is 14.

Structure of tyre

Tyre outer diameter (Fig 5)

It is the outer most diameter of the tyre (1)

Tyre width

The width of the tyre corresponds to the distance between the most protruding portions on both sides.

Overall tyre width

Rectilinear distance between both side, including all patterns and characters on tyre sidewalls.

Tyre height

Half of height obtained by subtracting the rim diameter from the tyre outer diameter.

Thread width

The width of the tyre tread surface. This corresponds as a rule to the distance between the most protruding portions on both sides.

Thread radius

This also referred to as the crown R. The radius of curvature is expressed in millimeters.

RIM width

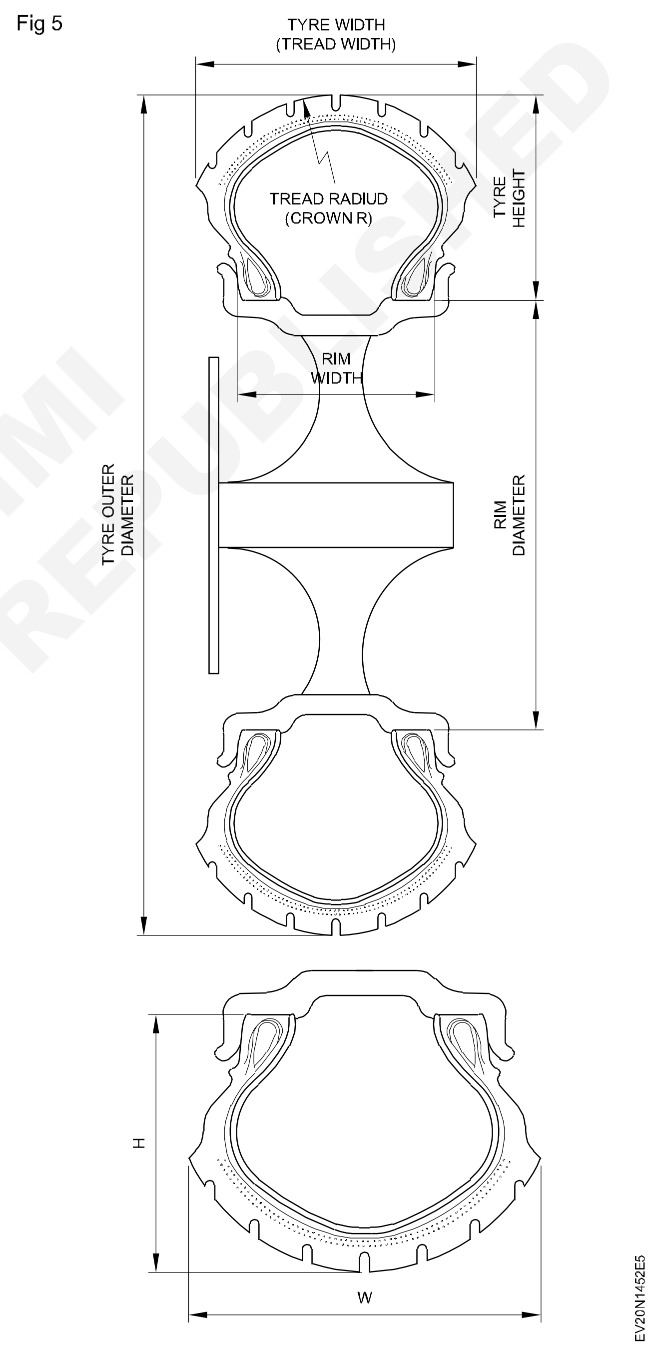
Rim width suitable for effective tyre performance

Bead circle diameter

The inside diameter of the tyre rim diameter is called as bead circle diameter of tyre.

Aspect ratio (Fig 5)

Fig 5



The aspect ratio, is, as shown in the drawing, percentage ratio of tyre height to tyre width.

Aspect Ratio (%age)= H/W x 100

H: Tyre height (mm)

W: Tyre width (mm)

1-Tyre outer diameter

2- Tyre height

3-Tyre width / Thread width

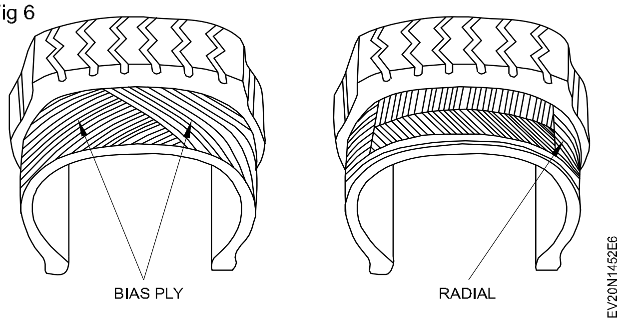
4-Thread radius

5-Rim width

6-Rim diameter (or) bead circle diameter.

Construction of a tyre (Fig 6)

Fig 6



It is divided into two types.

- Radial ply
- Cross-ply

Radial ply

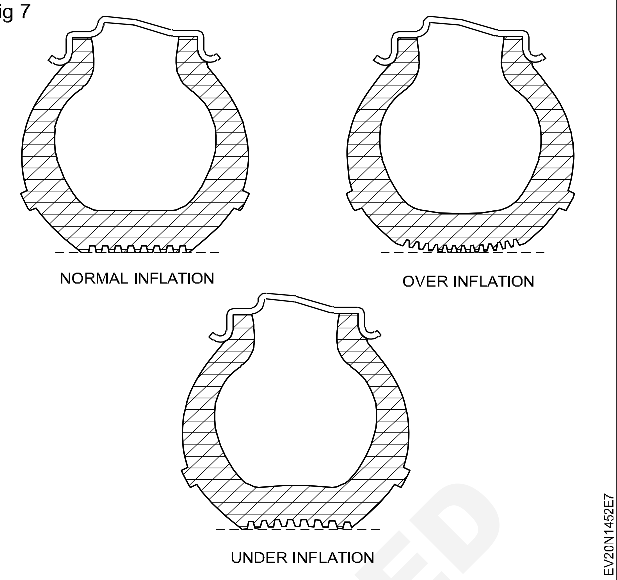
In this type plys are provided radially from bead to bead.

Cross-ply

In this type alternate plys are provided in opposite diagonal directions.

Tyre inflation (Fig 7)

Fig 7



All vehicle manufacturers specify pressure at which air should be inflated in the tyre. It depends upon the tyre size and load of vehicle etc. A tyre should be normal inflated at the specified pressure to have complete contact on road(1). If the tyre is over-inflated, it will have contact with the road only at the centre and the tyre will wear out faster at the centre (2). If it is under-inflated it will have contact with the road only at the edges which will wear out faster (3).

Tyre storage

- Tyres should be stored on a clean surface free from oil, grease, diesel or other liquid.
- Tyres should be kept vertically on the surface. So that they rest on their treads.
- Tyres should be stored away from electric appliances, gas heaters etc.
- Tyres should be protected from strong sunlight.

Size indication

METRIC INDICATION

110 /	70	R	17	54	V	
a	b	c	d	e	f	
a: Tyre width(110mm)	b:Aspect Ratio (70%)					c: Radial structure
d: Rim Diameter (17inch)	e: Max. Load (212 kg at 290 kpa)					f:speed limit (240 km/h)
130 /	90	-	18	69	H	
a	b	c	d	e	f	
a: Tyre width(130mm)	b:Aspect Ratio (90%)					c: Radial structure
d: Rim Diameter (18inch)	e: Max. Load (325 kg at 280 kpa)					f:speed limit (210 km/h)

INCH INDICATION

4.00	H	-	18	4PR
a	b		c	d
a: Tyre width(4 inch)	b:Speed limit (210 km/h)			c: Rim diameter (18 inch)
d: Tyre strength (4 ply rating)				

Load index

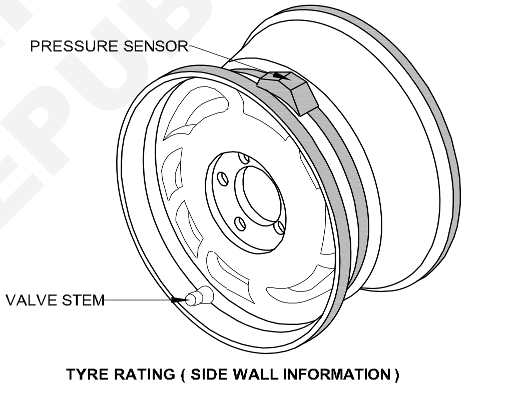
Maximum air pressure for each speed code. (P:225 kpa, S:250 kpa. H:280 kpa, V:290 kpa)

Load Index (kg)	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)	Load index	Max. Load (kg)
30	106	40	140	50	190	60	250	70	335
31	109	41	145	51	195	61	257	71	345
32	112	42	150	52	200	62	265	72	355
33	115	43	155	53	206	63	272	73	365
34	118	44	160	54	212	64	280	74	375
35	121	45	165	55	218	65	290	75	387
36	125	46	170	56	224	66	300	76	400
37	128	47	175	57	230	67	307	77	412
38	132	48	180	58	236	68	315	78	425
39	136	49	185	59	243	69	325	79	437

Speed index

Speed symbol	Max. speed (km/h)
J	100
N	140
P	150
S	180
H	210
V	240
ZR	Over 240

Fig 8



TYRE RATING (SIDE WALL INFORMATION)

Tyre pressure monitoring systems

Tire pressure monitoring systems are mandatory on all new vehicles produced in the United States starting in the 2004 model year. Some tire pressure monitoring systems have a pressure sensor strapped to the drop center in each rim (Fig.8). Other systems have a pressure sensor threaded onto the end of the valve stem. The pressure Sensors end radio frequency (RF) signals to the module in the tire pressure monitoring system. These RF signals change if the tire is deflated a specific amount. When the module senses a tire with low air pressure the module illuminates a warning light in the instrument panel.

Other tire pressure monitoring systems use the wheel speed sensor signals in the ABS to monitor tire inflation pressure. When a tire is deflated to some extent, the tire diameter is smaller and wheel speed increases. Therefore, the wheel speed sensor signals may be used to indicate low tire pressure.

Location	Color code
Right front	Blue
Left front	Green
Right rear	Orange
Left rear	Yellow

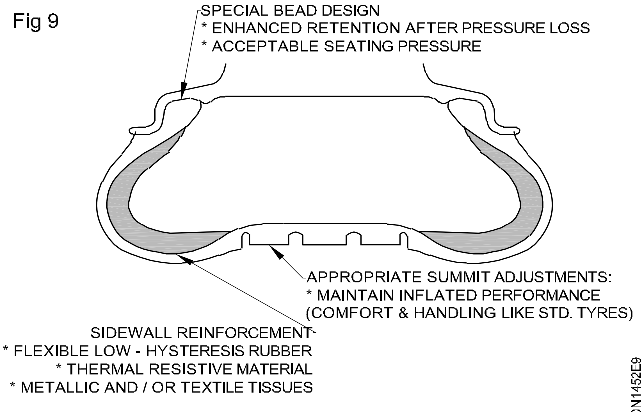
Warning: Pressure sensor inside tyre avoid contacting sensor with tire changing equipment tools or tire bead.

Service note: Pressure sensor must be mounted directly across from valve stem.

Run flat tyres (Fig 9 &10)

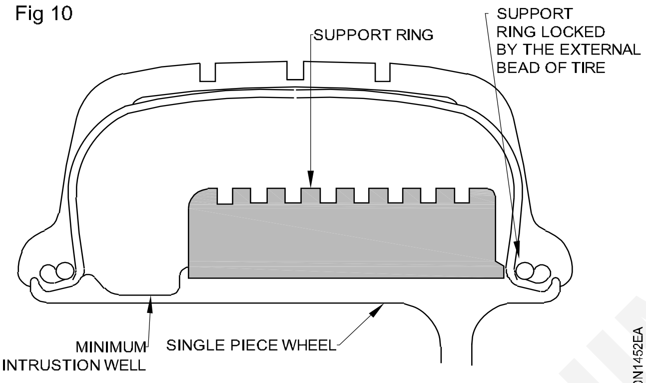
Some luxury and sport type vehicles are equipped with run-flat tires. Run-flat tires eliminate the need for a spare tire and a jack on these cars. This provides a weight and space savings. Run-flat tires must minimize the difference between run-flat tires and conventional tires and provide sufficient zero-pressure durability so the vehicle can be driven a reasonable distance to a repair facility.

Fig 9



A RUN - FLAT TYRE WITH SIDEWALL REINFORCEMENT

Fig 10

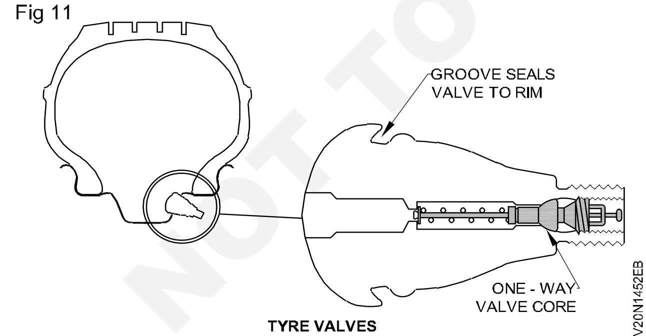


A RUN - FLAT TYRE WITH SUPPORT RING

Some run-flat tires have stiffer sidewalls that partially support the vehicle weight without air pressure in the tire. Other run-flat tires have flexible rubber support ring mounted on a special rim to support the vehicle weight if deflation occurs.

Tyre valves (Fig 11)

Fig 11



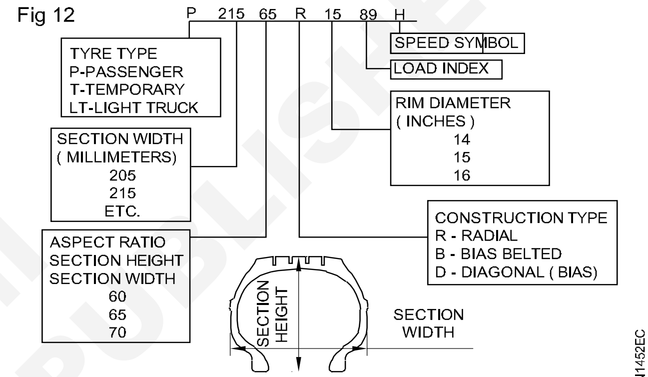
TYRE VALVES

The tire valve allows air to flow into the tire and it is also used to release air from the tire. The core in the center of the valve is spring loaded and allows air to flow inward while the tire is inflated. Once the tire is inflated, the valve core seats and prevents airflow out of the tire. The small pin on the outer end of the valve core may be pushed to unseat the valve core and release air from the tire. An air tight cap on the outer end of the valve keeps dirt out of the valve and provides an extra seal against air leakage. A deep groove is cut around the inner end of the tire valve. When the valve assembly is pulled into the wheel opening, this groove seals the valve in the opening.

Tyre ratings

A great deal of important information is molded into the sidewall of the average passenger car or light truck tire. The tire rating is part of the information located on the sidewall. The tire rating is a group of letters and numbers that identify the tire type, section width, aspect ratio, construction type, rim diameter, load capacity, and speed symbol. When a tire has a P215/65R15 89H rating on the side wall, the P indicates a passenger car tire (Fig 12).

Fig 12



TYRE RATING (SIDE WALL INFORMATION)

The number 215 is the size of the tire in millimeters measured from sidewall to sidewall with the tire mounted on the recommended rim width.

The number 65 indicates the aspect ratio, which is the ratio of the height to the width. With a 65 aspect ratio, the tire's height is 65 percent of its width. The letter R indicates a radial-ply tire design. A belted bias-ply tire design is indicated by the letters A B. The letter D indicates a diagonal bias ply - tire.

The number 15 is the rim diameter in inches. The load index is represented by the number 89. This load rating indicates the tire has a load capacity of 1,279 pounds. Various numbers represent different maximum loads. Some tire manufacturers use the letters B,C, or D to indicate the load rating. The letter B indicates the lowest load rating and the letter C represents a higher load rating. A tire with a D load rating is designed for light - duty trucks. This tire will safely carry a load of 2,623 pounds when inflated to the specified pressure.

Traction rating

Traction ratings indicate the braking capabilities of the tire to the consumer. To determine the traction rating, ten skid tests are completed on wetted asphalt and concrete surfaces. Test conditions are carefully controlled to maintain uniformity. The results of the ten skid tests are averaged and the traction rating is designated A, B or C with an A rating having the best traction.

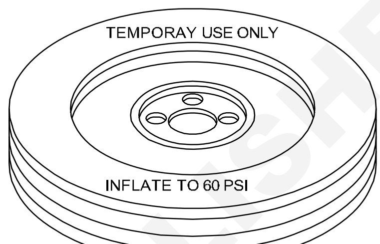
Temperature rating

Temperature resistance ratings indicate the tire's ability to withstand heat generated during tire operation. The National Highway Traffic Safety Administration (NHTSA) has established controlled procedures on a laboratory test wheel for temperature resistance testing of tires. The tire's temperature rating indicates how long the tire can last on the test wheel. Temperature ratings are A,B, or C. An A rating has the best temperature resistance. Tires must have a minimum letter C temperature rating to meet NHTSA standards in the United states.

Compact spare tyres

Since cars have been downsized in recent years, space and weight have become major concerns for vehicle manufactures. For this reason, many car manufactures have marketed cars with compact spare tires to provide a weight and space savings. The high - pressure mini spare tire is the most common type of compact spare (Fig13). This compact spare rim is usually 4 inches wide, but it is 1 inch larger in diameter compared to the other rims on the vehicle. The compact spare rim should not be used with standard tires, snow tires, wheel covers, or trim rings. Any of these uses may result in damage to these items or other parts of the vehicle. The compact spare should be used only on vehicles that offered it as original equipment. Inflation pressure in the compact spare should be maintained at 60psi (425 kpa). The compact spare tire is designed for very temporary use until the conventional tire can be repaired or replaced. Limit driving speed to 50mph (80 kph) when the high - pressure mini space is installed on a vehicle.

Fig 13



A CMPACT , HIGH - PRESSURE MINI SPARE TIRE

EV20N1452ED

Tube

Objectives: At the end of this lesson you shall be able to
- **state tuff up tube**
- **state the structure of tuff up tube**
- **state hole plugging mechanism**
- **state nitrogen filling in tyre**
- **state tyre thread patterns.**

Tuff up tube

The two chamber tube has two separate chambers that are independent from each other. One is the air and other is the liquid chamber. The newly developed anti-puncture sealant gel is sealed in the chamber located on the tyre tread side during the manufacturing process. As the sealant chamber is always pressed against the tyre by the pressure from the air chamber, when there occurs a hole the sealant gel enters in the hole and closes it.

Structure of tuff up tube

This show how the two chamber tube closes the hole. Usually in an event of a puncture, a hole is pierced through the sealant gel chamber to the air chamber. When a hole occurs, the gel is forced into the hole, and the fibrous material contained in the gel is squeezed out. At that time, the fine ceramic particles fill the openings of the fiber, and the vacant spaces are filled with the gel. As there is a pressure inside of the inner tube, minimal quantity seeps into the air chamber but without causing any harm as it is a water based gel.

Hole plugging mechanism

This shows a picture of the cross - section of the hole closed by the newly developed anti-puncture sealant gel, taken after the sealant gel oozes out, dries and seals the puncture.

Tuff up tube can be repaired like an ordinary tube

Though it is an innovative technology, tuff up tube is easy to repair and with some simple precautions, it can be repaired at any repair shop or by road side mechanic.

Nitrogen filling in tyers

1 Car tyres are normally inflated with compressed air
2 Air is approximately 80% nitrogen, 20% oxygen
3 Nitrogen is comparatively inert, oxygen is a reactive gas.
4 The nitrogen used for inflation in tyre depots is normally generated by a separation process from compressed air. It still contains about 5% oxygen.
5 Nitrogen used at race tracks and in industry may be 99%+ pure and contained in high pressure cylinders at 2000+psi

6 Both sources of nitrogen will be treated to reduce the amount of water vapour.

Now a days nitrogen is used in all tyres in place of air. It is used because it doesn’t expand and compress like normal air in altitude and temperature changes. That is why it is used in aviation applications.

Nitrogen is chemically a non-flammable, non - toxic inert gas. An inert gas does not react with any other gas at any temperature. This basic nature of nitrogen helps in keeping minimum moisture in the tyres.

Pros

Nitrogen reduces the running temperature of the tyre, which is advantageous when the car or bike is operating at its maximum load and speed capacity.

Nitrogen in tyres improves the ride quality. That gas is very slightly lighter than air, benefits the tires in terms of un-sprung weight.

It is assumed that nitrogen increases tyre life. It reduces the operating temperature during times of load and speed and thus, enhances the life of a tyre.

It is believed that nitrogen keeps tyre pressures more constant. The gas is assumed to provide more stable pressure range in connection to the tyre temperature. However, again, the factor is applicable in times of heavy load/high - speed conditions.

Tyres are susceptible to loss of pressure as a result of being porous in nature. Due to its chemical structure, nitrogen leak out slowly as compared to compressed air. Therefore, it slows the rate of pressure loss.

Oxygen reacts with the tyre and rim materials causing oxidation or the rust formation in the metal parts. Nitrogen, being an inert gas, does not react with the tyre and rim materials.

Cons:

Inflating tires with nitrogen is quite costly.

Filling tyres with nitrogen requires more maintenance as compared to compressed gas.

The availability factor is the biggest disadvantage of inflating tyres with nitrogen, as the gas is not readily available. It is usually found only with specialist tyre dealers.

Generally its not that much advantages in case of commuter bikes. More ever 78% air is itself nitrogen. It is advantages only in case of formula cars, high speed racing cars & motorcycles & high load carriage vehicle.

Tyre tread patterns

- Function
- Improve grip
- Arrest skidding
- Keeps tyre cool
- Provide longer life
- Can be retreaded

Indicators are provided to show the limits upto which it can be used before renewing or ready for rectreading different commercial names are given by manufactures.

Types of tyre tread (samples)

- Knobby tread
- Lug tread
- Diamond tread
- Highway tread
- Saw totth trade

Sketches given below (Fig1)

Fig 1

Monitoring systems

Tyre pressure monitoring systems are designed both to recognise the air loss in the tyre and also to warn the driver.

The following types of tyre pressure monitoring systems are used in motor vehicles:

- Indirect measuring systems
- Direct measuring system

Indirect measuring systems

When pressure is lost, the tyre’s rolling circumference, which increases the engine speed in relation to the other tyres, is reduced. The engine speeds are determined via the ABS or ESP sensors. However, the driver is not warned until there is a difference in air pressure of ore than 30% between the tyres.

Direct measuring system

The pressure is measured directly by sensors in the tyre. The following functions are fulfilled:

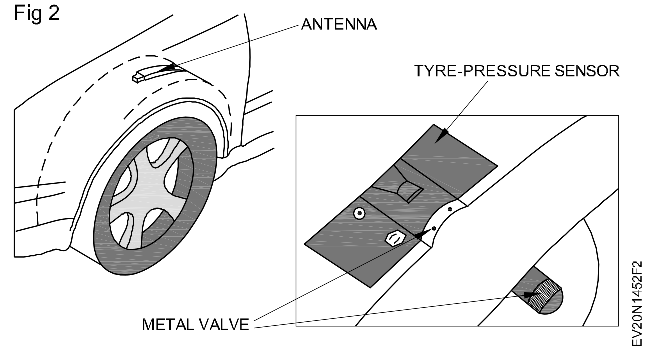
- Continued monitoring of tyre pressure whilst driving and when the vehicle is stationary.
- The driver is given early warning in the event of a pressure loss, reduced pressure and flat tyre.
- Automatic individual wheel recognition and wheel positioning.

- Diagnostic procedure for systems and components in the workshop.

The system is composed of:

- 1 tyre-pressure sensor per wheel (Fig 2)

Fig 2



- Antennae for tyre pressure monitoring
- Instrument panel with display
- ECU for tyre-pressure monitoring
- Function-selector switches

Tyre-pressure sensor and antenna

Tyre-pressure sensor: This sensor is bolted to the metal valve and can be reused when changing the tyres or wheel rims. In addition, a temperature sensor, transmitting antenna, measuring and control electronics as well as a battery with a service life of approximately 7 years are integrated. Since the filling pressures are altered by temperature inflences the pressures and temperatures recorded in the ECU to a standard temperature of 20°C.

To avoid damaging the sensor irreparably when changing a tyre, the tyre must be pressed down on the side opposite the valve.

ECU: The ECU obtains the following information from the transmitting antenna:

- Individual identification number (ID code), ised for individual wheel recognition.
- Current inflation pressure and current temperature.
- Condition of the lithium battery.

The ECU evaluates the signals transmitted by the antenna for the tyre pressure monitoring and imparts the information for the driver on the display screen, according to the importance of this information. If wheels are changed on the vehicle, for example, from the axle to the rear axle and vice versa, the ECU must be recoded with the new pressures.

Individual wheel recognition: The sensors belonging to the vehicle are recognised by the ECU and stored. The sensors are recognised when the vehicle is being driven, to avoid interference from the sensors on cars parked nearby.

Nitrogen Air	Atmospheric Air
1 It is 99% purity nitrogen gas	It is the mixture of 78% Nitrogen plus other constituents
2 It does not react or oxidised with rubber of tyre hence tyre life increases.	It reacts with rubber and gets oxidised life of tyre decreases
3 Tyre runs cooler	Tyres becomes hot

Tyre rotation

Objectives: At the end of this lesson you shall be able to
- **state tyre rotation**
- **state the tyre wear pattern.**

Tyre rotation

Uneven tyre wear on all the wheels will cause instability of the vehicle. Front tyres wear out faster than the rear tyres, as the front wheels steer the vehicle at turns. In order to have uniform wear on all the wheels, it is necessary that the wheel position is changed after completing a specified travel.

Changing the position of wheels in a set pattern is called tyre rotation. All manufacturers recommend a set pattern of tyre rotation after covering certain kilometres. A simple pattern of tyre rotation is shown in the Fig 1. In this, at the time of tyre rotation the spare wheel (5) is fitted to the rear right. The rear right (1) to front left. The front left (2) is fitted to rear left. The rear left (3) to the front right and the front right (4) is kept as the spare wheel.

Tyre wear

Tyre wear depends upon its position (front or rear), load, road condition, inflation and mechanical faults of the car.

The different types of tyre wear are as follows.

Rapid wear at shoulders (Fig 2)

Tyre wears out faster at the shoulder. Under-inflation is the main cause for this.

Fig 1

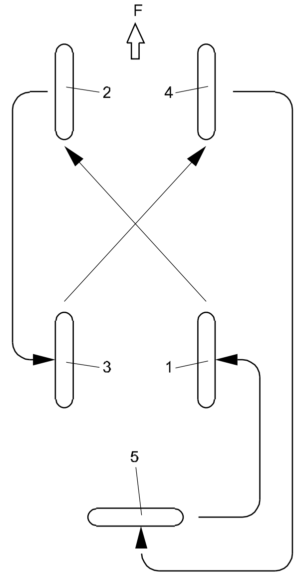
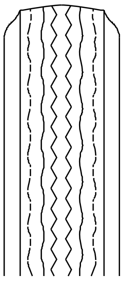
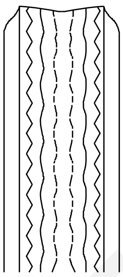


Fig 2



Rapid wear at centre (Fig 3)

Fig 3



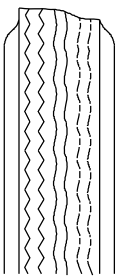
Over-inflation is the main cause for this.

Cracked treads

The main causes for this are under-inflation or excessive speed.

Wear on one side (Fig 4)

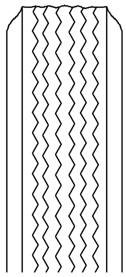
Fig 4



The main cause for this is improper camber.

Feather edge (Fig 5)

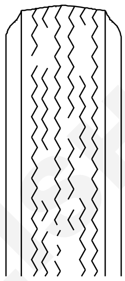
Fig 5



The main cause for this is incorrect toe-in.

Bald spots wear (Fig 6)

Fig 6



The main cause for this is improper dynamic and static balancing of wheels.

Fierce braking driving habits also may lead such to such patchy wear.

Tyre properties

A tyre must have the following desired properties

1 **Non-skidding:** The tyre should not skid or slip on the road surface. It show grip.

2 **Uniform wear:** The tyre must get wear uniformly over its outer circumference.

3 **Load carrying:** The tyre should be able to carry the vehicle load, and stresses during each revolution.

4 **Cushioning:** The tyre should be able to absorb vibrations set-up by the thus providing cushioning effect.

5 **Power consumption:** While rolling on the road, the tyre should consume power developed by the engine.

6 **Noise:** The tyre should create minimum noise while running on the road.

7 **Balancing:** The tyre should be balanced dynamically as well statically.

Tube

A tube - tyre enclose a tube inside it. The tube is held between the rim and the tyre. Air is forced under pressure inside the tube, through a non - return valve, which projects outside through a hole in the rim. Tubes are made of rubber by moulding to conform the shape tyre. Special tyres of tubes are available which minimize the danger of punctures or blowouts. These tubes are self sealing constructions.

Tubes are manufactured with the same care and attention as tyres. Raw material are analyised and tested before use. In the manufacture of tubes but rubber is used of because of its superior qualities. Front warm - up mills the tube stock goes to machine from which it comes out on to a conveyor as an endless sleeve. This is then marked with the proper size, cut to length and stored in specially designed skids.

The ends of the tubes are then joined together on automatic splicing machines and are then fitted with the valves specified for each size. Each tube is then put around a forming ring and inflated to mould shape and is then cured in a steam heated mould. The mould opens automatically at the end of curing period and the cure tube is taken out. Each tube is thoroughly inspected for defects, then polished, packed and made ready for shipping out.

Tyre pressure
Conversion table for PSI and kg/cm²

PSI	Kg/cm²
23	1.6
26	1.8
29	2.00
32	2.2
35	2.4
38	2.6
41	2.8
44	3.00
46	3.2
50.3	3.5
54.62	3.8
57.5	4.00
60.00	4.15
71.87	5.00
86.25	6.00
100.625	7.00
115.00	8.00
129.375	9.00
143.75	10.00

Wheels

Objectives: At the end of this lesson you shall be able to
- **state the function of wheels**
- **list out the various type of wheels**
- **state wheels construction**
- **explain static and dynamic wheel balance and effect of unbalance.**

Wheels

Wheels are connected to the front and rear axles. As power is supplied to either front or rear axle, axle shafts turn the wheels and the vehicle moves.

The wheel assembly consists of a hub, rim, tyre and tube. To perform its function the wheel should be:

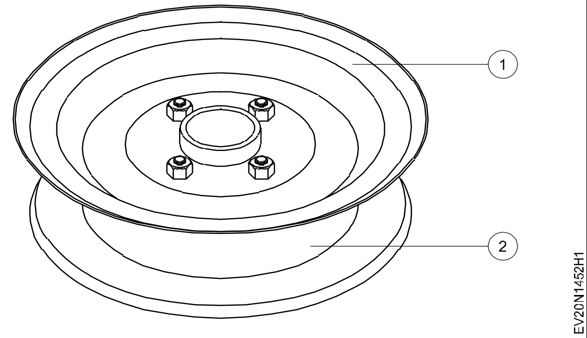
- able to withstand the driving and braking torque, and support the weight of the vehicle
- able to absorb road shocks
- statically and dynamically balanced
- able to grip the road surface.

Types of wheels

- Disc wheel
- Wire wheel
- Split wheel
- Heavy vehicle wheel

Disc wheel (Fig 1)

Fig 1

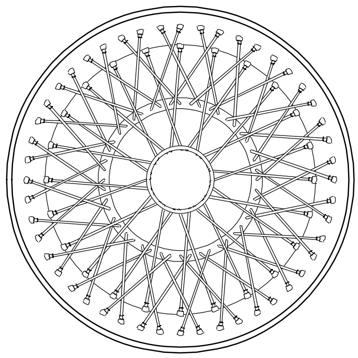


In this type, a steel rim (1) is welded on to a steel disc (2). The tube and tyre are fitted on to the rim (2). The disk is provided with holes to mount it on the hub.

Wire wheel (Fig 2)

In this type the hub and rim are connected by a number of wire spokes. Alternate spokes are screwed to slope forward and backward towards the rim to absorb the braking and driving torque respectively. (Eg.Bicycle/ Motor cycle wheels)

Fig 2



Split wheel (Figs 3 & 4)

In this type two separate discs are clamped together and a flange of discs provide seating surface for the tyre and tube. This types of wheels are used in car and scooter.

Fig 3

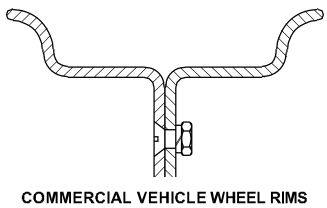
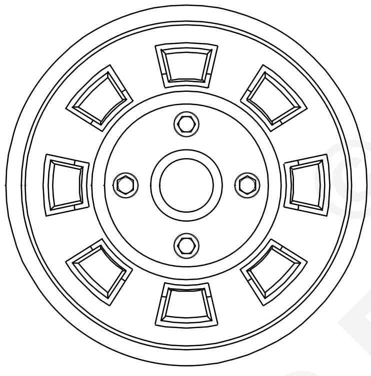


Fig 4



Heavy vehicles wheels

These wheels are similar to disc wheels except that a thicker plate is used for the disc.

Rims

The rim provides seating surface for the tyre and tube.

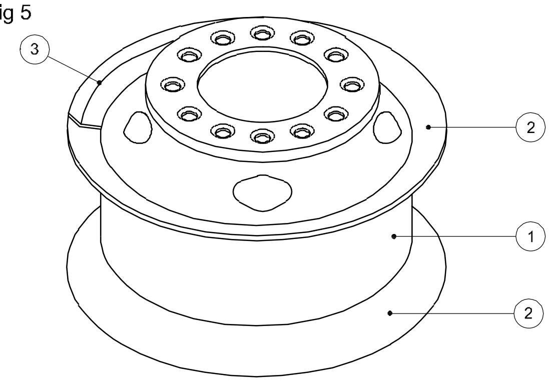
Two types of rims are used.

- Flat base rim
- Drop centre rim.

Flat type rim (Fig 5)

In this type the rim's centre position (1) is kept flat. One edge of the rim has a projection (2), and the other end is removable to install into or remove the tyre and tube from the rim. One plain ring and one split lock ring (3) are provided on the removable end of the rim to lock the tube and tyre in position. This arrangement enables the removal of the tyre without stretching the bead.

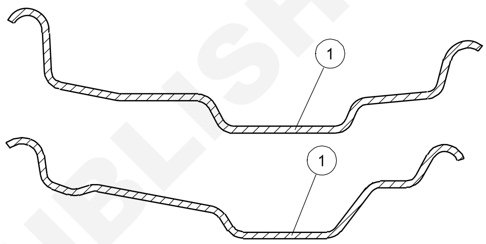
Fig 5



Drop centre rim (Fig 6)

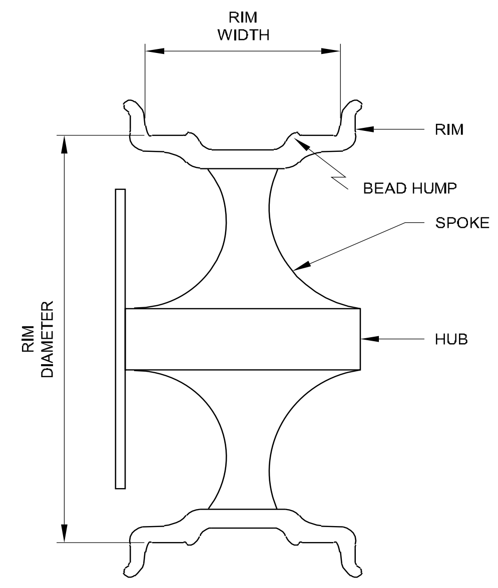
In this type a small diameter well (1) is provided at the centre of the rim. It enables removal or installation of the tyre by stretching beads and throwing them in or out of well.

Fig 6



Wheel construction (Fig 7)

Fig 7



Function of each part

Wheels must have the strength to endure shocks and repulsion forces from the road surface as well as braking and driving forces. At the same time they must have the rigidity to maintain stability and maneuverability. Lastly, they must be light in order to reduce unsprung weight.

Wheel can be divided into three parts with the following functions.

Hub

This is the part linked with the frame. It has bearings in the center. The bearings link the rotating wheel to the non - rotating frame. High linkage rigidity and dimensional precision are required for the non-rotating part, while smooth rotation and no play are required for the rotating part. This part supports the spokes and is required to have the appropriate supporting function. It is also designed to facilitate the rotating parts of the brake, the drive system and speedometer.

Spokes

The spokes support the rim while fulfilling the following conditions:

Assure accurate roundness of the rim and ensure its center aligns with the center of the axle shaft (Vertical vibration).

Ensure high degree of flatness with no distortion, and the surface is perpendicular to the axle shaft (horizontal vibration)

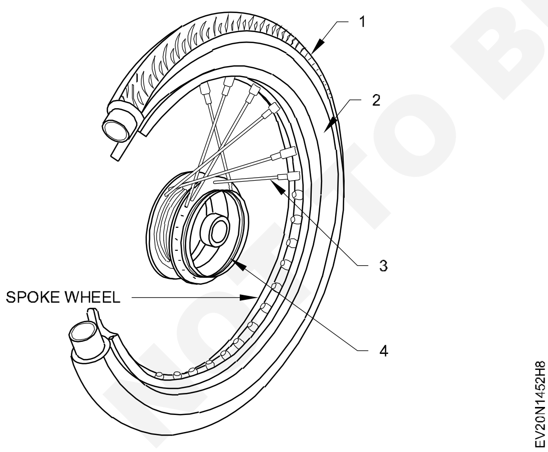
RIM

The rim holds the tyre in the correct position. In the case of tubeless tyres, internal pressure is maintained by close adhesion between the bead surface of the tyre and the flange surface of the rim. The rim width indicates the internal width of the flange and is given in inches. The rim diameter is the diameter at the bottom of the rim and is also given in inches. A rim on which tubeless tyre can be fitted is stamped, “Tubeless Tyre Applicable”.

Wheel construction

Wire spoke wheels (Fig 8)

Fig 8



Thin steel spokes connect the rim and the hub. This type of wheel is light and inexpensive

Main parts of spokes wheel are

1 Tyre

2 Rim

3 Spokes

4 Hub

5 Tube

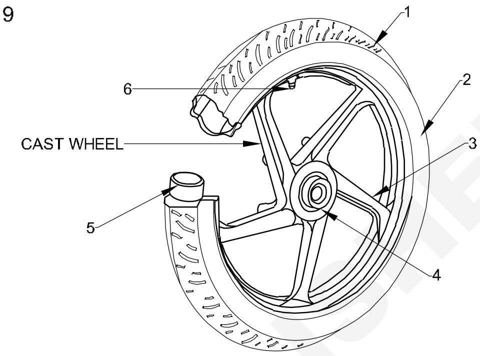
6 Valve

Cast wheel

This wheel is cast from aluminum alloy as a single component. The design became possible following technological development of new materials and manufacturing methods. This type of wheel has high precision, lightweight, high rigidity and high flexibility of design.

Major parts of cast wheel are (Fig 9)

Fig 9



1 Tyre

2 Rim

3 Spokes

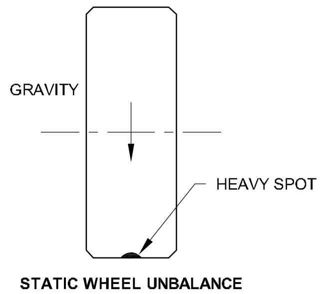
4 Hub

5 Tube

Some vehicles are equipped with cast aluminum alloy wheel rims or cast magnesium alloy wheel rims. Sometimes these wheels are referred to as “mag” wheels. These wheels are lighter and generally more accurately designed compared to pressed steel wheel rims.

Static wheel balance (Fig 10)

Fig 10

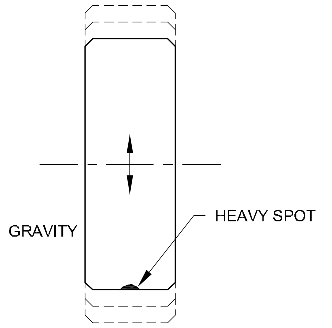


When a wheel and tire has proper static balance, it has the weight equally distributed around its axis of rotation and gravity will not force it to rotate from its rest position. If a vehicle is raised off the floor and a wheel is rotated in 120 degree intervals, a statically balanced wheel will remain stationary at each interval. When wheel and tire are statically unbalanced, the tire has a heavy portion at one location. The force of gravity acting on this heavy portion will cause the wheel to rotate when the heavy portion is located near the top of the tire.

Results of static unbalance

Centrifugal force may be defined as the force that tends to move a rotating mass away from its axis of rotation. As we have explained previously, a tire an d wheel are subjected to very strong acceleration d deceleration forces when a vehicle is in motion. The heavy portion of a statically unbalanced wheel is influenced by centrifugal force. This influence attempts to move the heavy spot on a tangent line away from the wheel axis. This action tends to lift the wheel assembly off the road surface. (Fig 11)

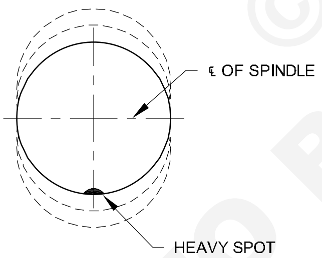
Fig 11



EFFECTS OF STATIC UNBALANCE

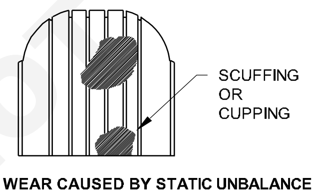
The wheel lifting action caused by static unbalance may be referred to as wheel tramp (Fig 12). This wheel tramp action allows the tire to slip momentarily when it is lifted vertically. When the wheel and tire move downward as the heavy spot decelerates, the tire strikes the road surface with a pounding action. This repeated slipping and pounting action causes severe tire scuffing and cupping. (Fig 13)

Fig 12



WHEEL TRAMP

Fig 13



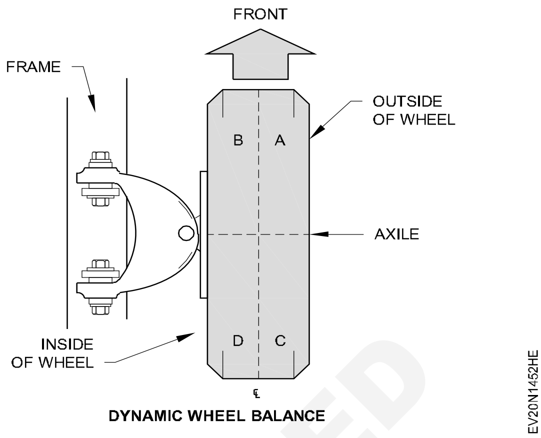
CUPPING TIRE WEAR CAUSED BY STATIC UNBALANCE

The vertical wheel motion from static unbalance is transferred to the suspension system and is then absorbed by the chassis and body. This action causes rapid wear on suspension and steering components. The wheel tramp action resulting from static unbalance is also transmitted to the passenger compartment which causes passenger discomfort and driver fatigue.

Dynamic wheel balance theory

When a wheel and tire assembly has correct dynamic balance, the weight of the assembly is distributed equally on both sides of the wheel center viewed from the front. Dynamic wheel balance may be explained by dividing the tire into four sections (Fig 14)

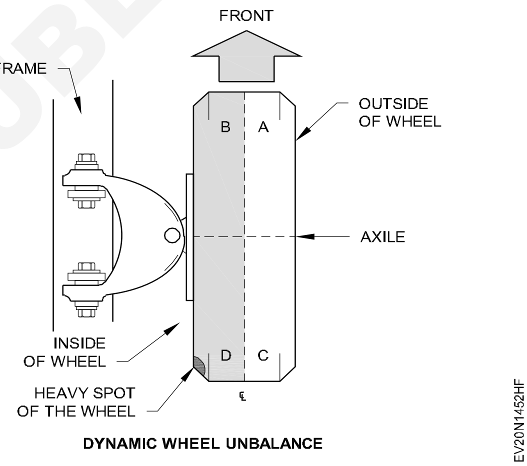
Fig 14



DYNAMIC WHEEL BALANCE

In Fig 14, if sections A and C have the same weight and sections B and D also have the same weight, the tire has proper dynamic balance. If a tire has dynamic unbalance, section D may have a heavy spot and thus sections B and D have different weights. (Fig 15)

Fig 15



DYNAMIC WHEEL UNBALANCE

From our discussion of dynamic balance, we can understand that a tire and wheel assembly may be in static balance but have dynamic unbalance. Therefore, wheels must be in balance statically and dynamically.

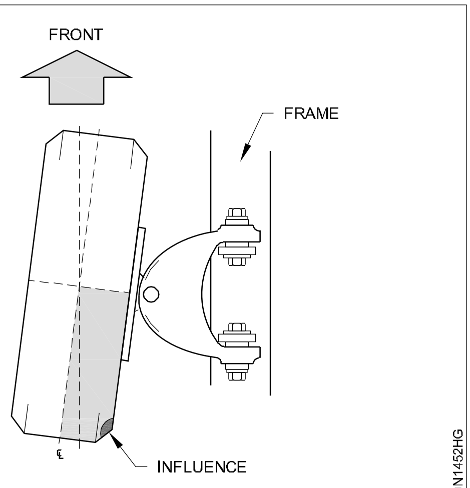
Results of dynamic wheel unbalance

When a dynamically unbalanced wheel is rotating, centrifugal force moves the heavy spot toward the tire center line. The center line of the heavy spot are is at a 90 degree angle to the spindle. This action turns the true center line of the left front wheel inward when the heavy spot is at the rear of the wheel (Fig 16)

When the wheel rotates until the heavy spot is at the front of the wheel, the heavy spot movement turns the left front wheel outward.

From the these explanations we can understand that dynamic wheel unbalance causes wheel shimmy. This action causes steering wheel oscillations at medium and high speeds with resultant driver fatigue and passenger

Fig 16



DYNAMIC WHEEL UNBALANCE

discomfort. Wheel shimmy and steering wheel oscillations also cause unstable directional control of the vehicle. Wheel shimmy is the rapid, repeated lateral wheel movement.

Wheel alignment: wheel alignment involves a mechanical adjustment of vehicle suspension to influence the direction and angle of tyre contact with road surface. The optimum alignment for each make and model of vehicle is set by the manufacturing in order to influence the performance and handling

Importance of wheel alignments

- Impact overall safety
- Increase the tyre life and reduce the type wear
- Boosting vehicle fuel consumption
- Improving vehicle handling and steering function
- It reducing braking distances compared to misaligned vehicles
- It helps to wheels pointed in the right direction and smooth drive

Signs of incorrect wheel alignment

- Vehicle pulls towards the left or right side
- The steering wheel is off centre when driving straight
- Steering wheel vibration
- Abnormal tyre tried worn out
- Steering geometry collocate

Process of wheel alignment

- Inspect the vehicle steering and suspension system including tyre condition and air pressure
- Place the vehicle on alignment rack, mount and calibrate sensors
- Print out initial alignment settings
- Place the vehicles on the wheel alignment ramp
- Adjust camber caster and top angles, ride height adjustment and steering angle adjustment
- Print out final alignment readings
- Bring the vehicle to on road test
- Drive and test the vehicle to make sure alignment is good as per manufactures recommendation.

Electrical vehicle body engineering

Objectives: At the end of this lesson you shall be able to
- **State the vehicle body styling**
- **State the vehicle body exterior, interior and trims**
- **State the vehicle integration**

Vehicle body design: The automobile body designs build in many ways. Particularly the electric vehicle's are build in the following designs, (1) body on frame, (2) Unibody (3) monocoque body on Space frame (4) backbone chassis. This vehicle body designs includes the front and rear body hood doors, roofline and overall body shape and body styling made for attract the vehicle buyers and creating unique identity for a particular brand of a vehicle.

Body on frame: Body on frame construction is poised for a resurgence in passenger vehicles with the new skateboard chassis concept a low profile chassis that fully integrates the power train and suspension to which various bodies can be attached. The low profile nature of electric motors and batteries lend themselves. Some manufactures autonomy concept that integrated a fuel cell, hydrogen tanks and batteries into rolling chassis propelled by four wheel motors.

unibody design: Uni body is short for unit body. it is used floorboards and major chassis structural support and crash protection elements are welded, /bonded/, molded or joined into a single structural element. This method affords the opportunity for Considerable weight Savings as compared to constructing a body and then mounting it to a separate Structural frame.

The Modern Cars and crossover SUV now used the unibody Construction, though the air flow concept of welding looks like a full frame underneath to add skiffness and strength and to reduce noise, vibration and harshness. This unibody is heavier than similar body on frame

monocoque body: Monocoque body is structural system. in which loads are supported by: objects external body shell. The monocoque frame construction considered for better suited for seadans and hatchback vehicles

Space - frame designs: The space frame metal tubes or Composite Stringers bears most of the load while the exterior body bears very little. The space frame can be considered the opposite of a monocoque body

Backbone chassis: - The body over frame has a thick metal box or U shaped stampings or rails welded and riveted together. The main structural members are two side rails Connected by a series of cross members for high load Carrying capacities.. The separate frame is made of much heavier gauge steel than the body panels chassis includes the engine, suspension system, Steering System and other mechanical parts with body

Vehicle body sections: The vehicle body commonly divided into three sections, as Front, center and rear section. The front section includes bumber, grille frame rails, front suspension parts, engine, lights and other electrical components etc

The vehicle center section includes the body parts that from the passenger Compartments floor panel, roof panel, Cowel, doors, door pillars, glass and related parts

The rear section of the Vehicle Commonly Consists, of the rear quarter panels, trunk, rear frame rails, rear bumber rear lighting components etc.

Body classification

Objectives: At the end of this lesson you shall be able to
- state the vehicle body classification
- state the vehicle body materials
- state the vehicle construction and frame tests
- state the vehicle collision repair measurements.

Body classification: Various methods used for classifying the vehicle body. Body classifications mostly recognised by consumers as a car size, body shape, seat arrangement, number of door used in the vehicle and engine type, fuel system type, drive line type.

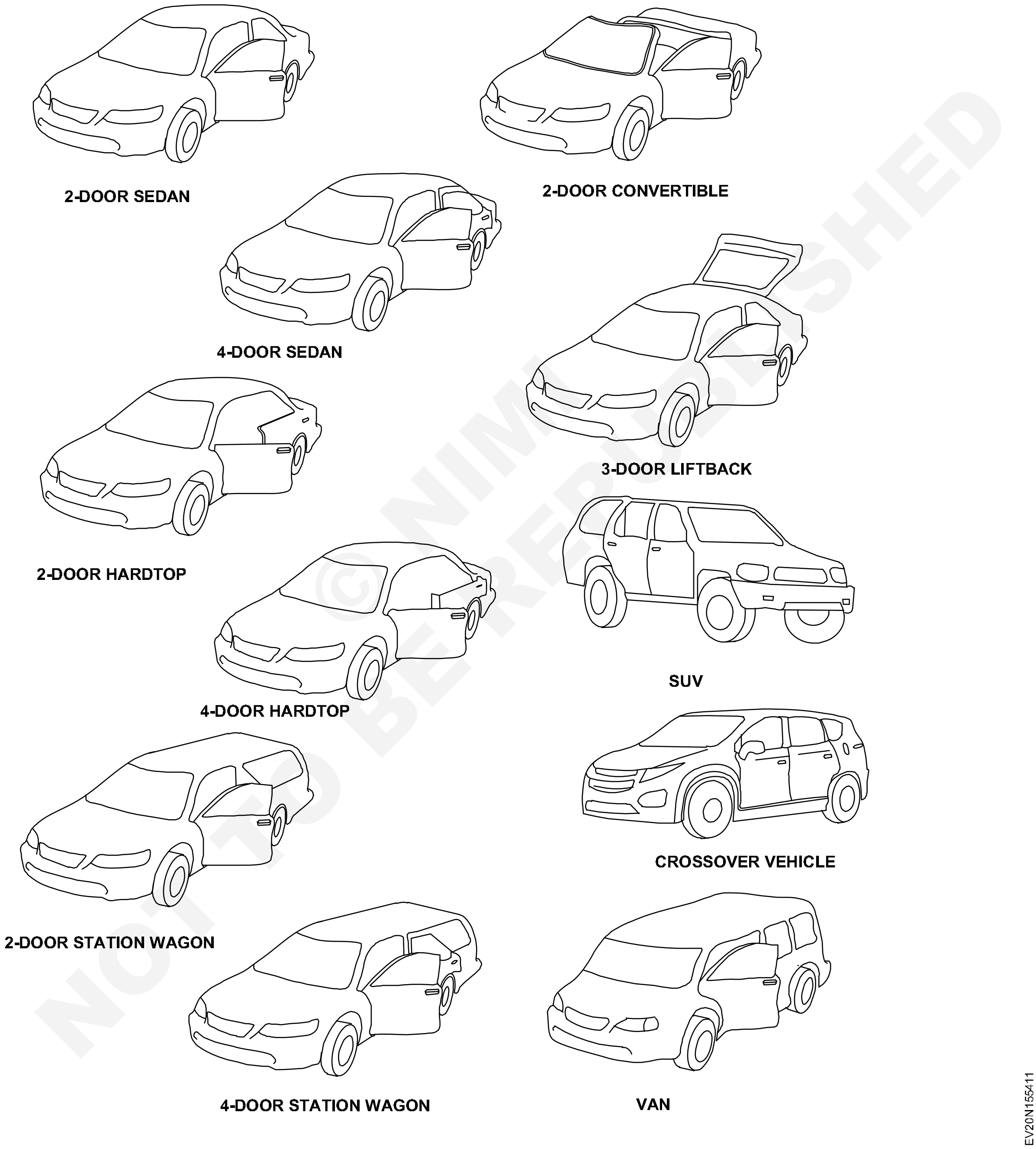
Car size: There are three type of car size as a compact or economy car, intermediate car and full size car or luxury car small size car uses a three or four cylinder engine and intermediate car uses a four or six cylinder engine and luxury car uses a high performance V8 engine. Full size cars can have either unibody or body over frame construction.

Roof designs: (Fig 1) There are several basic body or roof designs used as follows.

- A sedan refers to a body design with a center pillar that supports the roof.
- A hard top does not have a center pillar to support the roof, so the roof must be reinforced to provide the enough strength of hard top of the car.

- A hatch back roof design has a large third door at the back. The design is commonly found on small compact cars.
- A convertable car roof uses a retractable canvas roof with a steel tube frame work. The top folds down behind the seat. Some convertables uses as a removable hard top.
- A station wagon roof extends straight back to the rear of the body to allow access to the large storage area.
- A van type car has a large box shaped body to increase interior volume or space.
- Sport utility or SUV vehicle body and roof is designed as drilling through snow and mud at all-weather.
- Pick up trucks has a separate cab and bed.

Fig 1

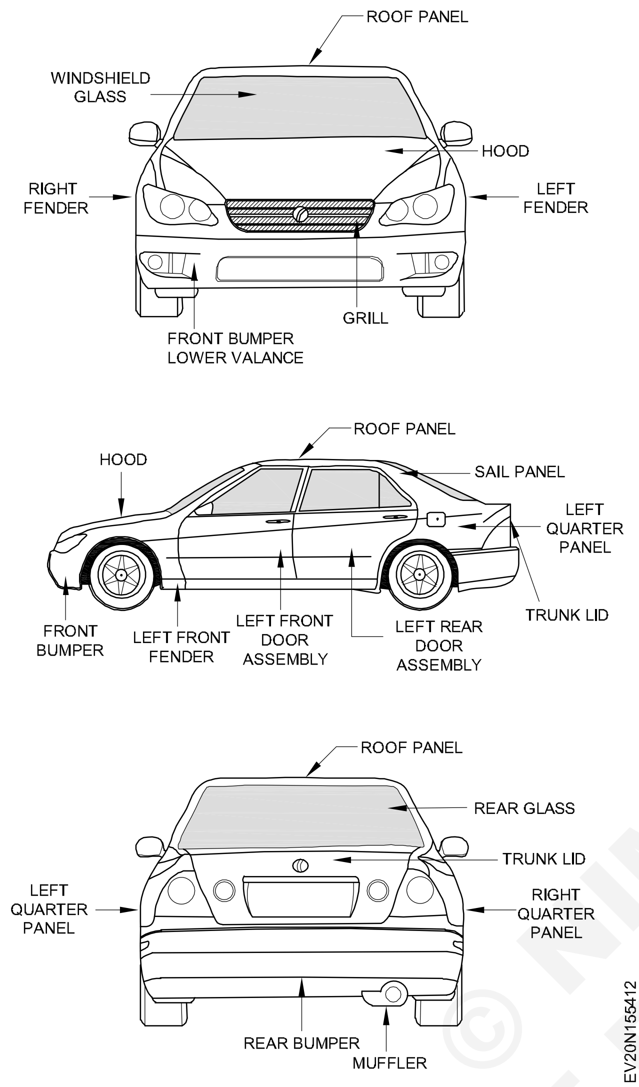


Body panels: (Fig 2) Body panels refers to an individual unit used to build a vehicle. Several parts are fastened together form as vehicle body assembly. A panel is a steel aluminium or plastic sheet stamped or moulded into body part various panels are used in a vehicle as the name of the panel is self-explanatory,

- Hood panel
- Fender panel
- Trunk lid panel or roof panel

The giant machines are used to crush the thin flat sheet metal in a die machined to match the shape of the desired

Fig 2



body shape. Body panels usually have compound curves formed to increase stiffness with unibody construction, panels are welded together to form the unibody frame at the vehicle assembly plant.

Unibody panels and their parts: It is important to know which type of auto body construction is used, while because repair work different for each type of the vehicle construction. The technician must know how to repair both full frame and unibody vehicles with great precision. Some panel parts are same for both unibody and full frame vehicles.

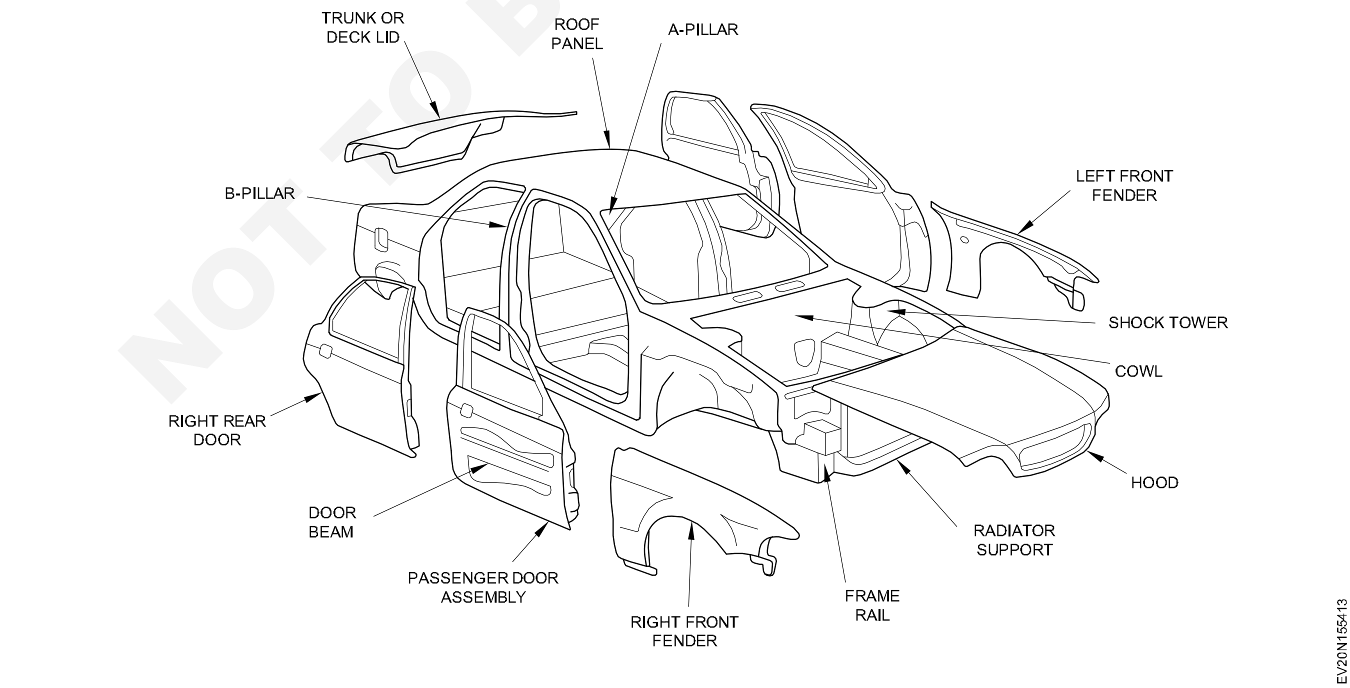
Front section parts: The unibody front section parts of the frame rails are the box members extending out rear the bottom of the front section. They are strongest part of a unibody. Frames or rails are welded to the firewall and to the bottom of the fender aprons. The cowel is the assembly of panels at the rear of the front section right in front of he wind shield. This assembly includes the top cowel panel and side cowel panels. (Fig 3)

The front fender aprons are inner panels that surround the wheels and tyres to keep out road debris. They are bolted or welded to the frame rails and cowel.

The shock towers or strut towers are reinforced body areas for holding the upper parts of the suspension system. The coil springs and strut or shock absorbers fit up into the shock towers. The radiator core support is the frame work around the front of the body structure for holding the cooling system radiator and other related cooling system parts. These parts are often fastens to the frame rails and inner fender aprons.

The hood is hinged panel for accessing the engine compartment. Hood hinges bolted to the hood and cowel panel, allow the hood to swing open. The hood is made of

Fig 3

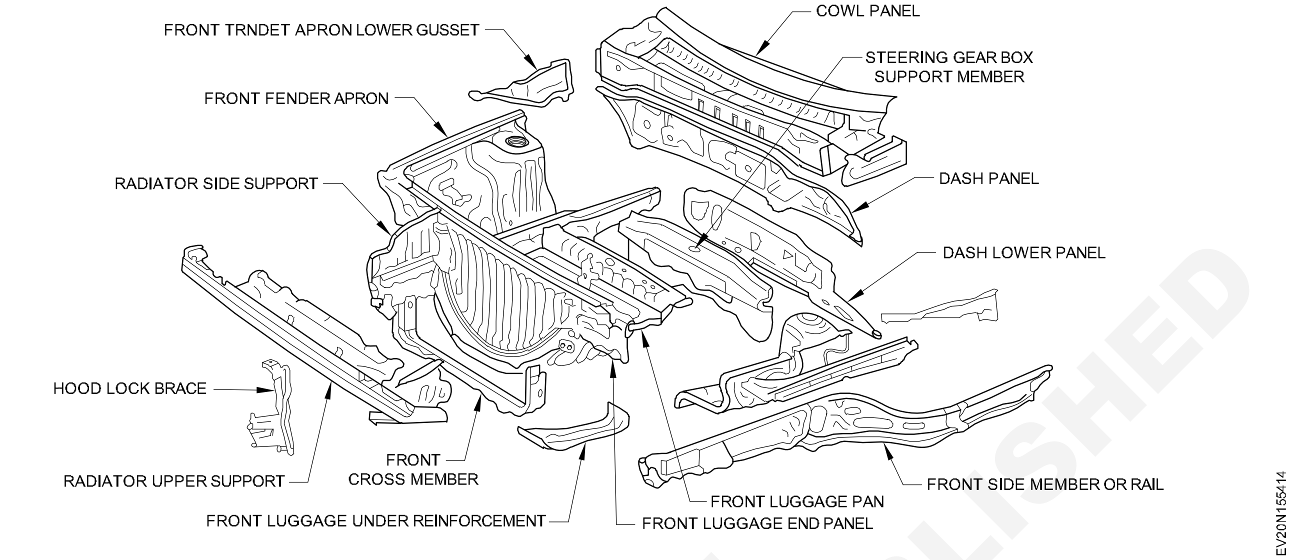


two or more panels welded or bonded together to prevent flexing and vibrations.

The dash panel or fire wall or bulk head. Panel is dividing the front section and the center passenger compartment section. The dash panel protect the passengers in the event of a fuel leaks and resulting engine fire.

The front fenders covers front suspension and inner aprons. The bumper assembly bolts to the front frame horns to absorb minor impacts. The grille is the center cover over the radiator support it has opening for airflow through the radiator. (Fig 4)

Fig 4



Center section parts: The floor pan is the main structural section in the bottom of the passenger compartments. It is stamped as one large piece of steel.

The unibody pillers are vertical body members that hold the roof panel and protect the passengers in case of a roll over accidents.

There are three types of pillars are used in modern cars. Front pillers extend up next to the edges of the wind shield they are steel box members that extend down from the roof panel to the main body section.

Center pillars are the roof supports between the front and rear doors on four door vehicles, it helps strengthen the roof and provide a mounting point for the rear door hinges.

Rear pillars extend up from the quarter panels to hold the rear of the roof and rear window glass.

Rocker panels or door sills are strong beams that fit at the bottom of the door openings. They are welded to the floor pan and to the pillars. Kick panels or quarter panels. The kick panels are small panels between the front pillars and rocker panels.

The rear shell is a thin panel behind the rear seat and in front of the back glass. The rear bulkhead panel separates the passengers compartment from the rear trunk area.

The doors are made up of outer skin, inner door frame, door panel, window regulator, glass and related parts door hinges are bolted between the pillars and door frame.

The roof panel is a large panel that fits over the passenger compartment. It is normally welded to the pillars. Some vehicles roof panel have a provision to removable top pieces.

The dash panel is the assembly including the soft dash pad, instrument pad, instrument cluster, radio, heater and air conditioning controls vents and similar parts. The dash panel can be damaged in a major collision, when people fail to wear their seat belt as well as by air bag deployment.

Rear section parts: The rear frame rails are strong boxed structures that give strength to the rear of the vehicle. The trunk floor panel is a stamped steel part that forms the bottom of the rear storage compartment.

The deck lid is a hinged panel over the rear storage component. A rear hatch is a larger panel and glass assembly hinged for more access to the rear of the vehicle.

The quarter panels are the large side body sections that extend from the side doors back to the rear bumper. They are welded in place and form a vital part of the rear body structure. The rear body panel fits behind the rear bumper and between the quarter panels. The rear shock towers hold the top of the rear suspension. The inner and outer wheel housings surround the rear wheels and weld to the quarter panels. The upper rear panels are the area between the back glass and trunk lid.

Cross members are thick gauge supports that extend across the frame rails of both unitized and full frame vehicles. They provided more strength for holding various parts of the vehicle. Cross members increase the stiffness and strength it may be welded or bolted in place.

Unibody design factors: There are many types of vehicle construction designs are used in modern vehicles that should be understood. The following designs are considered for the unibody vehicles. (Fig 5)

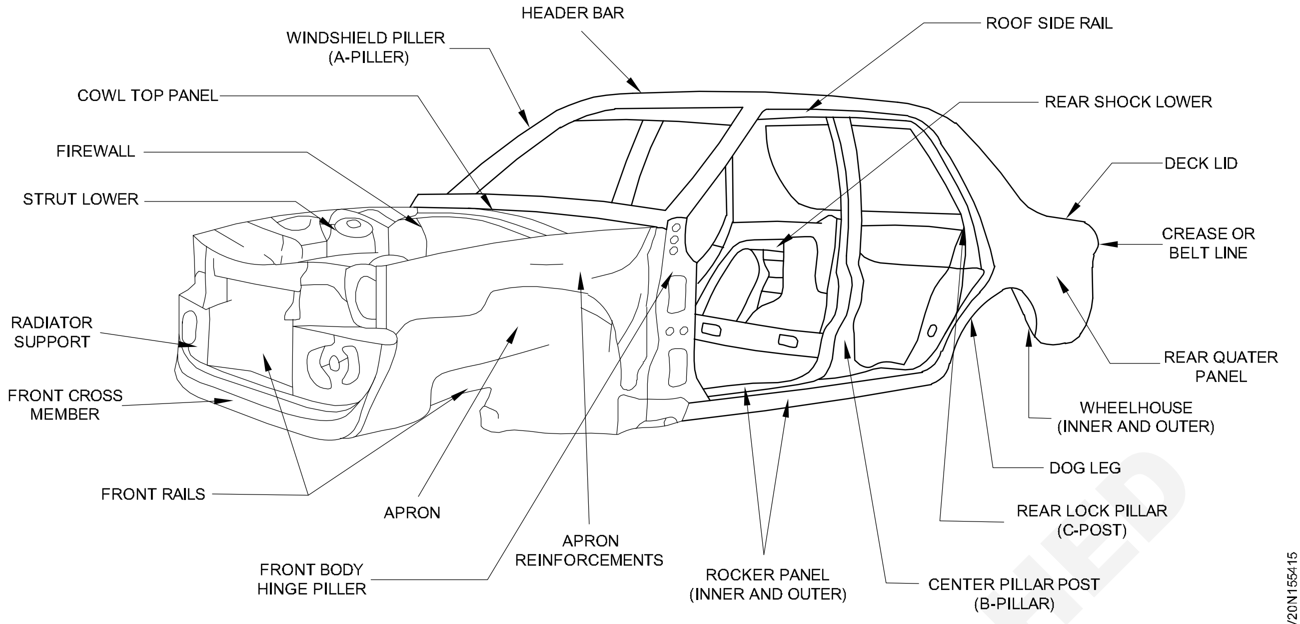


Fig 5

Semi utilized frame body: These type of frame body uses heavier gauge steel stub rails that are bolted to the front and rear of the body structure it secure mechanical chassis parts and also add to the structural integrity of the vehicle during a collison. The design provides the advantages of both unitized and full frame construction on the same vehicle.

Unibody torque boxes: It allows controlled twisting and crushing of the structure during severe collisions. Unibody torque boxes help to secure the passenger compartment to the frame rails by increasing the surface area.

Stress hull design: This type of structure is often compared to an egg shell. This design is used for the bodies of aircraft.

Crush zones: Crush zones are areas in the unibody that are intentionally made weaker in order to collapse during a collisions crush zones provides control of secondary damage and a safer passenger compartment in a unibody structure the front and rear areas will crush, whereas the passenger compartment area tends to stay intact.

Advantages of aerodynamics: Aerodynamics is a measurement of how well a motor vehicle moves without resistance against wind. Vehicle body aerodynamics design helps to increase the vehicle speed against the air resistance and save fuel. A tear drop is the perfect aerodynamic shape or rounded aerodynamic shape for increased fuel economy. Aerodynamic design provide good look to the vehicle.

General unibody characteristics: Vehicle body integrates the frame and body into one assembly is known as a unibody. It has the following characteristics. (Fig 6)

- A unibody structure is made by combining pieces of thin sheet metal pressed to form panels of various shapes and joined into the integrated structure by spot welding. The light weight structure is highly rigid and resistant to bending or twisting.
- The bulk or space taken up by a separate frame can be used to make the car more compact and lighter.

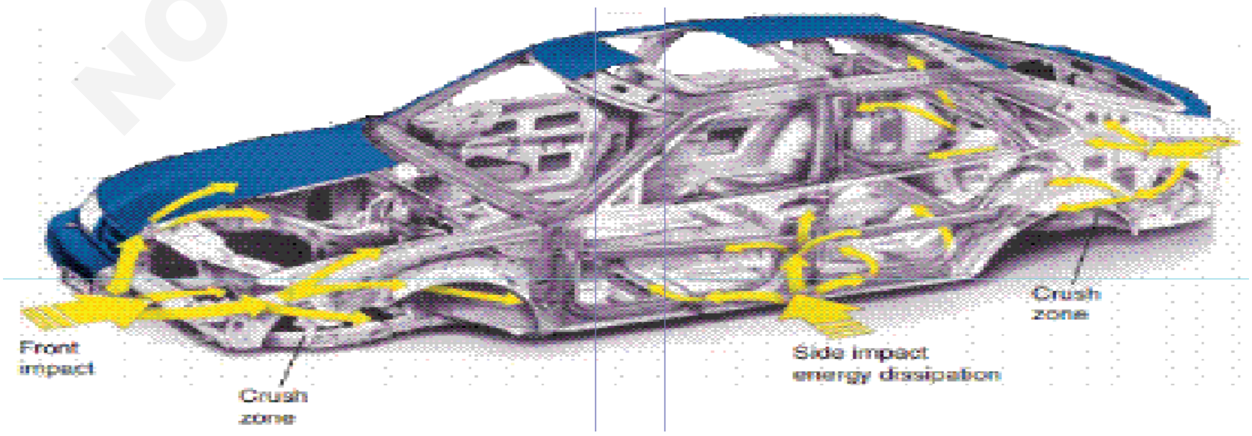


Fig 6

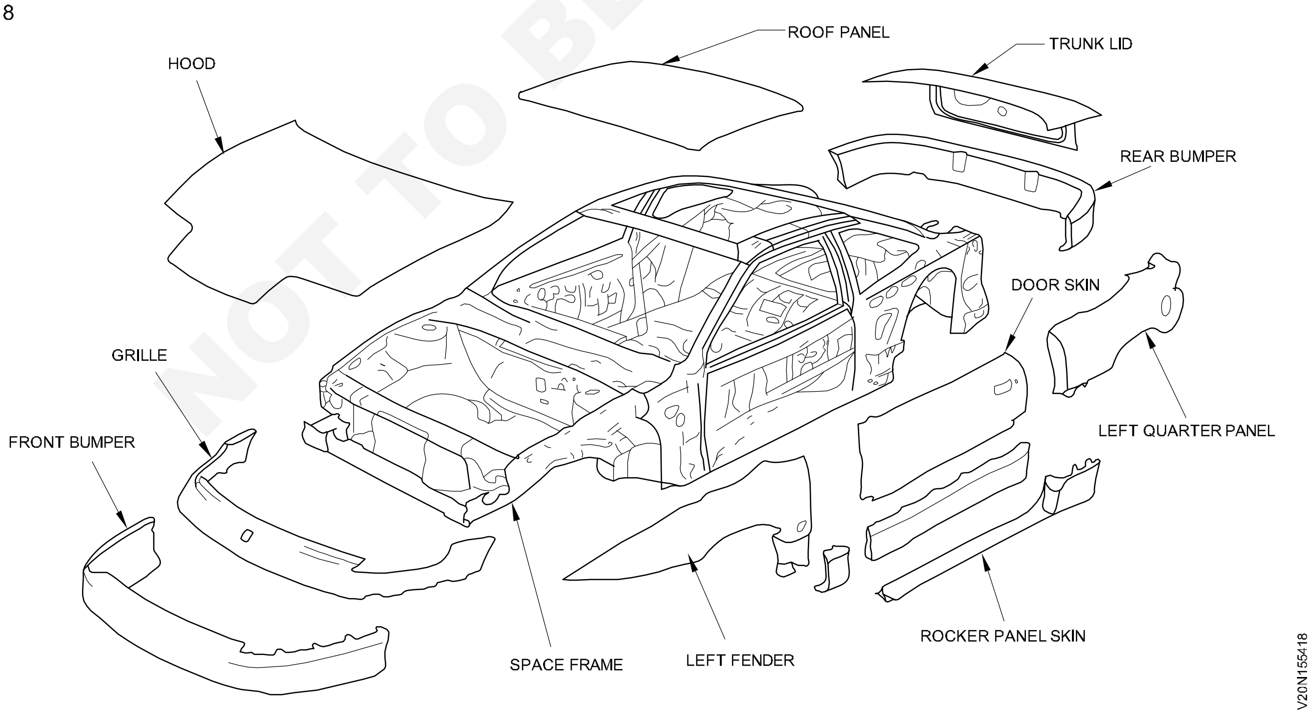
- Vibration and noise from the drivetrain and suspension enter the floor pan are amplified by the body, which acts as an acoustic chamber. This makes it necessary to add extra sound deadening materials to the inside of the body to quiet the passenger compartment.
- Anti corrosion materials are used for prevent rusting of metal parts.
- The stiffer sections used with unibody design even sections that are buckled or torn loose might have pased along heavy force before deforming.
- The unibody underbody includes the floor pan, trunk pan rocker panels cross members, front and rear members and related parts must resist rusting and add strength to the unibody structure.
- There are four basic unibody structures: Front engine, rear drive (FR), front engine front drive (FF), mid engine rear-drive (MR) and rear engine front wheel drive (RR). (Fig 7)
- The transmission and differential are combined and the drive shaft is eliminated, providing a substantial weight reduction.

Fig 7

- Overall noise and vibration are reduced because they are confined to the front of the vehicle.
- The engine and transmission are located in the front, the load on the front suspension and tires is increased.

Plastic parts and panels: (Fig 8) Plastic is a polymer material made from the processing of crude oil. It is a very light, strong, flexible, corrosion resistant material. Plastics parts are being used in the construction of modern new vehicles for various smaller body and trim parts.

Fig 8



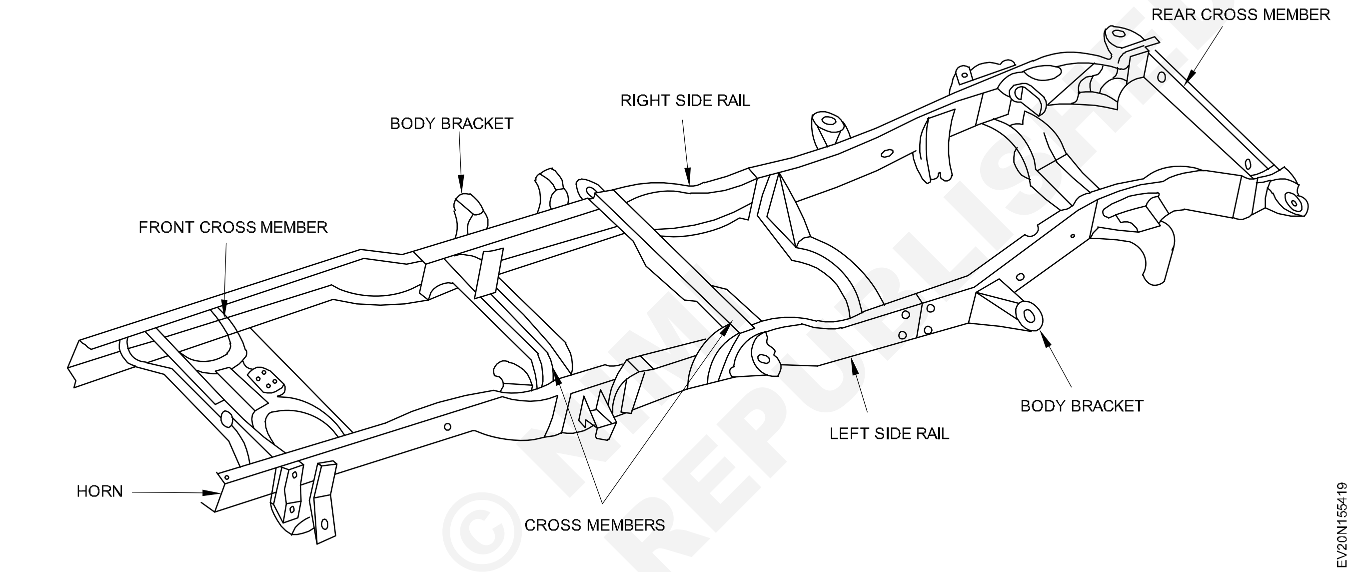
Fiber glass is used to strengthen plastic parts, it is a glass filament or fine strands of glass that can be added to plastic to increase its stiffness and strength sheet moulded compound refers to reinforced plastic materials that are formed into body panels. Carbon fiber is a composite of fiberglass cloth reinforced with strands of graphite. Carbon fiber panels are very light and strong.

Composite unibody: A composite unibody is made of specially formulated plastics and other materials such as carbon fiber, to form the vehicle many manufacturers are experimenting with composite unibody construction.

Aluminium vehicle construction: Aluminium is much lighter than steel and can reduce the vehicles curb weight to reduce fuel consumption. Aluminium will also resist rust and corrosion much longer than steel. Aluminium hoods, fenders, roof and other panels are commonly fastened to conventional steel unibody vehicles. Aluminium panels are forced using a super plastic forming process. The aluminium is heated to near its melting point and forced into a complex die using high air pressure. This allows the aluminium to be formed into very complex shapes.

Body-over frame constructions: In this system, the frame is the vehicle's foundation. Vehicle body and all major parts are attached to the frame, it provide the support and strength needed by the assemblies and parts attached to it. The frame is the most important part of the vehicle. (Fig 9)

Fig 9



Characteristics of body over frame vehicles

- Fewer road-induced vibrations are transfered to the body.
- Rubber mountings between the body and frame insulate the body from vibrations and noise, providing a quiet interior.
- High amounts of energy can be absorbed by the frame during some collisions.
- Under surface of the thin body panels are protected over rough roads by the thick frame work.
- Suspension and power train parts can be quickly assembled on the basic frame.
- A heavy frame made of thick sheet metal is approximately

  $\left(\frac{3}{64} \text{ to } \frac{1}{8} \text{ inch}\right)$ 12 to 3.1 mm thick

- The vehicle ride height is often higher off the ground.
- Total vehicle weight is increased over unibody construction, which lowers fuel economy and handling.
- The load - carrying ability of body-over frame construction is normally higher than for unibody construction.

Full frame designs: There are three types of conventional vehicle frame have been used by the auto industry. They are as follows.

-Ladder frame

-Perimeter frame

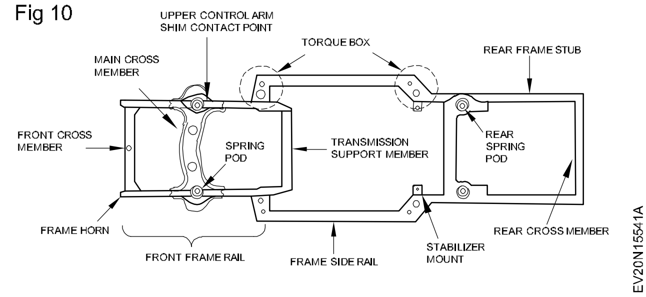
-X-frame or backbone frame

The ladder frame consists of two side rails not necessarily in parallel, connected to each other by a series of cross members like ladder. This type of frame improved to absorb impact energy more efficiently. (Fig 10)

The perimeter frame's full length side rails supports the body at its greatest width, which provides more protection to the passengers in the event of the side impact to the body. The areas behind the front wheels and in front of the rear wheels are stepped to form a torque box structure. (Fig 11)

The 'X' frame narrows in the center giving the vehicle a rigid structure that is designed to with stand a high degree of twist. Heavy front cross members are used to support

Fig 10



the upper and lower suspension control arms and coil springs. (Fig 12)

Now a days 'X' frame considered as absolute model.

The back bone frame has a single thick beam or box section in the center section it is used some of sports cars.

Vehicle interior dedign: The Vehicle interior design refers to features provided inside of the cabin. The interior design is vary from vehicle brand to brand and model to model. It refers the features of dashboard indicators

Fig 11

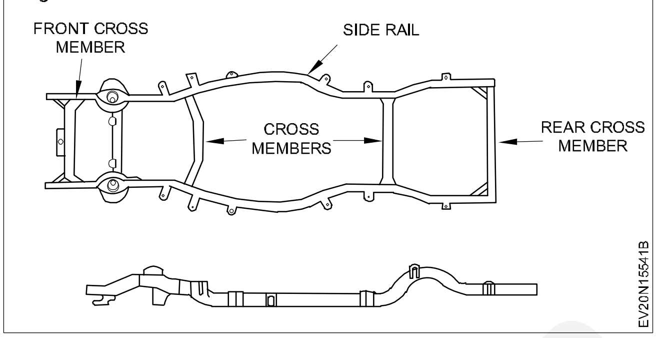
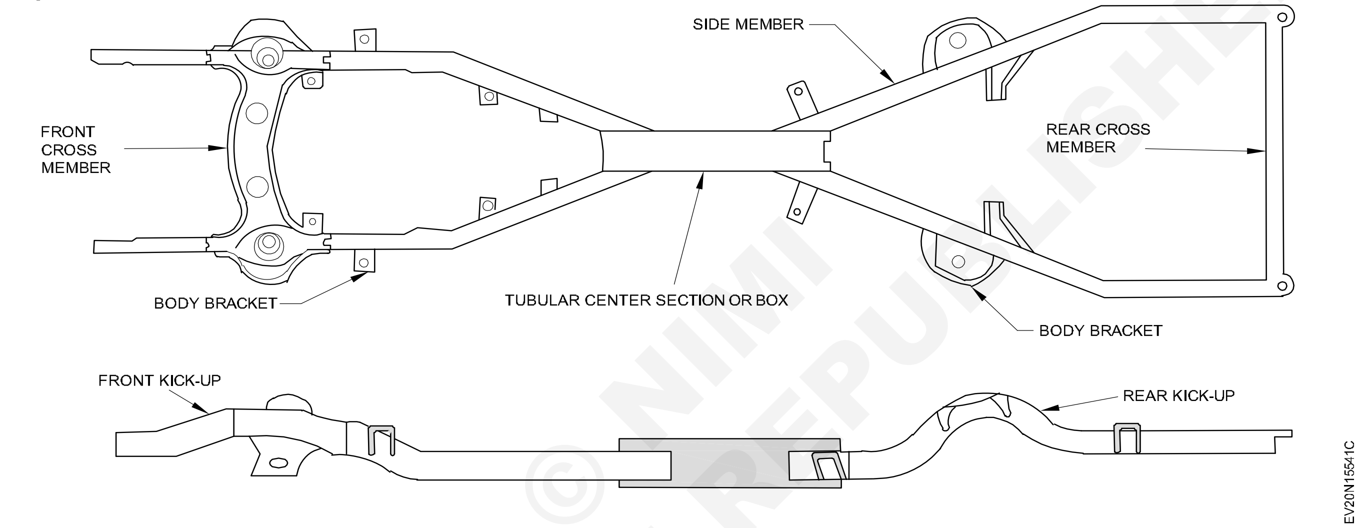


Fig 12



and warning lights, seat belt, seat comfortability, steering arrangement power steering, center console roof air condition, Audio and Vedio system, gauges, mobile charger, wifee, center clock, GPS Camera, Electric controle components ete, interior design refers about new technological comfortability and functional space available for the driver and other passenger of the vehicle.

Exterior design of the Vehicle: The exterior design of the Vehicle refers to visible components provided on exterior of vehicle body-like body panel, grill, head light, tail light and other lights. The vehicle body designed to meet resistance while vehicle run on the surface. The vehicle manufacturers change their vehicle design to reduce the vehicle cost and attract the new customers

Trims:- The vehicle trim refers the same model of the vehicle upgrade version have different features, options and material. A vehicle may have a base trim, a mid level trim and high end trim, each new options with different levels of luxary performance and have a new technological features.

Vehicle Integration: Vehicle Integration involves the coordination of various aspects of vehicle design and development to ensure that all components and systems work together seamlessly. This includes the use of digital mock-up (DMU), ergonomics, layout, and packaging studies.

Dash board monitor unit (ECU):-

DMU is a computer-based tool that allows engineers to create a virtual representation of a vehicle and simulate how different components and systems will interact. DMU can be used to analyze the performance and functionality of various parts and systems, as well as to identify potential design problems early in the development process

Ergonomics: Ergonomics refers to the study of how people interact with machine and envirnoments. In the context of vehicle integration, ergonomics focuses on designing the vehicle's interior layout and controls to optimize driver and passenger comfort, safety, and accessibility. This includes considerations such as seat position, pedal placement, steering wheel angle, and control placement

Layout and packaging studies: Layout and pakaging studies involve the arrangement of the vehicle components and systems to optimize space weight distribution, and overall perfomance . This includes considerations such as the location of the engine, battery pack, transmission, and fuel tank, as well as the size and palcement of the vehicle's wheels and tires.

Marking material

Objectives: At the end of this lesson you shall be able to
- **name the common types of marking material**
- **select the correct marking material for different applications.**

Common types of Marking Materials

The common marking materials are Whitewash, Cellulose Lacquer, Prussian Blue and Copper Sulphate.

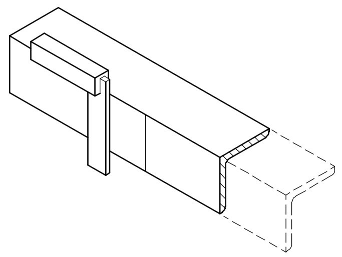
Whitewash

Whitewash is prepared in many ways.

Chalk powder mixed with water Chalk mixed with methylated spirit White lead powder mixed with turpentine

Whitewash is applied to rough forgings and castings with oxidised surfaces. (Fig 1)

Fig 1



Whitewash is not recommended for workpieces of high accuracy.

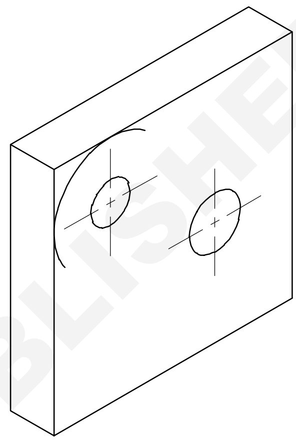
Cellulose Lacquer

This is a commercially available marking medium. It is made in different colours, and dries very quickly.

Prussian Blue

This is used on filed or machine-finished surfaces. This will give very clear lines but takes more time for drying than the other marking media. (Fig 2)

Fig 2



Cleaning tools

Objectives: At the end of this lesson you shall be able to
- **state the different types of cleaning tools and their use**
- **state the precautions to be observed in the use of cleaning tools.**

Mechanical Cleaning Involves, brushing and abrasive Cleaning. It should be used very carefully on soft metals. Heavy deposits that exists even after chemical Cleaning can be removed by mechanical cleaning.

The General Cleaning Tools are

1 Wire brushes

2 Emery sheets.

Wire Brushes

Wire brushes are generally used for cleaning the work surfaces.

It is made of steel wires (or) Nylon bristles fitted on a wooden piece.

The steel wires are hardened and tempered for long life to ensure good cleaning action. Different types of wire brushes is shown in Fig 1.

Applications

1 Wire brushes can be used for cleaning uneven Surfaces

2 A hand wire brush can be used on exterior of the block and on the head.

3 A round wire brush fixed with a hand drill motor spindle can be used for cleaning of combustion chamber and parts of the head.

4 A wire wheel can be used to clean the valves.

5 Nylon bristles with impregnated abrasive brush can be used for Engine boring

6 A washing brush can be used to clean the cylinders by using Soap and Water.

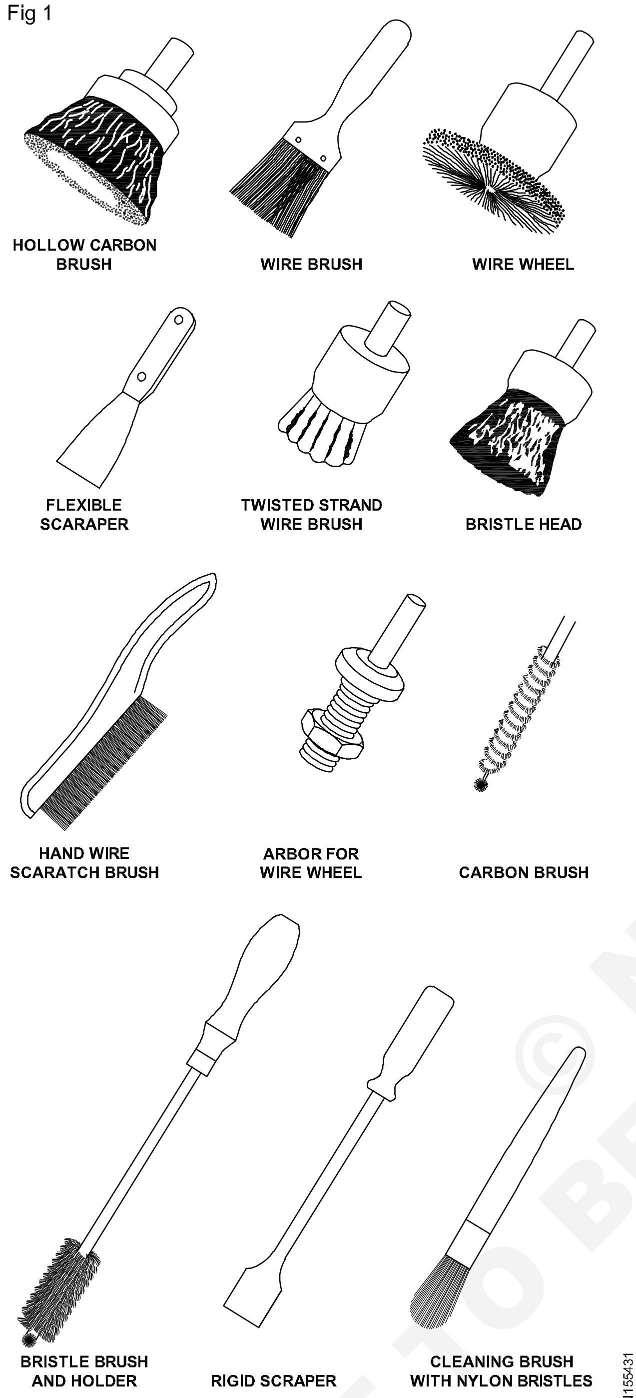
7 Oil passages of cylinder block can be cleaned by running a long bottle type brush through all holes in the cylinder block.

8 It is used to clean work surface before and after welding

Safety precautions

Steel wire brushes should be used carefully on soft metals. It should not make any scratches on the finished surface.

Fig 1

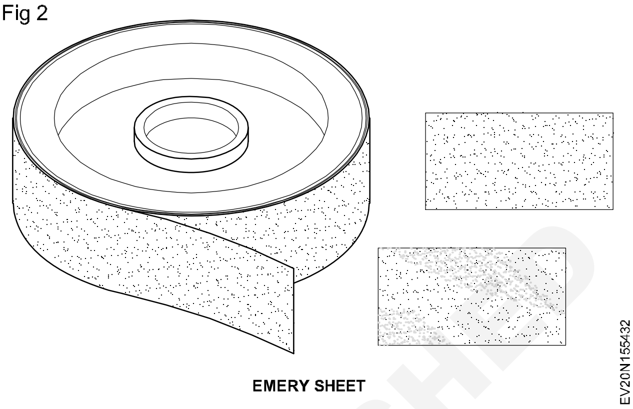


CLEANING TOOLS

Emery Sheet (Fig 2)

This is a type of paper used for sanding down hard and rough surfaces and also used for resistant technology purposes to give a smooth, shiny finish to manufactured products. Emery paper is defined as a paper coated with abrasive particles in one side and used to produce smooth, shiny finish to manufactured products.

Fig 2



EMERY SHEET

Description

The each and every abrasive particle act as a cutting edge. The emery is considered for a suitable abrasive for workshop practices and the final adjustment of steel parts for a perfect fit. The emery paper is also used for cleaning, to remove rust from polished metal components.

The emery is graded by numbers and the Common sizes are from coarse to fine: 40, 46, 54, 60, 70, 80, 90. 100. 120, F and FF.

Safety Precautions After cleaning with emery paper, component should be rinsed properly.

Scraper

Objectives: At the end of this lesson you shall be able to
- **name the different types of scrapers**
- **state the features of each type of scraper**
- **state the precautions to be observed while uses scraper.**

Scraper is a hand tool which is used to scrap the workpiece surface by removing the smallest metal particles.

Application

It is used to obtain a smooth non scored and uniformly bearing surface which is required for sealing, sliding and guiding surface.

In automobiles it is used to remove carbon particles from cylinder head, piston head and manifold pipes.

It is also used to scrap the bearings of cranks halt and sometimes the cylinder liner.

Type of scrapers

1 Flat scraper

2 Special scraper

Flat scraper: The cross section of this scraper is Flat.

The cutting edge has Flat surface.

Use It is used to scrap the high spots of a flat Surface

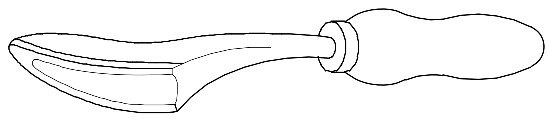
Special Scraper: Special scraper is available for scraping and finishing curved surfaces. They are

- half round scraper
- three-square scraper
- bull nose scraper.

Half round scraper

The cross- section of this scraper is a segment and it tapers to a rounded point (Fig 1).

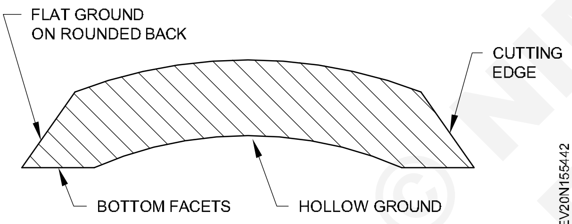
Fig 1



The round bottom face is curved and is hollow in the middle.

The bottom facet and the flat surfaces are ground along the edge to form the cutting edge. (Fig 2)

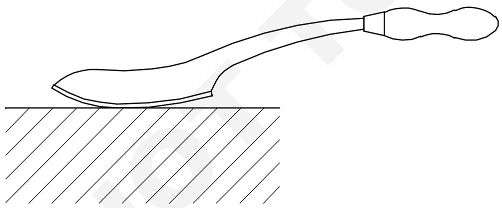
Fig 2



The cutting angle is between 45° and 65°.

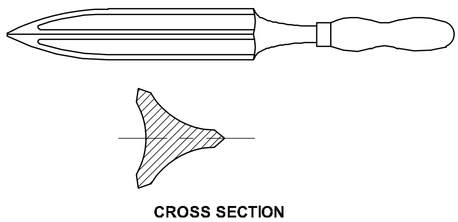
The curvature at the cutting edge helps to make point contact while scraping, and also helps to remove small spots. (Fig 3)

Fig 3



Three - square scraper (Fig 4)

Fig 4

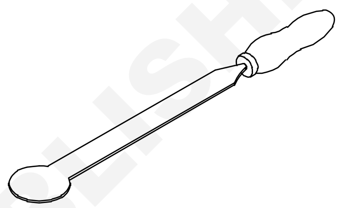


This scraper is used for scraping small diameter holes and deburring the edges of holes.

The cross-section of this is triangular. This has more number of cutting edges and the hollow portion between the cutting edges helps in re-sharpening easily.

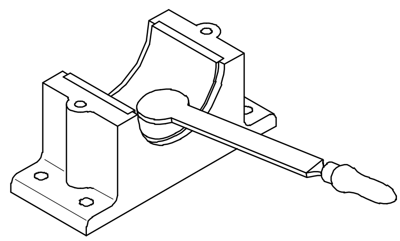
Bull nose scraper (Fig 5)

Fig 5



This scraper has the cutting edge shaped into a flat circular disc. The cutting edge forms about two thirds of the circle. It is useful for scraping large bearings. (Fig 6) This scraper can be used in a longitudinal direction like a flat scraper or with a circumferential movement like a half round scraper. This dual action helps to prevent ridges on the scraped surfaces.

Fig 6



Always use scrapers with firmly fitted handles.

Protect the cutting edges with a rubber cover when not in use.

Apply oil or grease on the cutting edges when not is use.

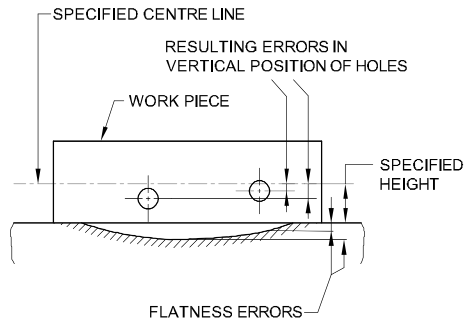
Surface plates

Objectives: At the end of this lesson you shall be able to
- **state the constructional features of surface plates**
- **state the application of different grades of surface plates**
- **specify surface plates and state the uses of marking tables.**

Surface plates - their necessity

When accurate dimensional features are to be marked or to be checked it is essential to have a datum plane with a perfectly flat surface. Marking using datum surfaces which are not perfectly flat will result in dimensional in accuracies. (Fig 1) The most widely used datum surfaces in machine shop work are the surface plates and marking tables.

Fig 1

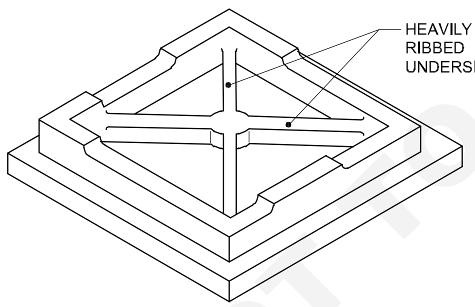


EFFECT OF MARKING-OUT FROM NON-FLAT SURFACE. NOTE THAT THE ERRORS IN THE HOLE POSITIONS ARE EQUAL TO THE FLATNESS ERRORS

Materials and construction

Surface plates are generally made of good quality cast iron which are stress-relieved to prevent distortion. The work-surface is machined and scraped. The underside is heavily ribbed to provide rigidity. (Fig 2)

Fig 2



CAST IRON SURFACE PLATE

For the purpose of steadiness and convenience in leveling. a three point suspension is given.

Smaller surface plates are placed on benches while the larger surface plates are placed on stands.

Other materials used

Granite is also used for manufacturing surface plates. Granite is a dense and stable material. Surface plates made of granite retain their accuracy, even if the surface is scratched. Burrs are not formed on these surfaces.

Classification and uses

Surface plates used for machine shop work are available in three grades - Grades 1, 2 and 3. The grade 1 surface plate is more acceptable than the other two grades.

Specifications

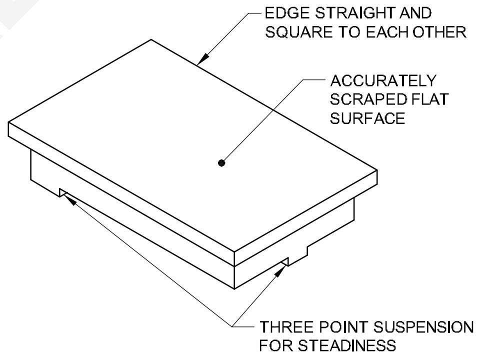
Cast iron surface plates are designated by their length, breadth, grade and the Indian Standard number.

Example

Cast iron surface plate 2000 x 1000 Gr1. I.S.2285.

Marking-off tables (Fig 3)

Fig 3



Wheelbase, wheel track and measuring tape

Objectives: At the end of this lesson you shall be able to
- **define wheelbase**
- **define wheeltrack**
- **state measuring tape, its types and uses.**

Wheelbase: The wheelbase of a vehicle equals the center distance between its front and rear wheels. (Fig 1)

Wheel/Track: The wheeltrack of a vehicle equals the center distance between its front wheels. As shown in the diagram. (Fig 4)

Measuring tape is a flexible ruler. It is made of ribbon cloth plastic fiber glass metal strip with lines for measurements. It is very common measuring tool used by many people. The available range are 3m, 5m and 10m.

Fig 1

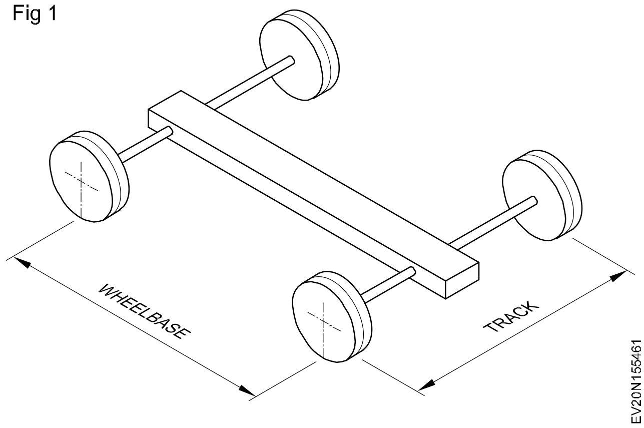
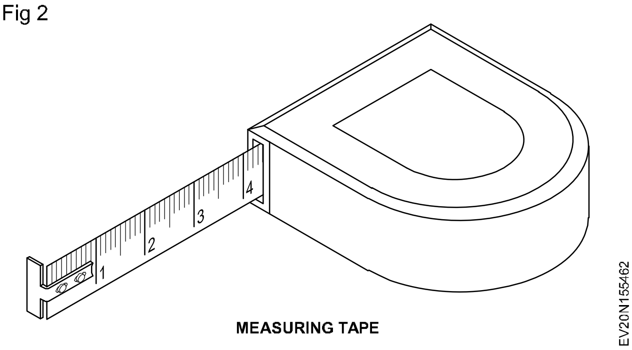


Fig 2



MEASURING TAPE

Fig 3

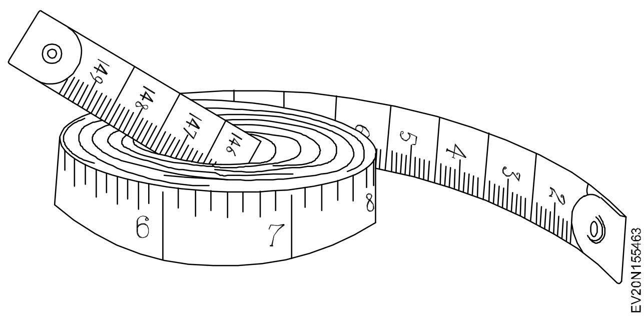
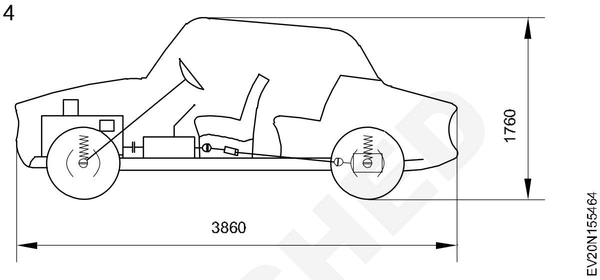


Fig 4



Types

1 Plastic Tape (Fig 3)

2 Metal Tape (Fig 2)

3 Fibre glass

4 Ribbon cloth

Application

Dress makers

Civil Engineers

Mechanical Engineers

Surveyors

Carpenters

Medical field

Accuracy

Measuring tapes are marks in metric and British system.

The accuracy in metric system is 1mm and in British system is 1/8”.

Limitation: Accuracy is not possible, because the tape is flexible and likely to elongate while measuring long ranges and distances.

Length measurement

Objectives: At the end of this lesson you shall be able to
- **name the base unit length measurement as per the International system of units of measurement (SI)**
- **state the multiples of a metre and their values.**

When we measure an object, we are actually comparing it with a known standard of measurement.

The base unit of length as per SI is the METRE Length SI UNIT and MULTIPLES

Base Unit

The base unit of length as per the System International is the metre. The table given below lists some multiples of a metre.

METRE (m) = 1000 mm

CENTIMETRE(cm) = 10 mm

MILLIMETRE (mm) = 1000 mm

MICROMETRE (m) = 0.001 mm

Measurement in engineering practice

Usually, in engineering practice, the preferred unit of length measurement is the millimetre (Fig. 1).

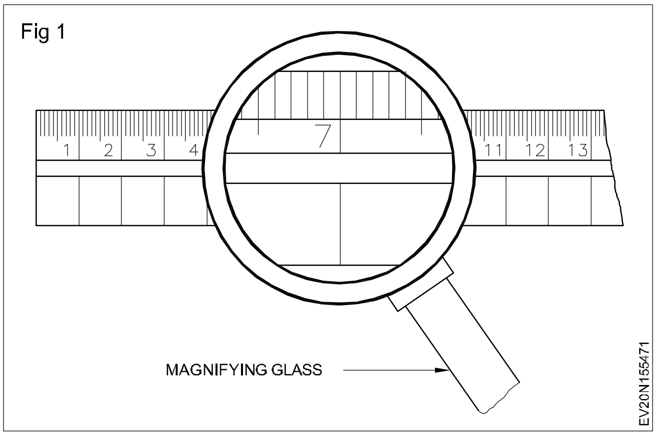
Both large and small dimensions are stated in millimetres

The British system of length measurement

An alternative system of length measurement is the British system. In this system, the base unit is the Imperial Standard Yard. Most countries, including Great Britain itself, have, however, in the last few years, switched over to SI units.

However in a regular Steel rule & in vernier caliper the main scale readings of metric in the bottom and imperial in inches in the top with corresponding vernier scales.

Fig 1



Engineer's steel rule

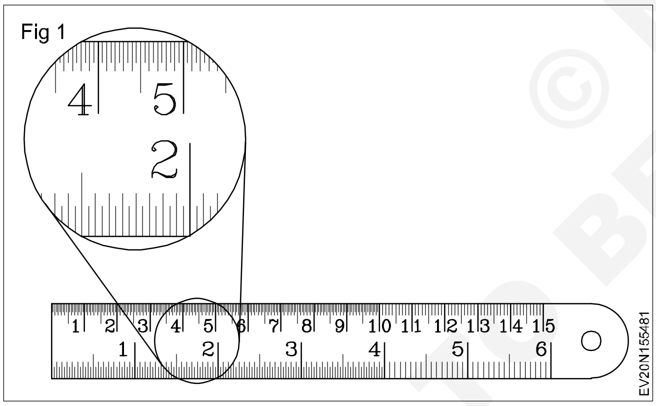
Objectives: At the end of this lesson you shall be able to
- **state the constructional features of an engineer's steel rule**
- **explain the uses of a steel rule**
- **state the maintenance aspects to be considered in respect of steel rules.**

When dimensions are given in a drawing without any indication about the tolerance, it has to be assumed that measurements are to be made with a steel rule.

Steel rule are made of spring steel or stainless steel. The edges are accurately ground to form straight edges. The surface of the steel rule is satin-chrome finished to reduce glare, and to prevent rusting.

Sizes of steel rules (Fig 1)

Fig 1



Steel rules are available in different length, the common sized being 150mm, 300 mm and 600 mm.

The engineer's steel rule is graduated in 10 mm, 5 mm, 1mm and 0.5 mm.

The reading accuracy of the steel rule is 0.5 mm.

These are heavily ribbed cast iron tables fitted with strong rigid legs. The top surface is accurately machined flat, and the sides square.

These are used for carrying out marking on heavy components. On certain types-parallel lines are engraved in both directions at a set distance.

These lines serve as guides for positioning components while setting and marking.

Try square

Objectives: At the end of this lesson you shall be able to
- **name the parts of a try square**
- **state the uses of a try square.**

The try square (Fig 1) is a precision instrument which is used to check squareness (angles of 90°) of a surface.

The accuracy of measurement by a try square is about 0.002 mm per 10 mm length, which is accurate enough for most workshop purposes. The try square has a blade with parallel surfaces. The blade is fixed to the stock at 90°.

Uses

The try squareness is used (Figs 2 & 3)

- check flatness of surfaces (Fig 3)
- mark lines at 90° to the edges of workpieces (Fig 4)
- set workpieces at right angles on work, holding devices. (Fig 5)

Try squares are made of hardened steel.

Try squares are specified according to the lengths of the blade, i.e 100 mm, 150 mm, 200 mm.

Use of a try square and steel rule.

Fig 6 shows the method of using a try square and a steel rule for accurate measurements.

Fig 1

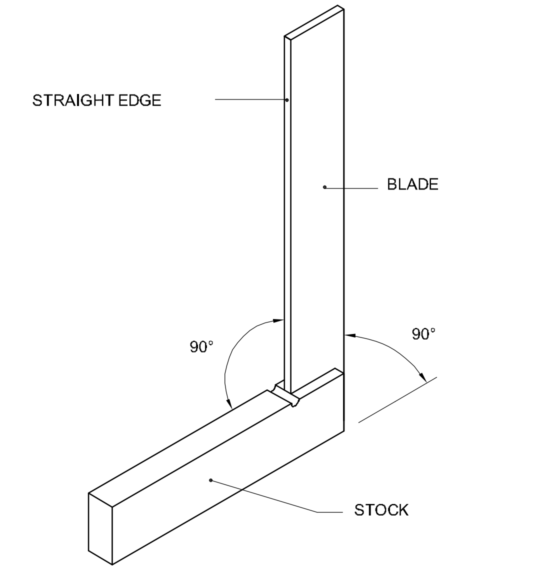


Fig 2

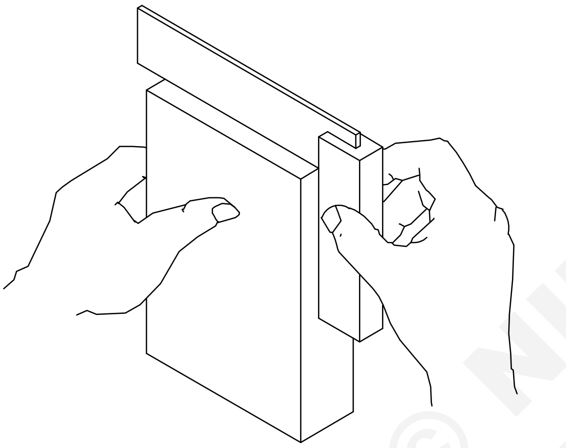


Fig 3

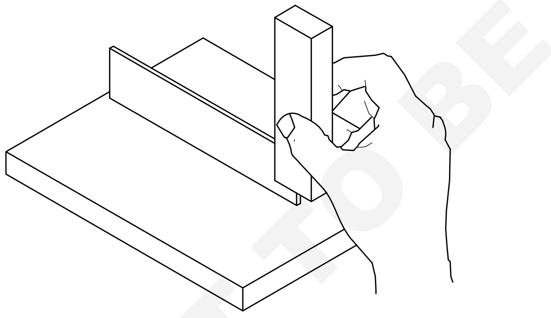


Fig 4

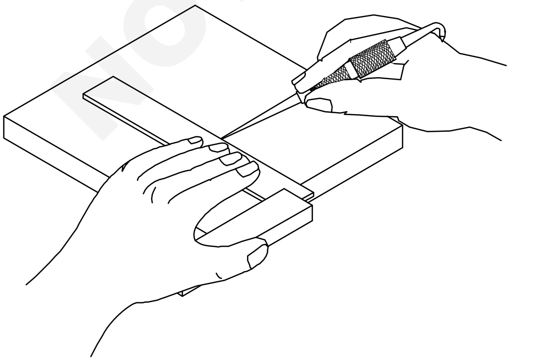


Fig 5

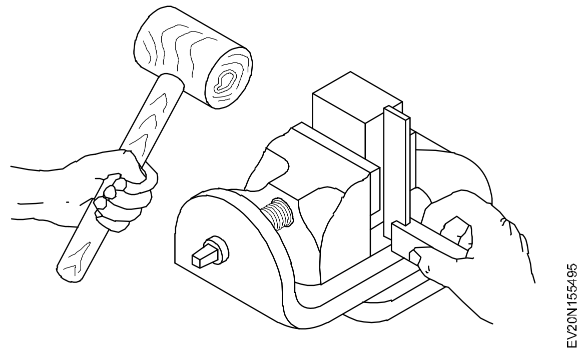
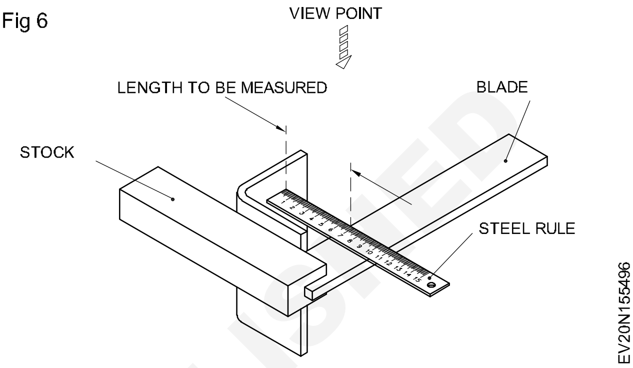


Fig 6



For maintaining accuracy it is important to see it, that the edges and surfaces of instruments are protected from damage and rust.

An experienced person can transfer measurements from a steel rule very accurately.

The steel rule graduations are accurately engraved, with the line thickness ranging from 0.12 to 0.18 mm.

Do not place a steel rule with any cutting tools. Apply a thin layer of oil when not in use.

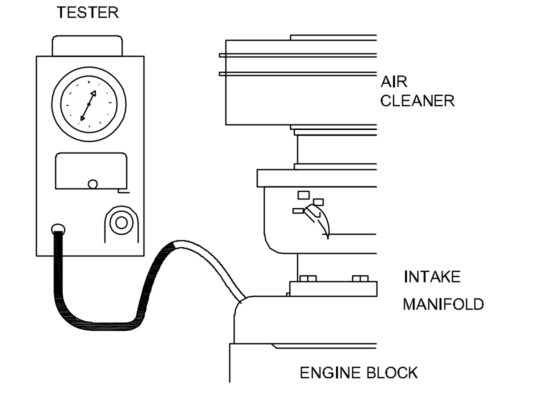
For Accurate reading it is necessary to read vertically to avoid errors due to parallax.

Vacuum gauge

Objectives: At the end of this lesson you shall be able to
- **state the purpose of vacuum gauge**
- **state the vacuum gauge attachment in an engine.**

A vacuum gauge (Fig 1) is a useful diagnostic and time-up tool.

Fig 1



It is used to detect vacuum leaks at idle speed, sticking valves, worn rings, clogged exhaust, incorrect timing and positive crank case ventilation (PCV)

Attaching Vacuum Gauge

At normal operating temperature connect the vacuum gauge to the intake manifold. Some manifolds incorporated a plug that may be removed so that vacuum line adopter may be installed.

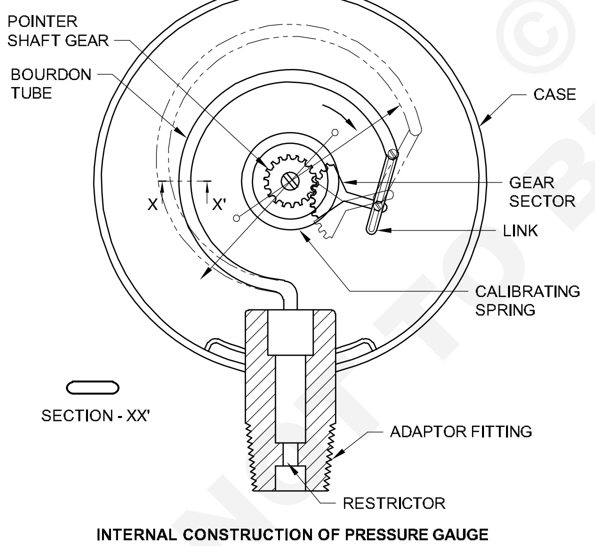
- A relative study high vacuum reading indicate an absence vacuum leak in the system (i.e) values and rings are in good sealing.
- Fairly study vacuum reading indicate vacuum leak in the system (i.e) value and rings are not in good sealing.
- Vacuum reading indicate uneven, valve are burned or sticky and damaged piston or blown gasket.

Tyre pressure gauge

Objectives: At the end of this lesson you shall be able to
- **state the construction and features of tyre pressure gauge**
- **use a tyre pressure gauge to check & set tyre pressure.**

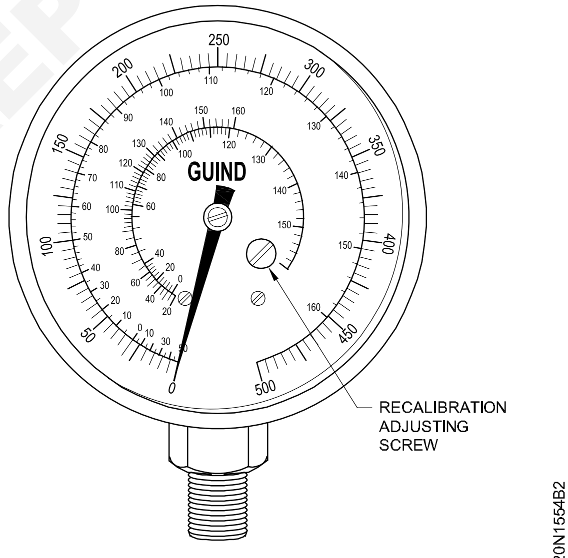
Pressure gauge (Figs 1, 2)

Fig 1



INTERNAL CONSTRUCTION OF PRESSURE GAUGE

Fig 2



PRESSURE GAUGE

It is used to check the pressure of tyre unit. Bourdon tube pressure gauges made by stainless steel. A Pressure rise in bourdon tube makes it tend to straighten. This movement will pull on the link which will turn the gear sector counter clockwise. The pointer shaft with then turn clockwise to move needle on a graduated scale to indicate pressure

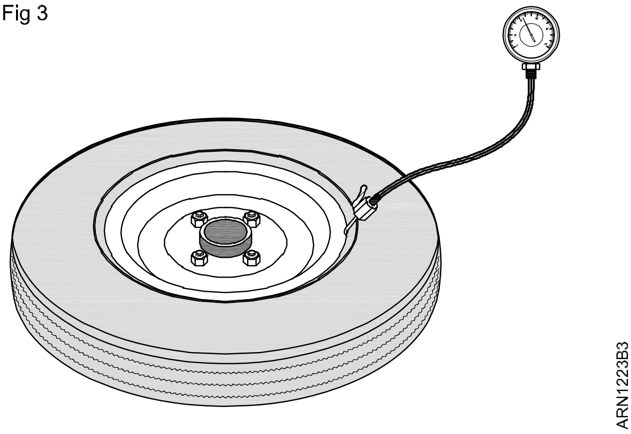
Special features

- Excellent load-cycle stability and shock resistance.
- All stainless steel construction
- Positive pressure ranges 0-200 P.S.I (Fig 3)

The pressure gauge hose has a adapter, which depresses the valve pin of tyre and compressed air get into the tube of the gauge. The pressure is indicated in the dial.

Compare the pressure to the recommended pressure by the manufacturer. If it is less, refill the tyre with compressed air by operating the trigger (Fig 3). When the required pressure is shown in the gauge stop filling.

Fig 3

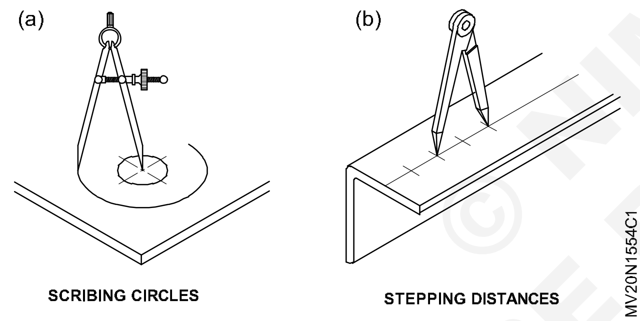


Dividers

Objectives: At the end of this lesson you shall be able to
- **name the parts of a divider**
- **state the uses of dividers**
- **state the specifications of dividers**
- **state the important aspects of be considered in respect of divider points.**

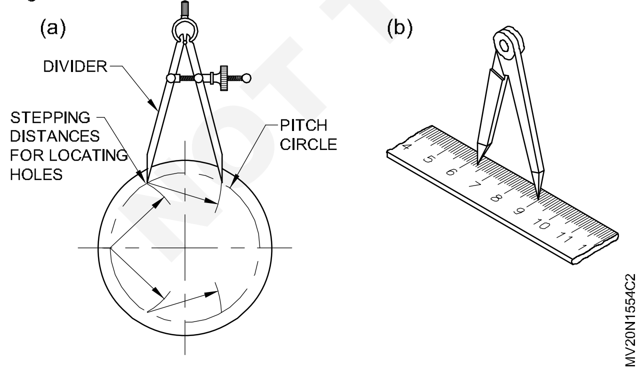
Dividers are used for scribing circles, arcs and transferring and stepping of distances. (Figs 1 a,b)

Fig 1



Dividers are available with firm joints and spring joints. The measurements are set on the dividers with a steel rule. (Fig 2 a,b)

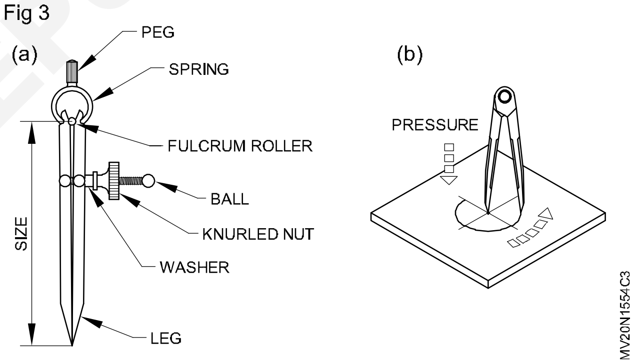
Fig 2



The sizes of dividers range between 50 mm to 200 mm. The distance from the point to the centre of the fulcrum roller (pivot) is the size of the divider. (Fig 3a)

For the correct location and seating of the divider legs, prick punch marks of 30o are used. (Fig 3b)

Fig 3



Both the legs of the divider should always be of equal length.

Dividers are specified by the type of their joints and length.

The divider point should be kept sharp in order to produce timelines. Frequent sharpening with an oil stone is better than sharpening by grinding. Sharpening by grinding will make the points soft.

Do not sharpen the divider points on grinding wheels.

Surface Gauges

Objectives: At the end of this lesson you shall be able to
- **state the constructional features of surface gauges**
- **name the types of surface gauges**
- **state the uses of surface gauges**
- **state the advantages of universal surface gauges.**

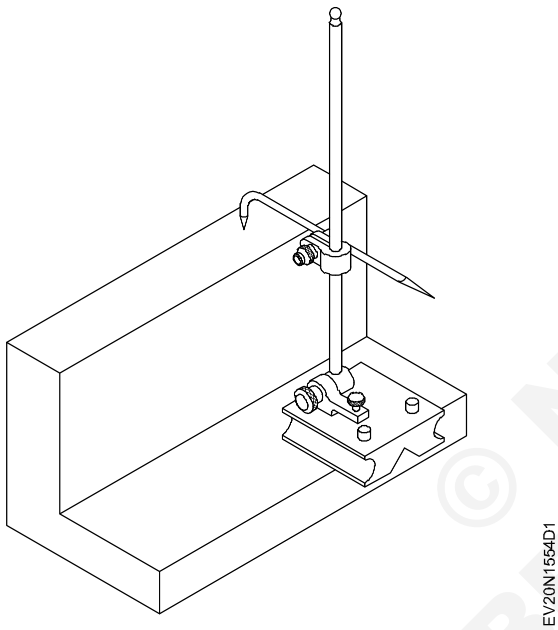
The surface gauge is one of the most common marking tools used for.

scribing lines parallel to a datum surface

Types of surface gauges

- Surface gauges/scribing blocks are of two types.
- Fixed
- Universal (Fig.1)

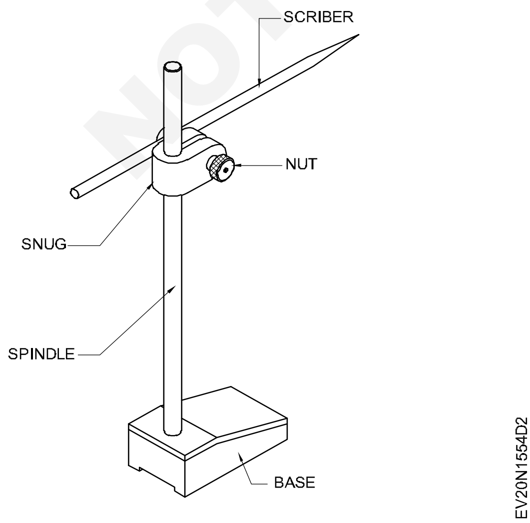
Fig 1



Surface gauge-fixed type (Fig 2)

- setting jobs on machines parallel to a datum surface
- checking the height and parallelism of jobs
- setting jobs concentric to the machine spindle.

Fig 2



The fixed type of surface gauge consists of a heavy flat base and a spindle, fixed upright , to which a scriber is attached with a snug and a clamp-nut.

Universal surface gauge (Figs 3&4)

This has the following additional features.

- The spindle can be set to any position.
- Fine adjustments can be made quickly.
- can also be used on cylindrical surfaces.

Fig 3

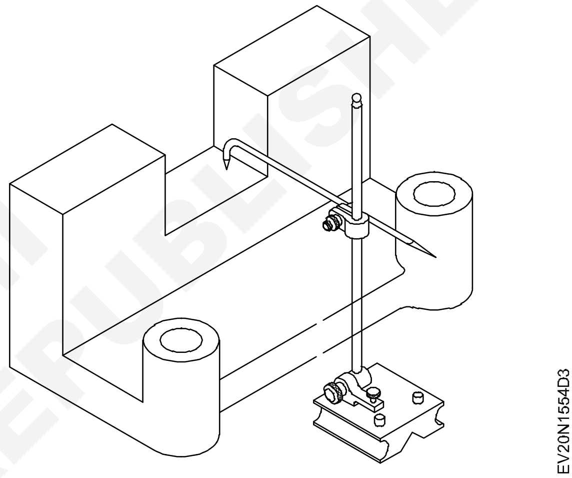
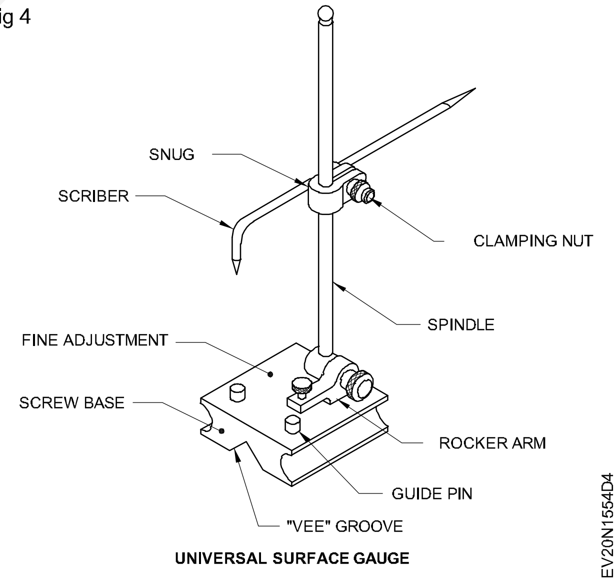


Fig 4



Scriber

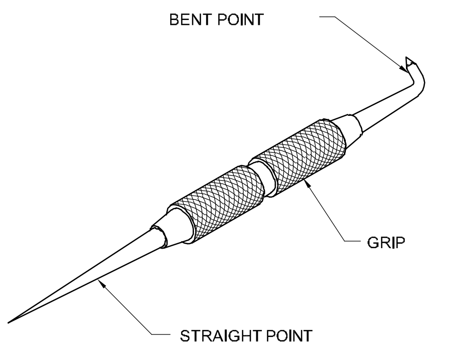
Objectives: At the end of this lesson you shall be able to
- **state the features of scribers**
- **state the uses of scribers.**

In layout work, it is necessary to scribe lines to indicate the dimensions of workpieces to be filed or machined .

The scriber is a tool used for this purpose. It is made of high carbon steel which is hardened. For drawing clear and sharp lines, a fine point is ground at one end.

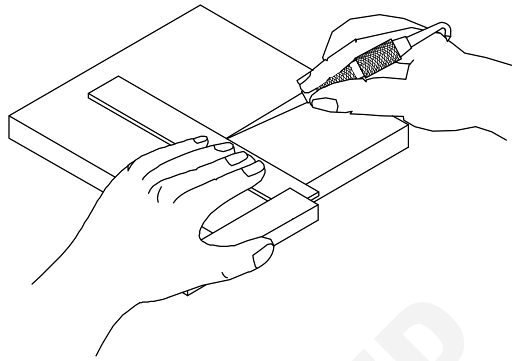
Scribes are available in different shapes and sizes. The one most commonly used is the plain scriber (Fig 1).

Fig 1



While scribing lines, the scriber is used like a pencil so that the lines drawn are close to the straight edge (Fig.2).

Fig 2



The point of the scriber should be ground and honed frequently for maintaining its sharpness.

> **Scriber points are very sharp, and they are to be handled very carefully. Do not put the scriber in your pocket. Place a cork on the point when not in use to prevent accidents. (when it is not in use)**

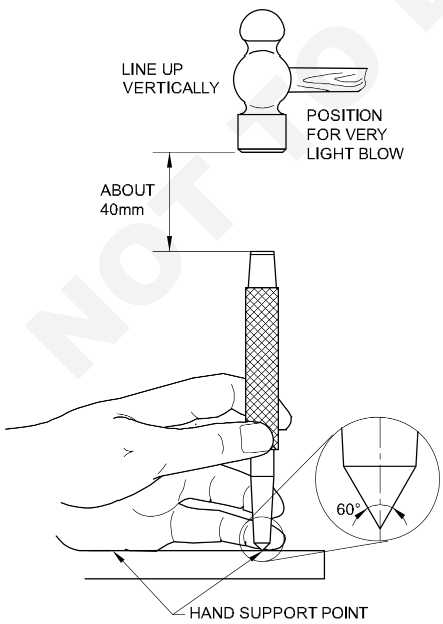
Hand tools

Objective: At the end of this lesson you shall be able to
- **state the application of punches.**

Punches are used in sheet metals and other work to mark position on work. (Fig 1)

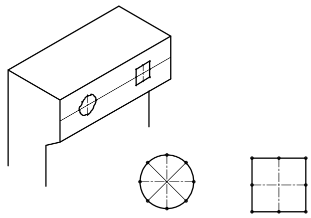
Prick punches

Fig 1



These punches are used to make witness marks on scribed lines. (Fig 2)

Fig 2



This makes it easier to see accurate marking out lines.

- to check the location of the centre positions before centre punching. (Fig 3)
- to locate the pivot points of compasses for scribing circles. (Fig 4)

A 100 mm prick punch with a 7 mm diameter body could have a 2.5 mm diameter point ground to an angle of 60° or 30°

Centre punches

These punches are similar to prick punch, and it is generally larger then prick punch.

A 100 mm centre punch could have a 10 mm diameter body and a 6 mm diameter point ground to an angle of 90°

Fig 3

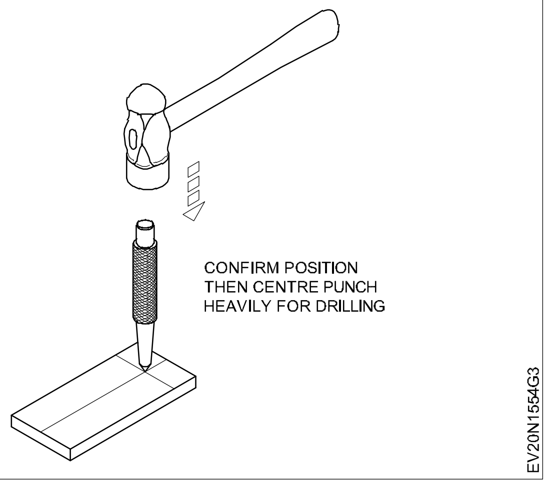
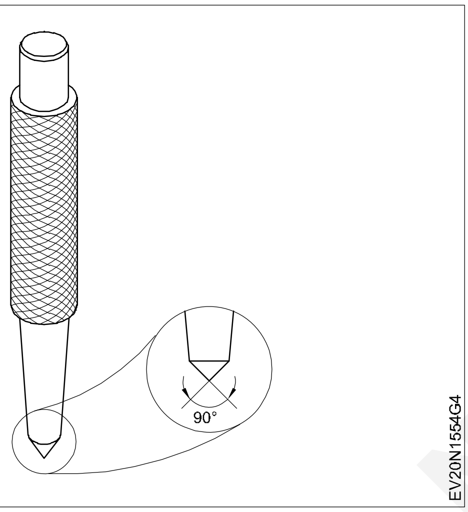


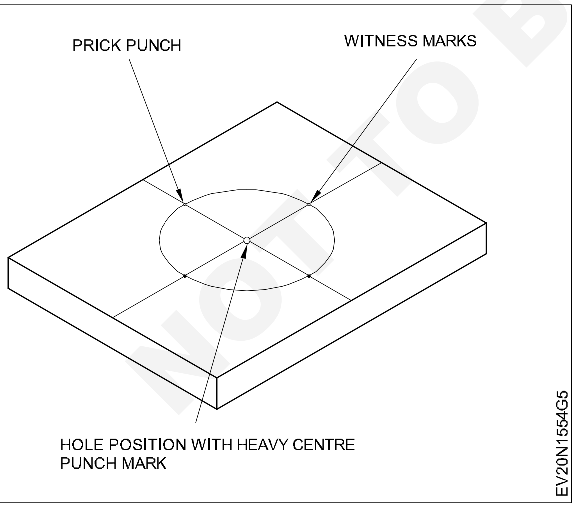
Fig 4



Centre punches are used

- to make deeper witness marks on scribed lines and to locate a centre position and make it easier for the drill to start correctly. (Fig 5)

Fig 5



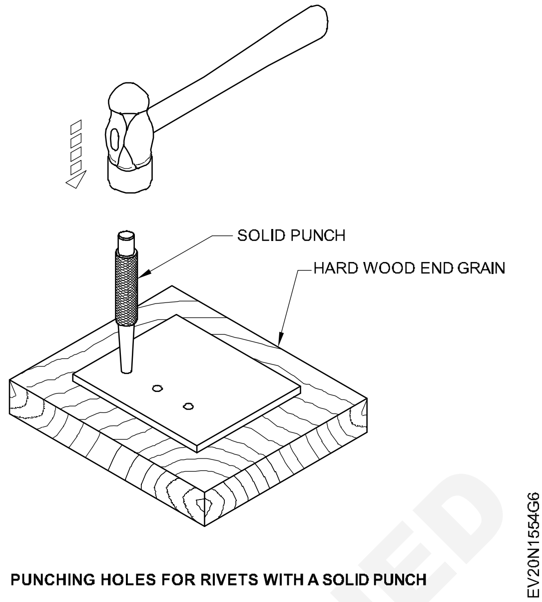
Solid punch (Fig 6)

In riveting sheet metal, holes must be equally spaced and lined up. The holes in the metal are usually punched with solid punches.

Letter and number punches

Also known as letter stamps or number stamps, letter punches are used to emboss the impression of a letter

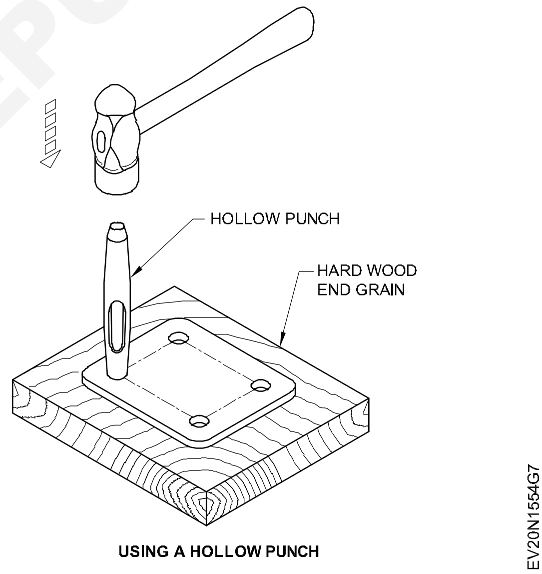
Fig 6



of number into a workpiece. They are most common in the reverse image, this allows the end result to be immediately readable, however they may be made as a positive image. This is essential in the case of die or mold making and ensure that the finished product will be readable, as a die is a negative image.

Hollow punch (Fig 7)

Fig 7



These punches are also used to punch holes in thin sheet metal, leather, plastic cork etc. Gaskets, seals and spacers are made using hollow punches.

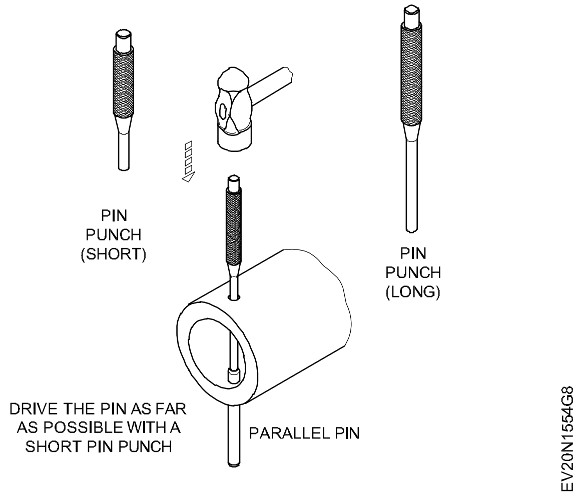
While using solid or hollow punches, the materials is rigidly supported with a block of wood (with the end of grain up) or lead. This will also avoid any damage to the tip of the punch while punching.

Pin punches (Fig 8)

Pin punches are used to drive locating or locking pins, dowels and rivets out of their holes.

Pin punches are available in a set of 5 pins of dia.3,4,5,6 and 8 mm with a knurled body to a length of approximately 150 mm.

Fig 8



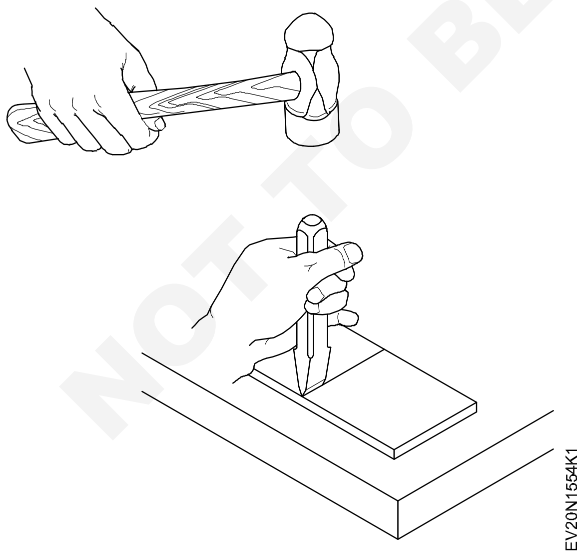
Hammers

Objectives: At the end of this lesson you shall be able to
- **state the uses of an engineer's hammer**
- **list the parts of an engineer's hammer and state their functions**
- **name the types of engineer's hammers**
- **specify the engineer's hammer.**

An engineer's hammer (Fig.1) is a hand tool used for striking purposes while

- punching
- bending
- straightening
- chipping
- forging
- riveting

Fig 1



Major parts of a hammer (Fig 2)

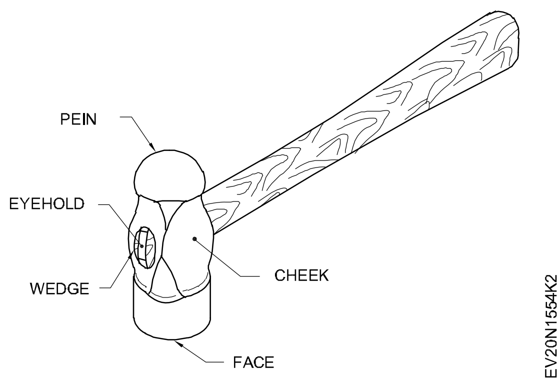
The major parts of a hammer are a head and a handle.

The head is made of drop-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer head are the

- face (1)
- pein (2)
- cheek (3)
- eyehole (4)
- wedge (5)

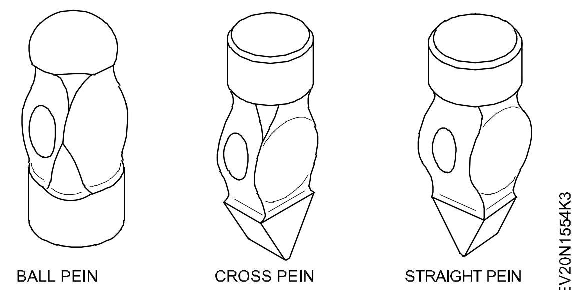
Fig 2



The face is the striking portion. Slight convexity is given to it avoid digging of the edge.

The pein is the other end of the head. It is used for shaping and forming work like riveting and bending. The pein is of different shapes like the (Fig. 3)

Fig 3



- ball pein
- crosspein
- straight pein

The face and the pein are hardened.

The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here.

This portion of the hammer-head is left soft.

An eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. The wedges fix the handle in the eye hole. (Fig 4,5)

Fig 4

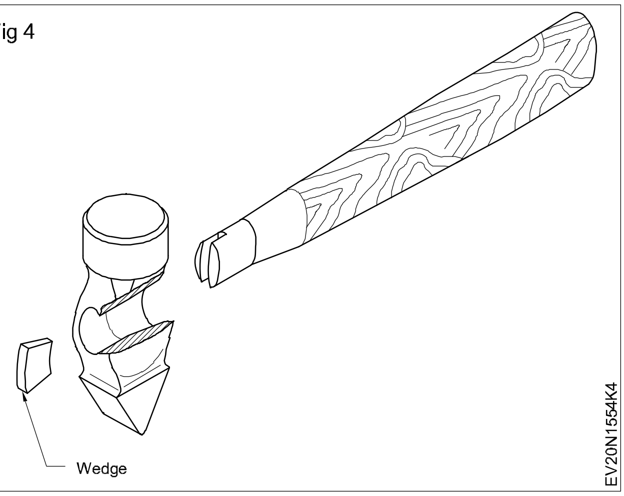
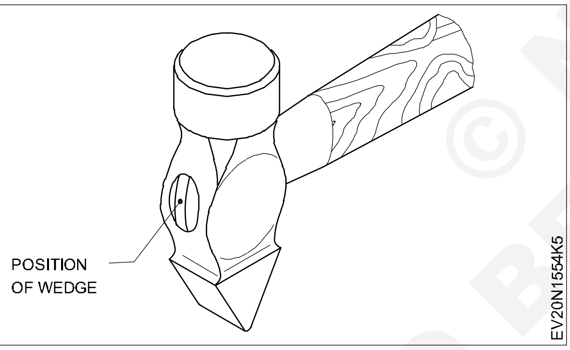


Fig 5



Specification

An engineer’s hammers are specified by their weight and the shape of the pein. Their weight varies from 125 gms to 1.5 kg.

The ball pein hammers are used for general work in a machine/fitting shop.

Before using a hammer

make sure the handle is properly fitted

select a hammer with the correct weight suitable for the job

check the head and handle for any cracks

ensure the face of the hammer is free from oil or grease.

The figure shows the different parts of a hammer (Fig 6). The handle is fitted in the eye-hole of the hammer.

The face of the hammer is used for general work, such as striking chisels and punches and levelling and working over joints. (Fig.7)

Fig 6

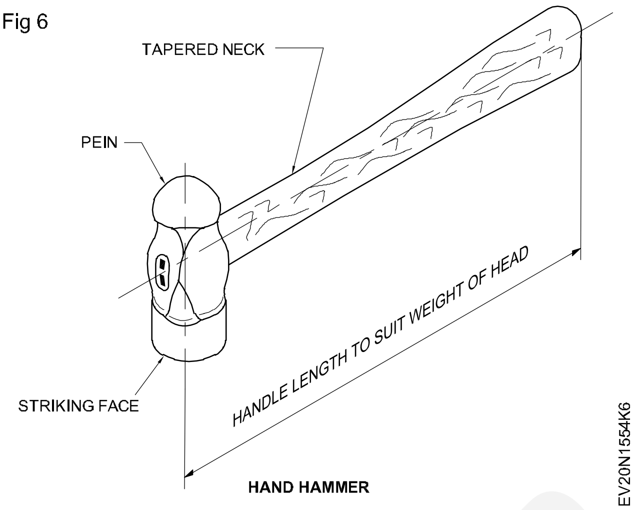
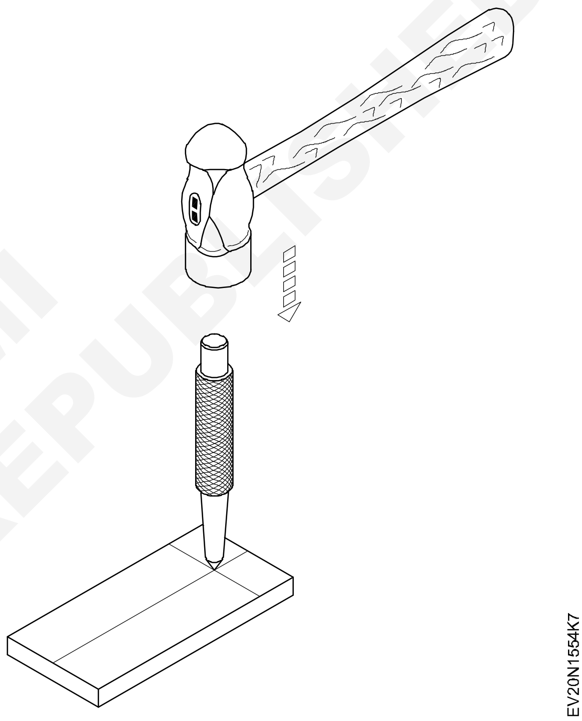
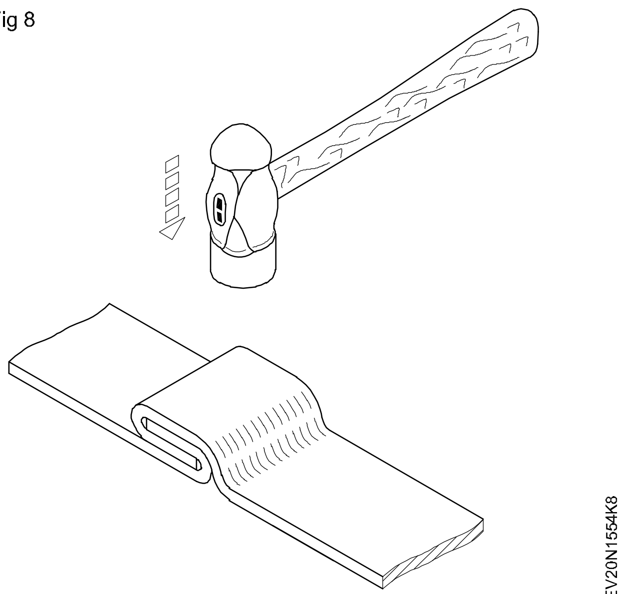


Fig 7



Ball pein hammer (Fig. 8)

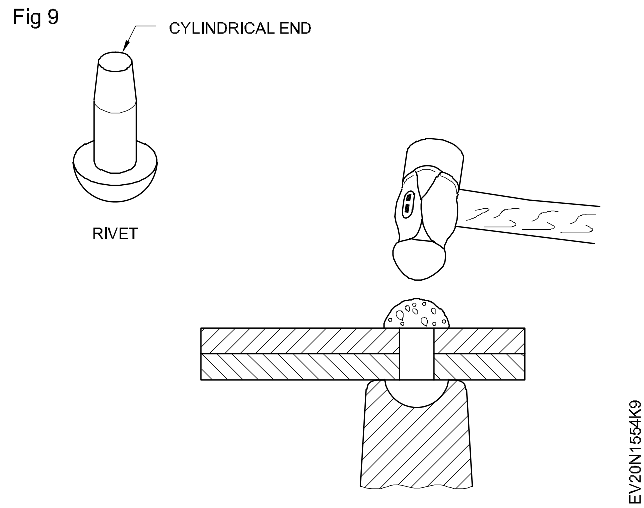
Fig 8



A ball pein head is used to spread metal in all directions.

This hammer has a semi-spherical pein suitable for riveting. (Fig 9)

Fig 9



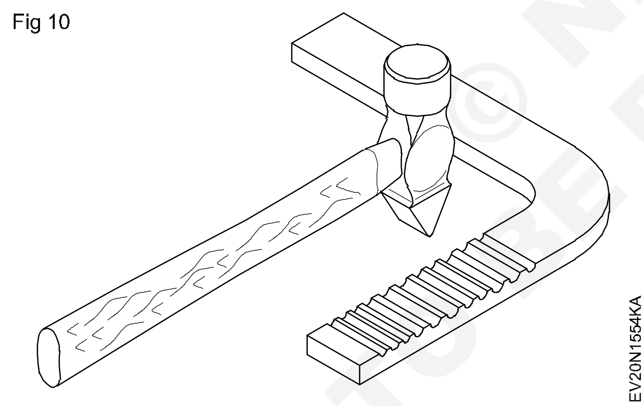
It is used for shaping the cylindrical end of a metal rivet to form a rivet head.

Cross pein hammer (Fig 10)

A cross pein head is used to spread metal in one direction in the line of striking.

This has a blunt wedge-shaped pein at right angles to the axis of the handle.

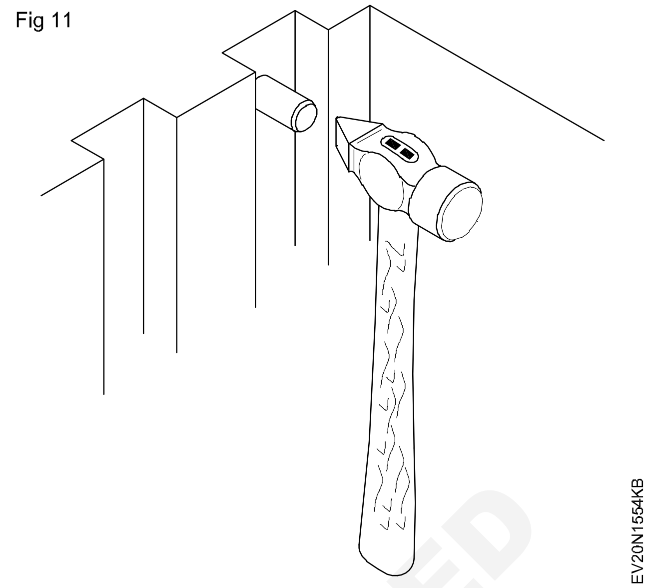
Fig 10



Straight pein hammer

A straight pein hammer is used to spread metal in one direction at right angles to the line of striking (Fig 11)

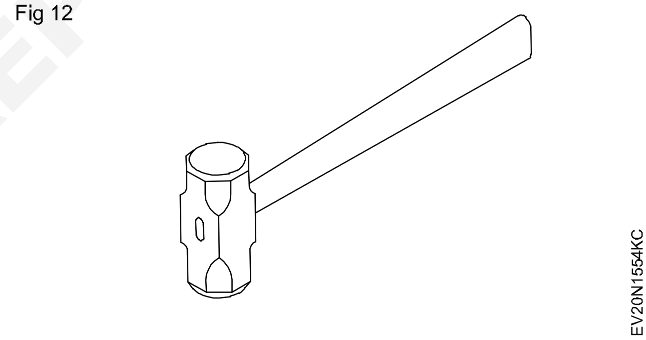
Fig 11



This hammer has a blunt wedge-shaped pein in line with the axis of the handle.

A lump hammer or club hammer is a small sledgehammer (Fig.12) whose relatively light weight and short handle allow single-handed use. It is useful for light demolition work, driving masonry nails, and for use with a steel chisel when cutting stone or metal. In this last application, its weight drives the chisel more deeply into the material being cut than lighter hammers.

Fig 12



Wooden Mallet

Objectives: At the end of this lesson you shall be able to
- **name the different types of mallets**
- **state the uses of each type of mallets.**

Mallets

Mallets are soft hammers and are made of raw hide, hard rubber copper, brace, lead or wood, and are used to strike a soft and light blow on the metal.

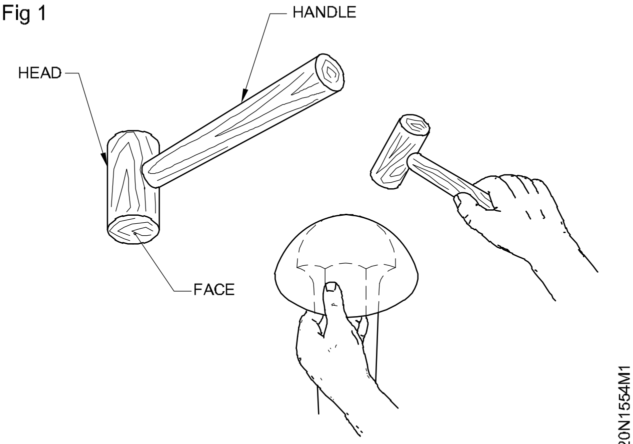
Types and uses

Standard wooden mallets (Fig.1) are used for general purpose work like flattening, bending etc.

Bossing mallets (Fig.2) are used for hollowing panel beatings etc.

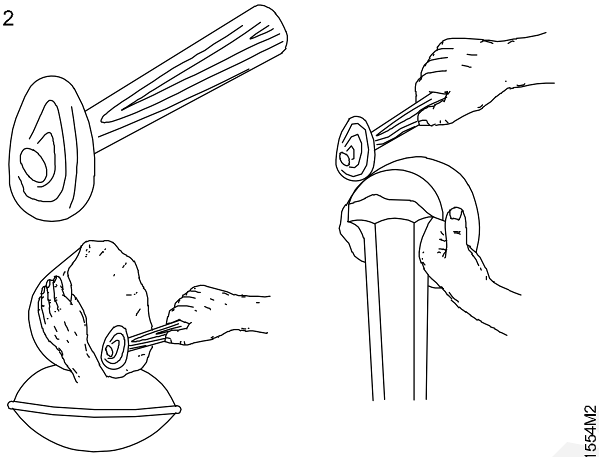
An end-faked mallet (Fig.3) is used for stretching, hammering etc.

Fig 1



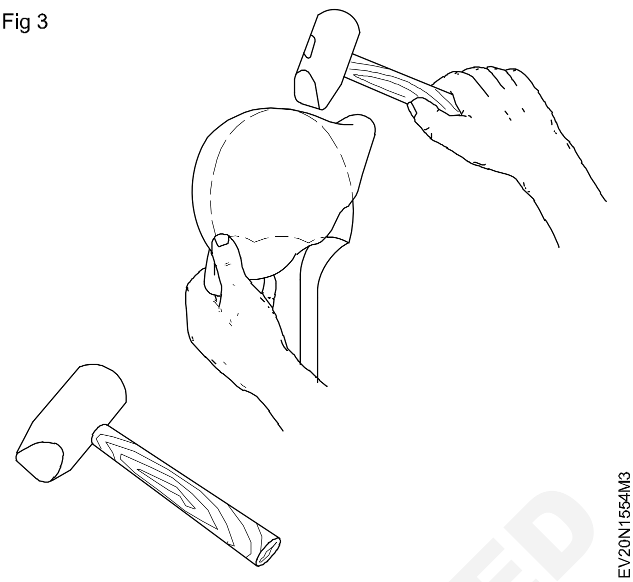
STANDARD WOODEN MALLET

Fig 2



SHAPING THE HEMISPHERICAL BOWL BY RAISING
BOSSING MALLET

Fig 3



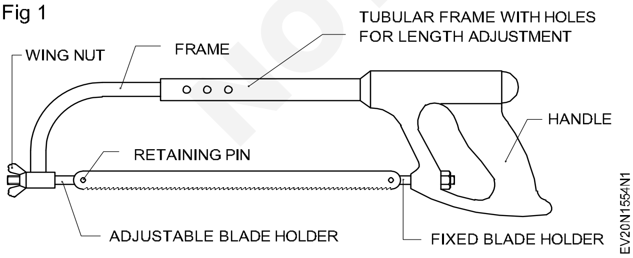
Hacksaw frame and blade

Objectives: At the end of this lesson you shall be able to
- **name the parts of the hacksaw frame**
- **specify hacksaw frame**
- **state the different types of hacksaw frame and their uses.**

Hacksaw frame

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours. The parts are identified in the (Fig 1).

Fig 1



Types of hacksaw frames

The two different types of hacksaw frames are solid frame and adjustable frames.

Solid frame

Only a particular standard length of blade can be fitted to this frame.

Adjustable frame (Flat type)

Different standard lengths of blades can be fitted to this frame.

Adjustable frame (Tubular type)

This is the most commonly used type. It gives a better grip and control, while sawing

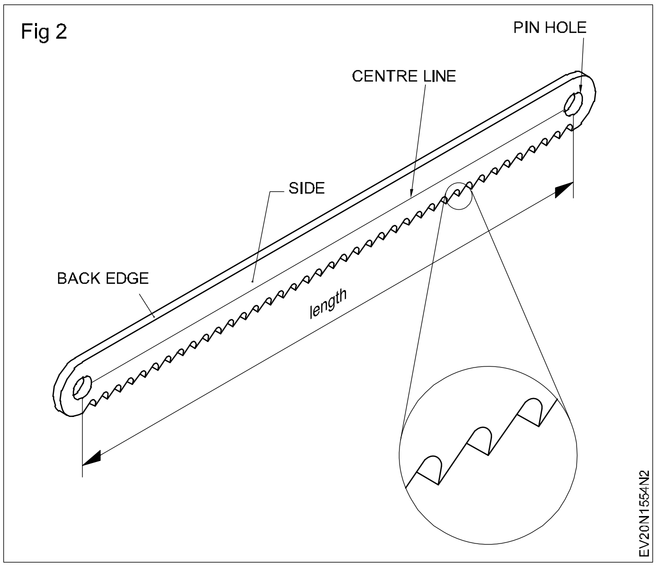
For proper working. It is necessary to have frames of rigid construction.

Hacksaw blades (Fig 2)

A 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. The blade is made of either low alloy steel (LAS) or high speed steel (HSS) and is available in standard lengths of 250 mm and 300 mm.

Types of hacksaw blades

Two types of hacksaw blades are available - all hard blades and flexible blades.



All hard blades

These are hardened to the full width between the pin holes.

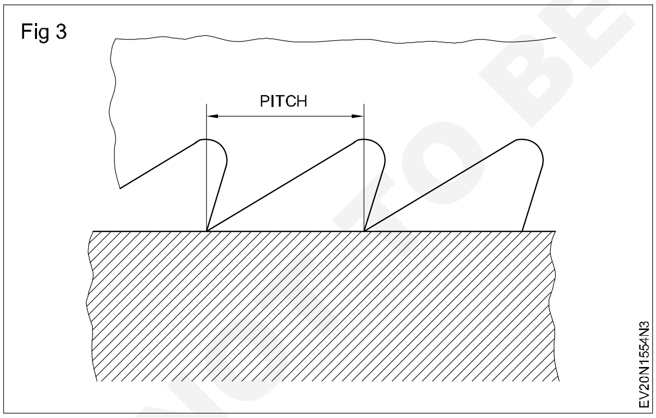
Flexible blades

For these types of blades. Only the teeth are hardened. Because of their flexibility, these blades are useful for cutting along curved lines.

Pitch of the blade (Fig 3)

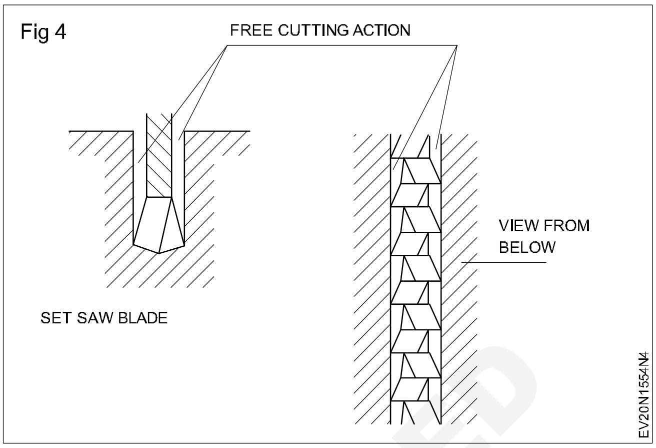
Hacksaw blades are designated according to their length, pitch and type.

To prevent the saw blade binding when penetrating into the material and to allow free movement of the blade, the cut is to be broader than the thickness of the saw blade. This is achieved by the setting the saw teeth. There are two types of saw teeth settings.



Staggered set (Fig 4)

Alternate teeth or groups of teeth are staggered. This arrangement helps for free cutting and provides for good chip clearance.



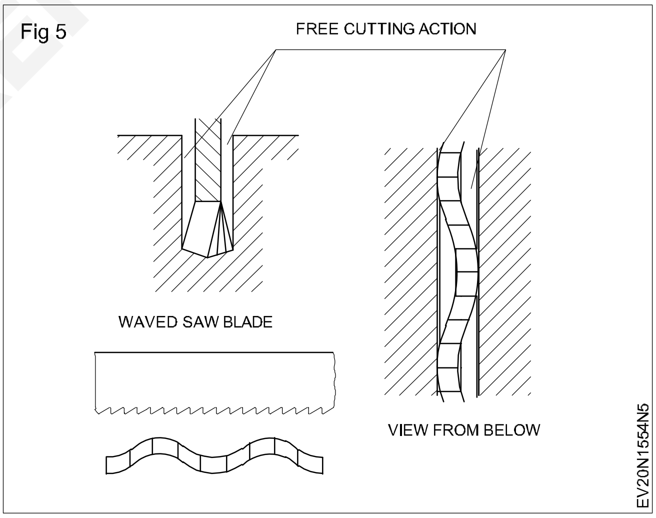
Wave set (Fig 5)

In this, the teeth of the blade are arranged in a wave form. Sets of blades can be classified as follows

For the best results, the blade with the right pitch should be selected and fitted correctly.

Pitch Type of Set 0.8 mm Wave -set 1.0 mm Wave or staggered Over 1.0 mm Staggered

For the best results, the blade with the right pitch should be selected and fitted correctly.



Elements of a file

Objectives: At the end of this lesson you shall be able to
- **name the parts of a file.**

The three methods of metal cutting are

- Abrasion (Fig 1A).
- Fusion (Fig 1B) and
- Incision (Fig 1C)

Filing is a method for removing excess material from a work pieces by using a file which acts as a cutting tool. (Fig 2) shows how to hold a file. Files are available many shapes and sizes.

Parts of a file (Fig 3)

The parts of a file as can be seen in figure 3, are

Fig 1

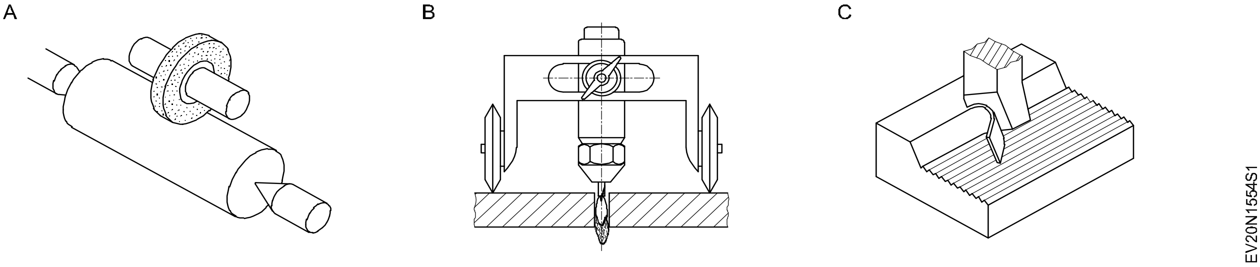
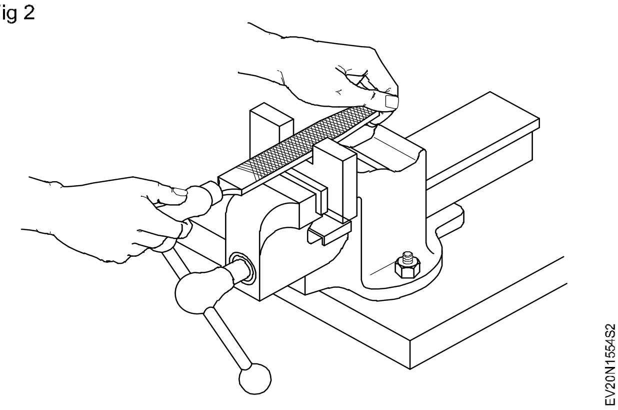


Fig 2



Tip or Point

The end opposite to tang

Face or side

The broad part of the file with teeth cut on its surface

Edge

The thin part of the file with a single row of parallel teeth

Heel

The portion of the broad part without teeth.

Tang

The narrow and thin part of a file which fits into the handle

Handle

The part fitted to the tang for holding the file

Parts of a file (Fig 3)

Ferrule

A protective metal ring to prevent cracking of the handle.

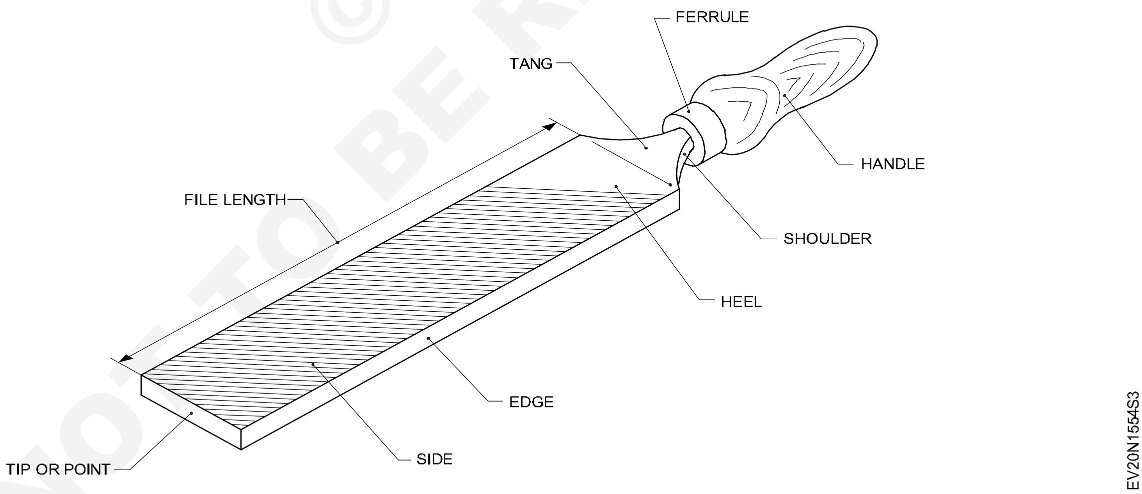
Materials

Generally files are made of high carbon or high grade cast steel. The body portion is hardened and tempered. The tang is however not hardended.

Shoulder

The curved part of the file separating tang from the body.

Fig 3



Cut of files

Objectives: At the end of this lesson you shall be able to
- **name the different cut of files**
- **state the uses of each type of cut.**

The teeth of a file are formed by cuts made on its face. Files have cuts of different types. Files with different cuts have different uses.

Types of cuts

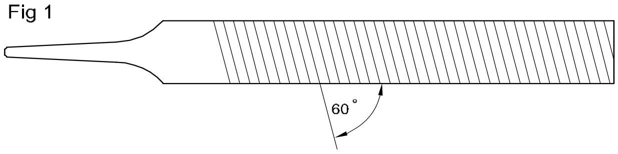
Basically there are four types.

Single cut. Double cut. Rasp cut and curved cut.

Single cut file (Fig 1)

A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60o to the centre line. It can chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper. Single cut files do not remove stock as fast as double cut files, but the surface finish obtained is much smoother.

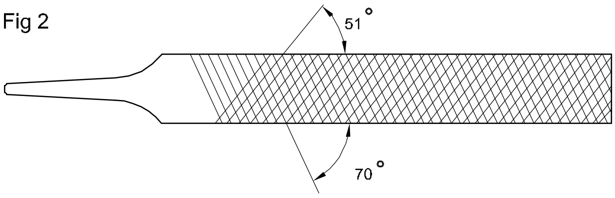
Fig 1



Double cut file (Fig 2 & 3)

A double cut file has two rows of teeth cut diagonal to each other. The first row of teeth is know as OVERCUT and they are cut at an angle of 70°. The other cut, made diagonal to this, is known as UPCUT and is at an angle of 51°. This removes stock faster then the single cut file.

Fig 2



The rasp cut has individual sharp pointed teeth in a line and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

Curved cut file (Fig 4)

These files have deeper cutting action and are useful for filing soft materials like - aluminium, tin, copper and plastic. The curved cut files are available only in a flat shape.

Fig 3

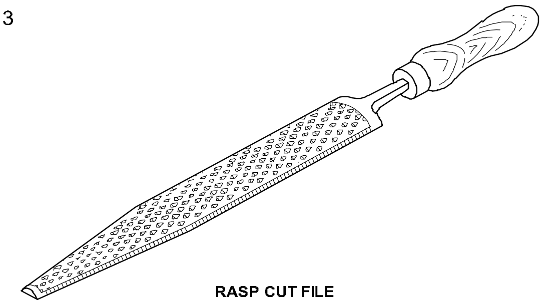
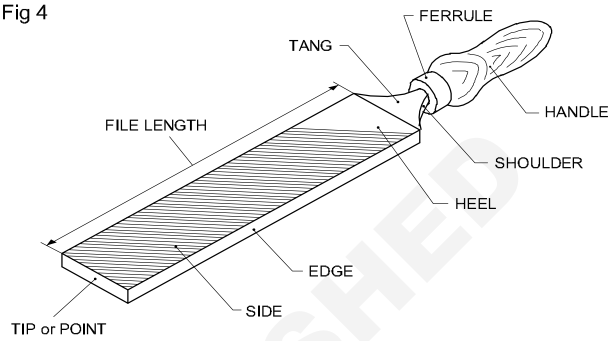


Fig 4



The selection of a file with a particular type of cut is based on the material to be filed. Single cut files are used for filing soft materials. But certain fies for example, those used for sharpening saws are also of single cut.

File specifications and grades

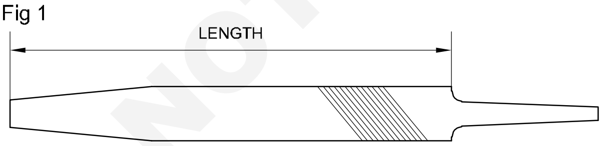
Objectives: At the end of this lesson you shall be able to
- **state how files are specified**
- **name the different types of grades**
- **state the application of each grade of file.**

Files are manufactured in different types and grades to meet the various needs.

Files are specified according to their length, grade, cut and shape.

Length is the distance from the tip of a file to the heel. (Fig 1)

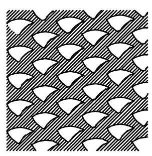
Fig 1



File grades are determined by the spacing of the teeth.

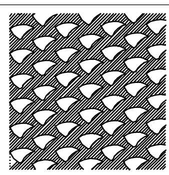
A round file (Fig 2) is used for removing rapidly a larger quantity of metal. It is mostly used for trimming the rough edges of soft metal castings.

Fig 2



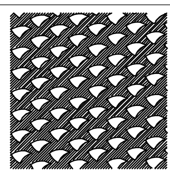
A bastard file (Fig 3) is used in cases where there is a heavy reduction of material.

Fig 3



A second cut file (Fig 4) is used to give a good finish on metals. It is excellent to file hard metals. It is useful for bringing the jobs close to the finishing size.

Fig 4



A smooth file (Fig 5) is used to remove small quantity of material and to give a good finish.

A dead smooth (Fig 6) file is used to bring to accurate size with a high degree of finish.

Fig 5

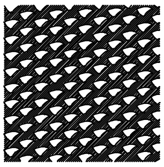


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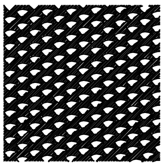
Fig 6



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The most used grades of files are bastard, second cut, smooth and dead smooth. These are the grades recommended by the Bureau of Indian Standards.

Different sizes of files with the same grade will have varying sizes of teeth. In longer files, the teeth will be coarser.

File applications

Objectives: At the end of this lesson you shall be able to
- **state the features of flat and hand files**
- **state the application of flat and hand files.**

Files are made in different shapes so as to be able to file and finish components to different shapes.

The shape of files is usually specified by their cross section.

The files useful for this exercise are flat files and hand files.

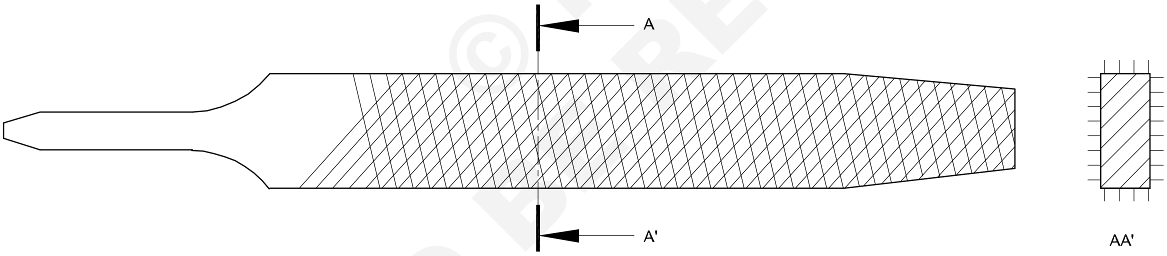
Flat files

These files are of a rectangular cross section. The edges along the width of these files are parallel up to two-thirds of the length, and then they taper towrads the point. The faces are double cut, and the edges single cut. These files are used for general purpose work. They are useful for filling and finishing external and internal surfaces.

Hand files (Fig 1)

These files are similar to the flat files in their cross section. The edges along the width are parallel through the length. The faces are double cut. One edge is single cut whereas the other is safe edge. Because of the safe edge, they are useful for filling surfaces which are at right angles to surfaces already finished.

Fig 1



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Shapes of files

Objectives: At the end of this lesson you shall be able to
- **name the different shapes of files**
- **state the uses of squre, round, half round, triangular and knife edge files.**

For filing and finishing different profiles, files of different shapes are used.

The shape of files is stated by its cross section.

Common files of different shapes

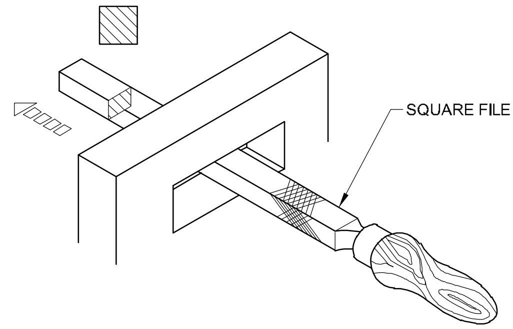
Flat file, Hand file, Square file, Round file Half found file, Triangular file and Knife-edge file.

(Flat and hand files have already been discussed).

Square File

The square file is square in its cross sectiion. It is used for filling square holes, internal square corners, rectangular opening, keyways and spines. (Fig 1)

Fig 1



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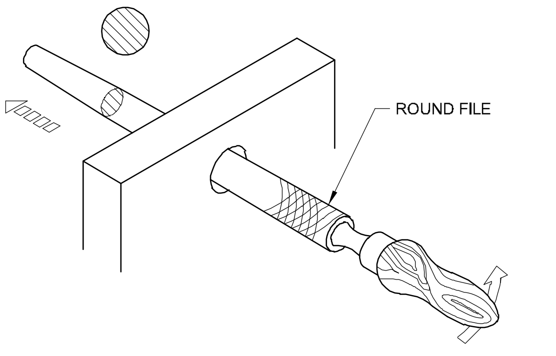
Round file

A round file is circular in its cross section. It is used for enlarging the circular holes and filing profiles with fillets. (Fig 2)

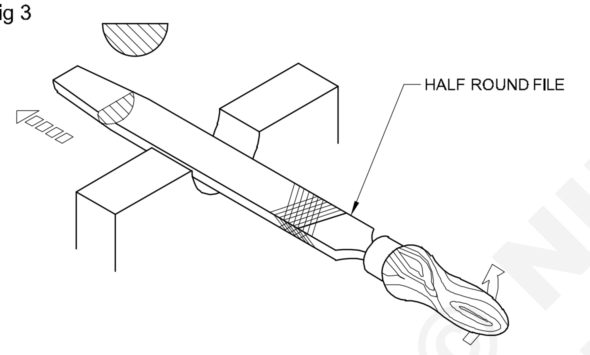
Fig 2



Half round File

A half round file is in the shape of a segment of a circle. It is used for filing internal curved surfaces (Fig 3)

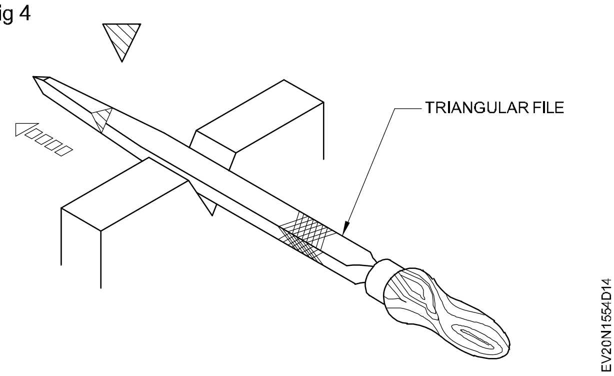
Fig 3



Triangular File

A triangular file is of a triangular cross section. It is used for filing corners and angles which are more than 600. (Fig 4)

Fig 4



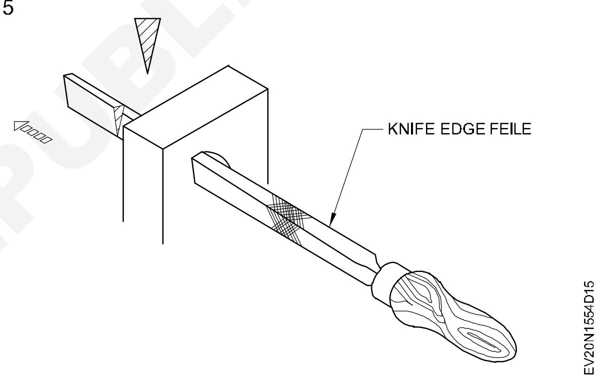
Knife-edge File

A knife-edge file has the cross section of a sharp triangle. It is used for filing narrow grooves and angles above 100. (Fig 5)

The above files have one third of their lengths tapered. They are available both in single and double cuts.

Square, round, half-round and triangular-files are available in lengths of 100, 150, 200, 250, 300 and 400 mm. These files are made in bastard, second cut and smooth grades.

Fig 5



Off hand grinding with bench and pedestal grinders

Objectives: At the end of this lesson you shall be able to

- **state the purpose of off hand grinding**
- **state the features of bench and pedestal grinders.**

Off-hand grinding is the operation of removing material which does not require great accuracy in size or shape. This is carried out by pressing the workpiece by hand against a grinding wheel.

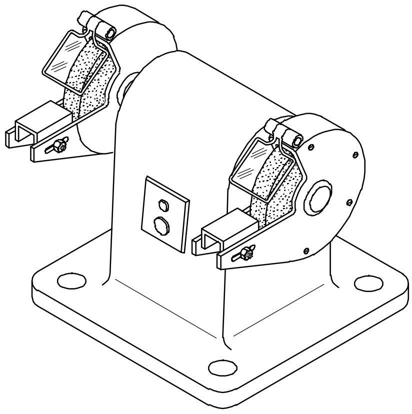
Off-hand grinding is performed for rough grinding of jobs and resharpening of scribers, punches, chisels, twist drills single point cutting tools etc.

Off-hand grinding is performed with a bench or pedestal grinder (Fig 1 and 2)

Bench grinders

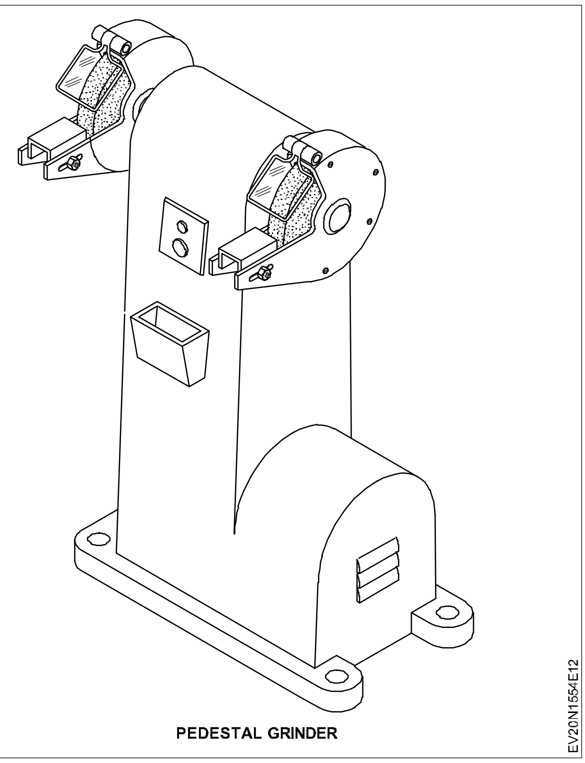
Bench grinders are fitted to a bench or table, and are useful for light duty work.

Fig 1



BENCH GRINDER

Fig 2



PEDESTAL GRINDER

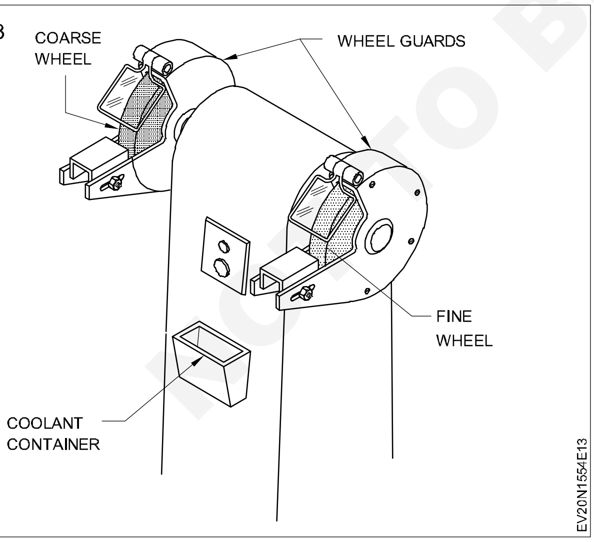
Pedestal grinders

Pedestal grinders are mounted on a base (pedestal), which is fastened to the floor. They are used for heavy duty work.

These grinders consist of an electric motor and two spindles for mounting grinding wheels. On one spindle a coarse-grained wheel is fitted, and on the other, a fine grained wheel. For safety, while working, wheel guards are provided. (Fig 3)

A coolant container is provided for frequent cooling of the work. (Fig 3)

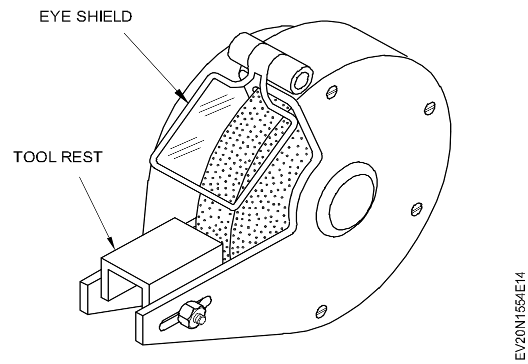
Fig 3



Adjustable work-rests are provided for both wheels to support the work while grinding. These work-rests must be set very close to the wheels. (Fig 4)

Extra eye-shields are also provided for the protection of the eyes. (Fig 4)

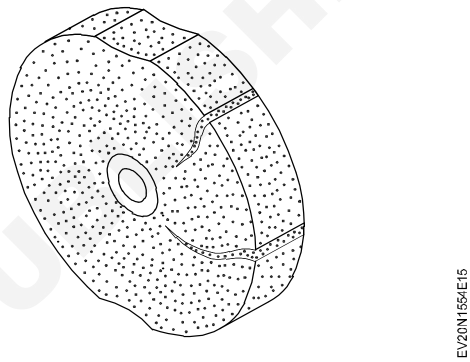
Fig 4



While grinding

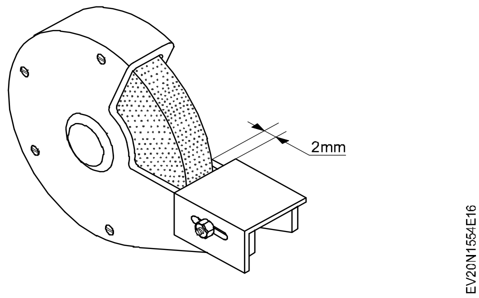
Adjust the tool-rest as close to the wheel as possible. The maximum recommended gap is 2 mm. This will help to prevent the work from being caught between the toolrest and the wheel. (Fig 5) Small jobs should be held with pliers or other suitable tools. (Fig 5)

Fig 5



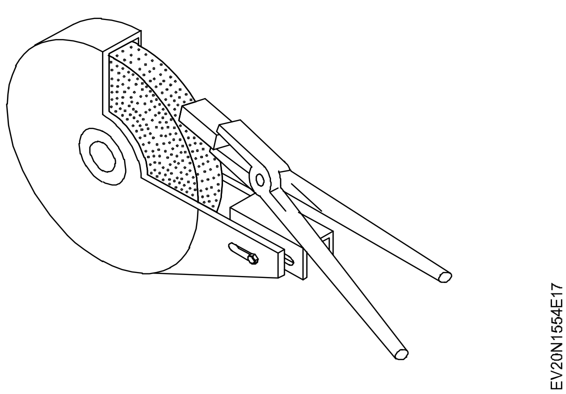
Never hold jobs with cotton waste or similar materials. Use gloves for your hands while grinding heavy jobs. Do not grind on the side of the grinding wheels. (Fig 6)

Fig 6



Move the work across the full face of the wheel to prevent uneven wearing of the grinding wheel. (Fig 7)

Fig 7



Safe working on off - hand grinders

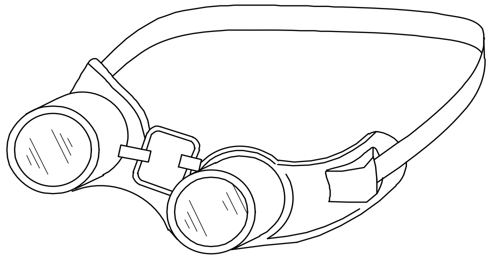
Objectives: At the end of this lesson you shall be able to
- **work safety on an off hand grinders.**

How to work on an off-hand grinder? While working on off-hand grinders, it is important to observe the following safety measures.

Before starting

Make sure the grinding wheel guards are in place. Wear safety goggles while grinding. (Fig 1)

Fig 1



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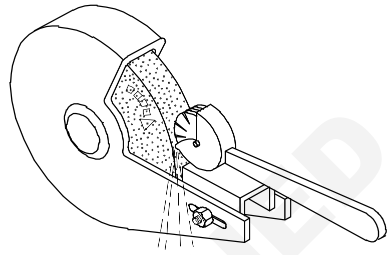
Do not work on grinding wheels which are loaded or glazed. Dress and true wheels whenever necessary. (Fig 2)

If any abnormal sound is noticed, stop the machine. Cracked or improperly balanced wheels are dangerous

Stand on one side of the machine while starting.

Fig 2



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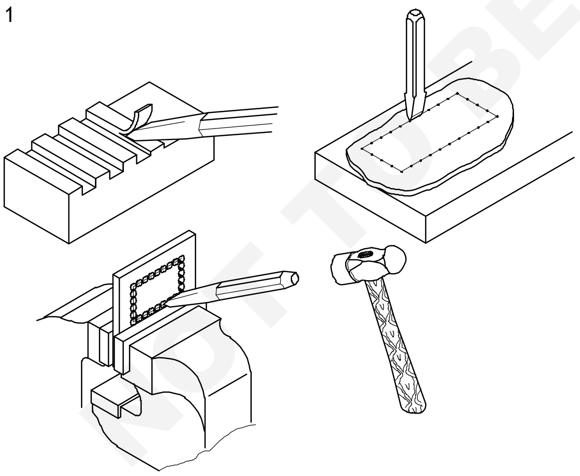
Chisel

Objectives: At the end of this lesson you shall be able to
- **list the uses of a cold chisel**
- **name the parts of a cold chisel**
- **state the different types of chisels.**

The cold chisel is a hand cutting tool used by fitters for chipping and cutting off operations. (Fig.1)

Chipping is an operation of removing excess metal with the help of a chisel and hammer. Chipped surfaces being rough, they should be finished by filing.

Fig 1



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Parts of a chisel (Fig.2)

A chisel has the following parts.

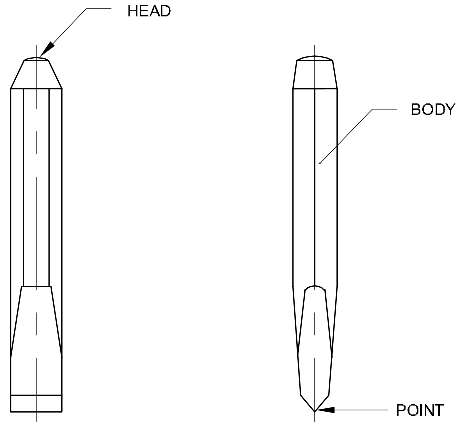
Head

Body

Point or cutting edge

Chisels are made from high carbon steel or chrome vanadium steel. The cross-section of chisels is usually

Fig 2



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hexagonal or octagonal. The cutting edge is hardened and tempered.

Common types of chisels

There are four common types of chisels

- Flat chisel (1)
- Cross-cut chisel (2)
- Hall round nose chisel
- Diamond point chisel

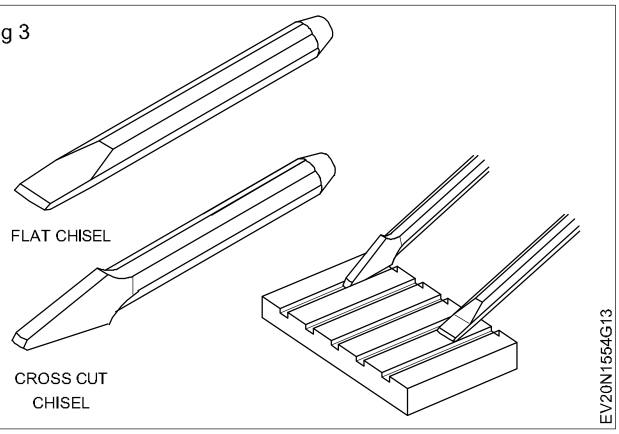
Flat chisels (Fig 3)

They are used to remove metal from large flat surfaces and chip excess metal of weld joints and castings.

Cross-cut or cape chisels (Fig 3)

These are used for cutting keyways, grooves and slots.

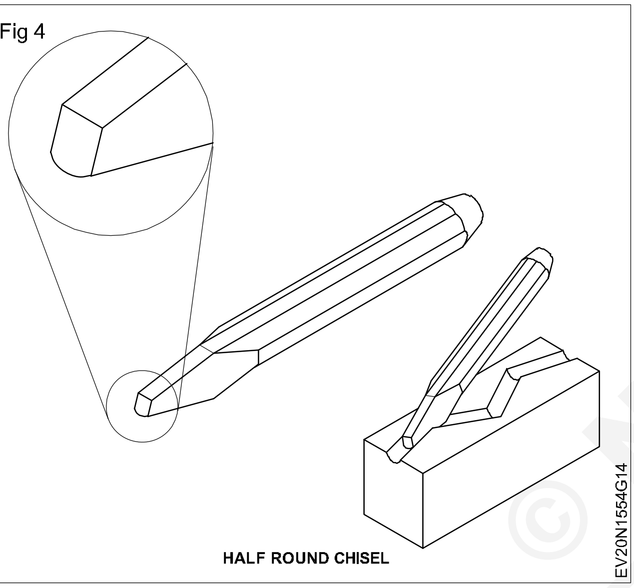
Fig 3



Half round nose chisels (Fig 4)

They are used for cutting curved grooves (oil grooves)

Fig 4



Diamond point chisels (Fig 5)

These are used for squaring materials at the corners.

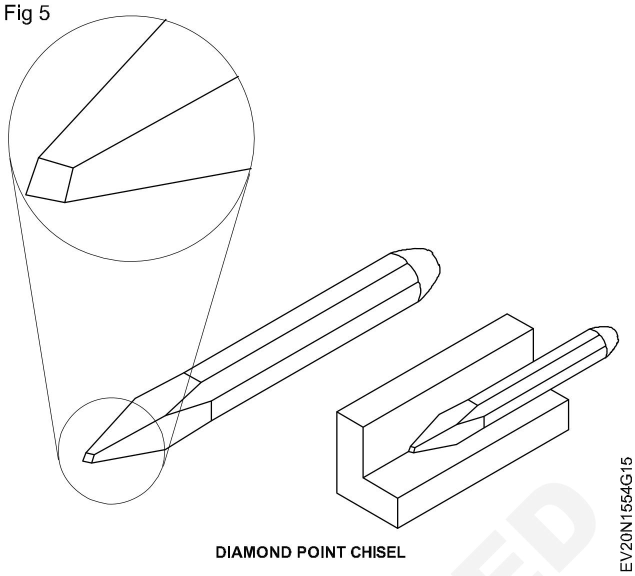
Web chisels/punching chisels (Fig 6)

These chisels are used for separating metals after chain drilling.

Chisels are specified according to their

- length

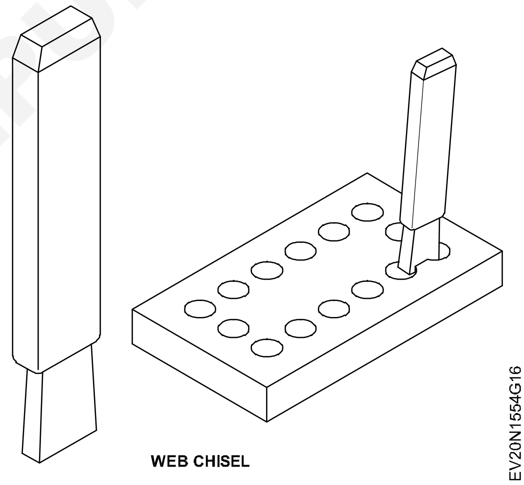
Fig 5



- width of cutting edge
- type
- cross-section of body

The length of the chisels ranges from 150mm to 400mm. The width of the cutting edge varies according to the type of chisels.

Fig 6



Angles of chisels

Objectives: At the end of this lesson you shall be able to
- **select the point angles of chisels for different materials**
- **state the different cutting angles of a chisel**
- **state the effect of rake and clearance angles.**

Point angles and materials (Fig 1)

Correct point/cutting angles of the chisel depends on the materials to be chipped. Sharp angles are given for soft materials, and wide angles for hard materials.

The correct point angle and angle of inclination generate the correct rake and clearance angles.

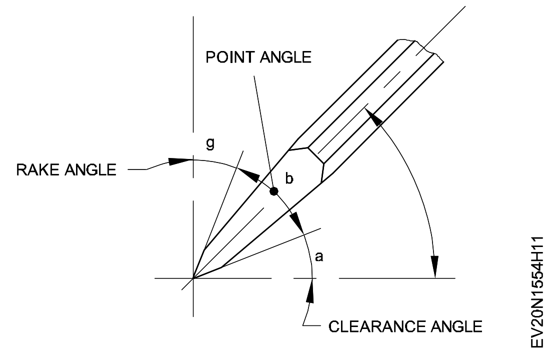
Rake angle (Fig 1)

Rake angle `g' is the angle between the top face of the cutting point, and normal to the work surface at the cutting edge.

Clearance angle (Fig 1)

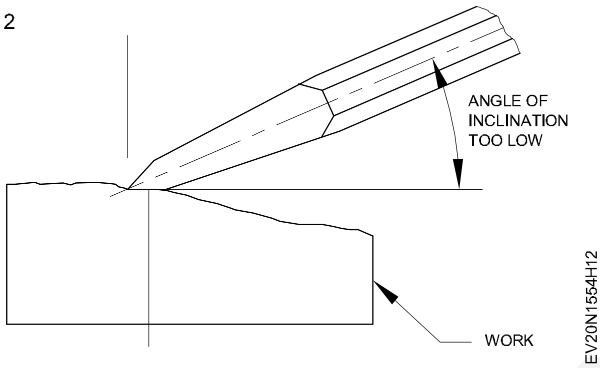
Clearance angle `a' is the angle between the bottom face of the point and tangent to the work-surface originating at the cutting edge.

Fig 1



If the clearance angle is too low or zero (Fig. 2), the rake angle increases. The cutting edge cannot penetrate into the work. The chisel will slip.

Fig 2



If the clearance angle is too great (Fig 3), the rake angle reduces. The cutting edge digs in, and the cut progressively increases.

Chipping goggles (Fig 4): It is used to protect the eyes while chipping the slag or grinding the job.

It is made of Bakelite frame fitted with clear glasses and an elastic band to hold it securely on the operator's head.

It is designed for comfortable fit, proper ventilation and full protection from all sides.

Fig 3

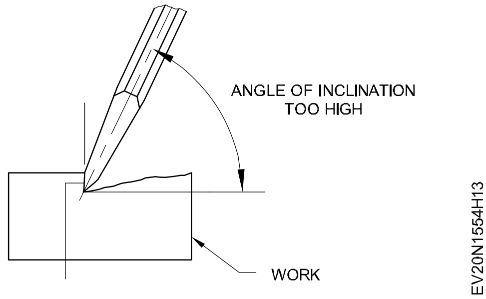
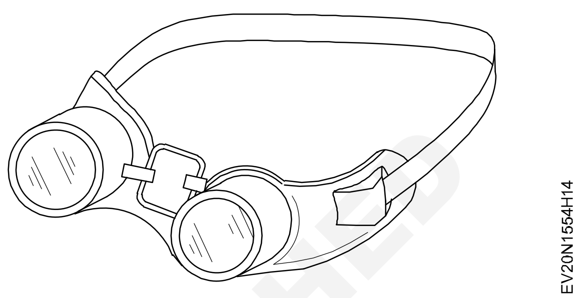


Fig 4



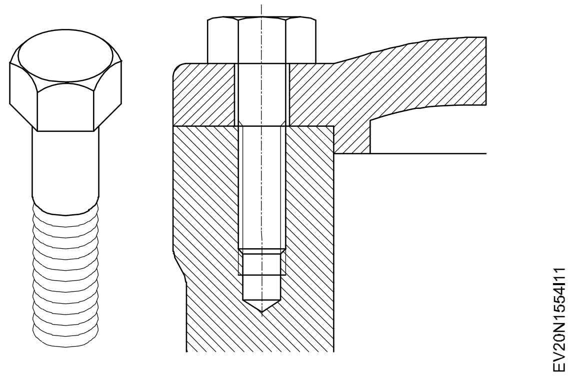
Material to be cut	Point angle	Angle Inclination
High carbon		
steel	65°	39.5°
cast iron	60°	37°
Mild stee	55°	34.5°
Brass	50°	32°
Copper	45°	29.5°
Aluminium	30°	22°

Different types of screws, nuts, studs and bolts

Objectives: At the end of this lesson you shall be able to
- **name the different types of machine screws used in heavy duty assembly**
- **name the different types of machine screws used in light assembly work**
- **state the uses of different types of machine screws**
- **name the different types of set screws.**

Machine screws are used when a nut cannot be used in the assembly and the component in the assembly has a threaded hole to receive the screws.(Fig 1)

Fig 1



Types of machine screws (Heavy duty)

- Hexagon head screws
- Hexagon socket head cap screws
- Square head countersink head screws

These are heavy duty screws.

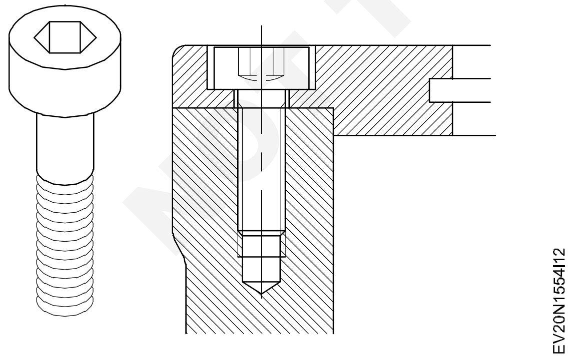
Hexagon head screws

These are used when the projection of the screw head will not be an obstruction in the assembly (Fig 1)

Hexagon socket head cap screws

These are used when the projection of the screw head above the surface is to be avoided. (Fig 2) The Indian Standard specification head socket cap screws cover the range from 1.6 mm to 36mm.

Fig 2



Hexagon head screws and hexagon socket head screws are made of steel. Hexagon head screws used in electrical work are made of brass.

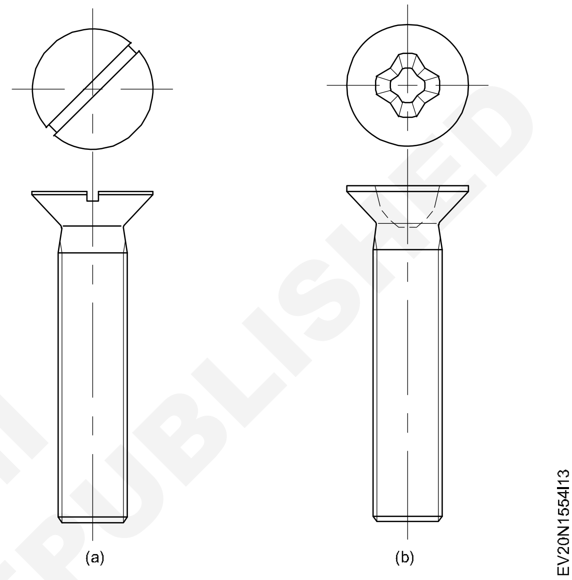
Countersink head screws

There are four types of countersink head screws in common use.

They are:

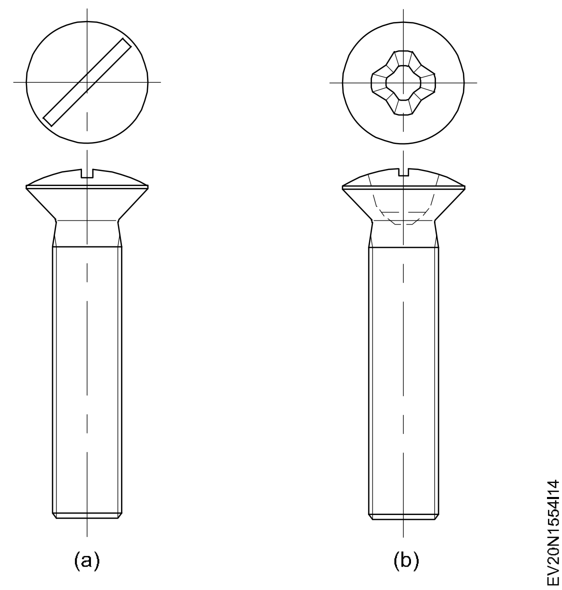
- Slotted countersink head screws (Fig 3a)
- Cross-recessed countersink head screws. (Fig 3b)

Fig 3



- Slotted raised countersink head screws (Fig 4a)
- Cross recessed, raised countersink head screws. (Fig 4b)

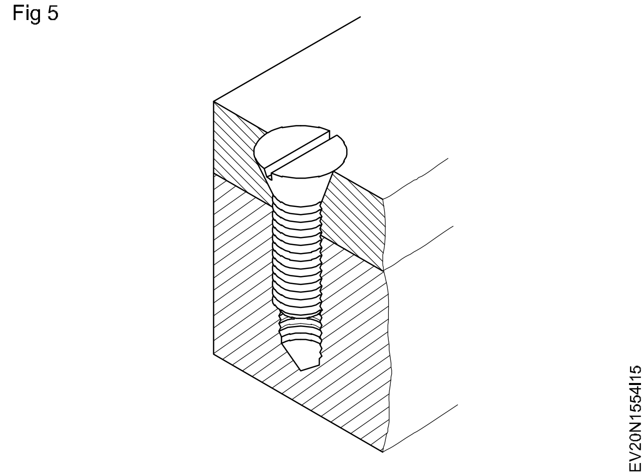
Fig 4



Countersink screws are capable of aligning the matching component correctly with the threaded hole. (Fig 5)

The projection of the screw head above the assembly is also avoided. B.I.S. specification covers the following ranges of countersink head screw sizes in different types.

Fig 5

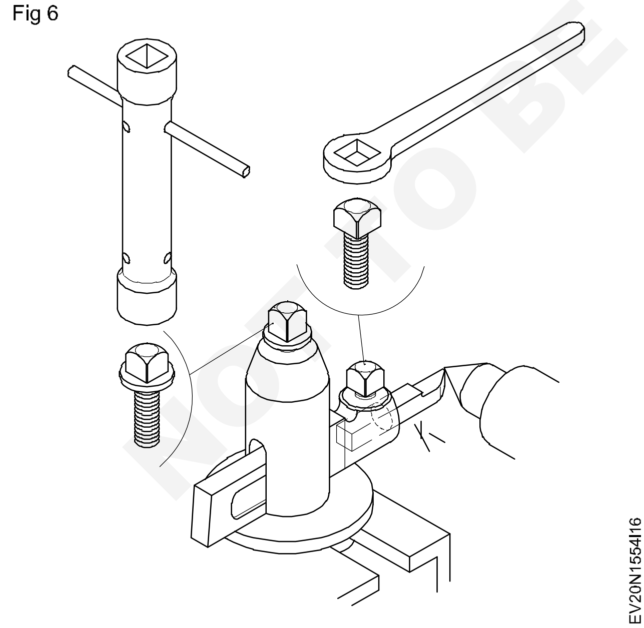


- Slotted countersink head screws M1 - M20
- Cross-recessed countersink head screws M1.6 to M10.
- Slotted raised countersink head screws M1 to M20.
- Cross-recessed raised countersink head screws M1.6 to M10.

Square head screws (Fig 6)

Square head screws are used in places where there is frequent removal and refitting of the assembly. These screws are tightened to a higher torque using a wrench. (Fig 6) Square head screws are also available with a collar. In this there is a washer at the base which is an integral part of the head. The purpose of this collar is to protect the work-surface from damages due to constant use of wrenches.

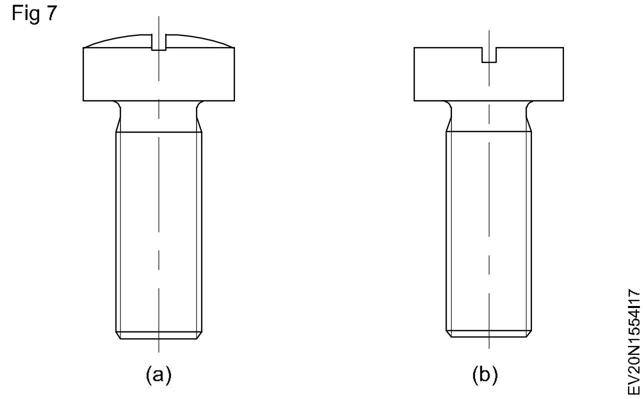
Fig 6



Other types of machine screws used in light assembly work are:

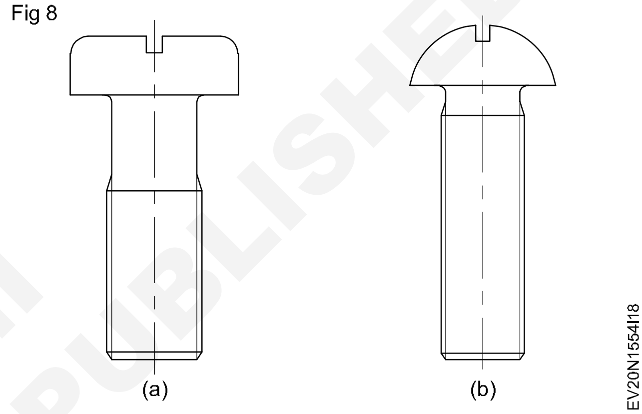
- Pan head (Fig 7a)
- Cheese head (Fig 7b)

Fig 7



- Raised cheese head (Fig 8a)
- Round head (Fig 8b)

Fig 8



These screws are also available with slotted head or as cross-recessed.

The screws used for light duty are normally available up to 10mm thread diameter.

These screws are made of steel, stainless steel or brass. These screws are either plain finished, zinc-coated or chrome-plated.

Set screws and grub screws Hexagonal socket set screws (Fig 9&10)

These are headless socket screws available with different points for various functional requirements.

These points either allow to bite into the metal or tighten without damage to the work-surface. They are used to fasten pulleys, collars etc. to the shafts. They are used for higher strength applications where space is limited.

Fig 9

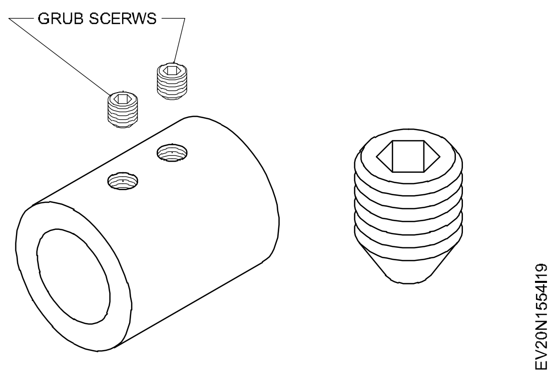
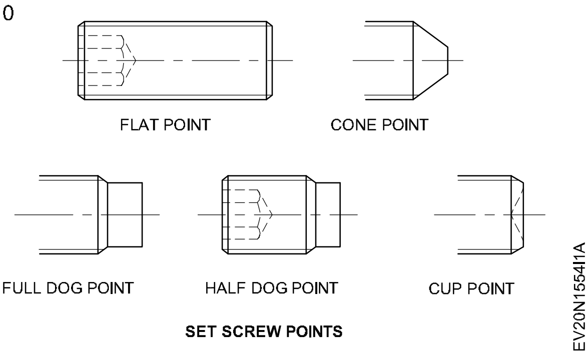


Fig 10

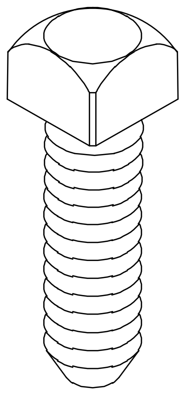


Square set screws (Fig 11)

These set screws have similar applications as hexagon socket set screws but have square heads projecting above the work-surface.

These are useful when the assembly needs frequent disassembly and setting.

Fig 11



Grub screws Grubs have similar application as hexagon socket set screws but are used for light holding. (Fig 12)

Grub screws are also available with different types of points (Fig 13)

Fig 12

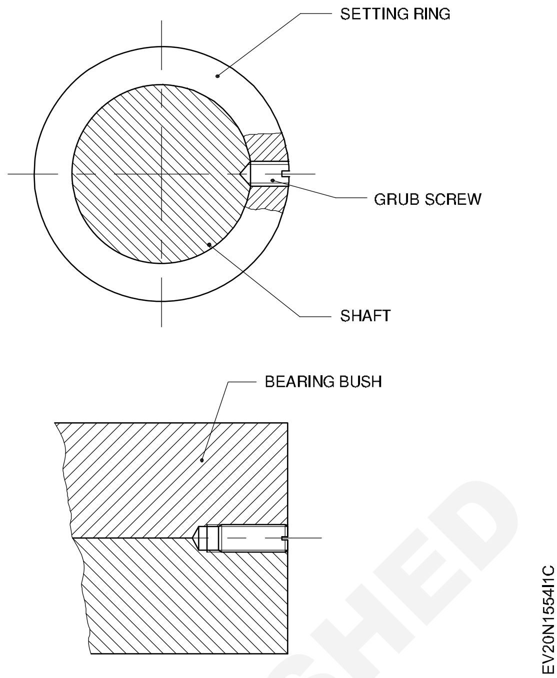
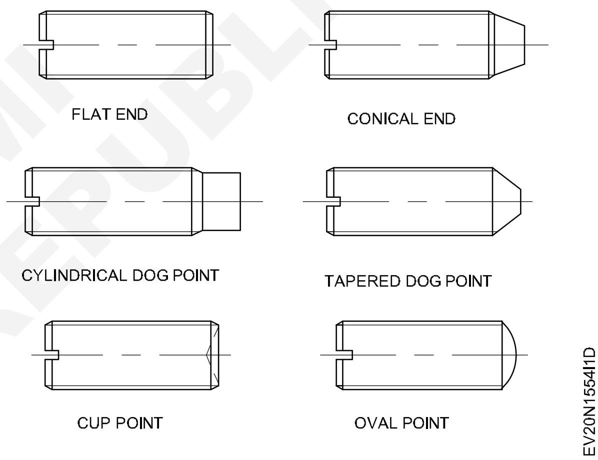


Fig 13



Thumb Screws

Objectives : At the end of this lesson you shall be able to
- **state the types of thumb screws**
- **state the uses of thumb screws**
- **designate thumb screws as per B.I.S. specification.**

Thumb screws are used in places where fixing and removal of components are frequent. Tightening and loosening of the assembly is finger tight only.

The uses of thumb screws are shown in Fig.1

Types

As per the Indian standard specification IS:3726-1972 there are five types of thumb screws.

Type-A Thumb screws partially threaded (Fig.2)

Type-B Thumb screws fully threaded (Fig. 3)

Type-C Slotted thumb screw partially threaded (Fig.4)

Type-D Slotted thumb screw fully threaded (Fig.5)

Type-E Flat thumb screws (Fig.6)

The type of thumb screw selected depends on the actual requirement in the assembly.

Sizes

Thumbs screws are available in the following sizes as per B.I.S.

M1.6, M2, M2.5, M3, M4, M5, M6, M8 and M10.

Designation of thumb screws

Thumb screws shall be designated by the nomenclature, type, thread size, nominal length, the number of Indian Standard and the symbol for mechanical properties.

Fig 1

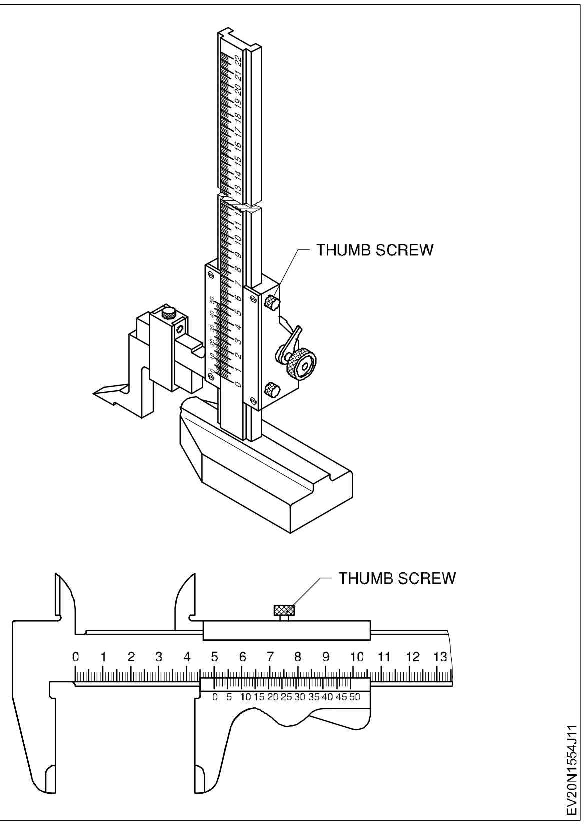


Fig 2

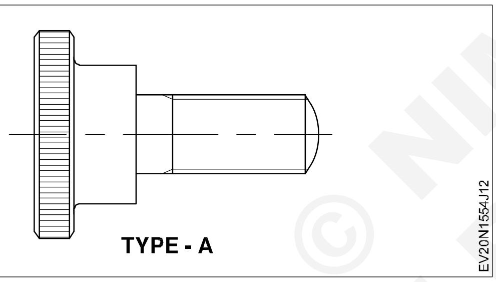


Fig 3

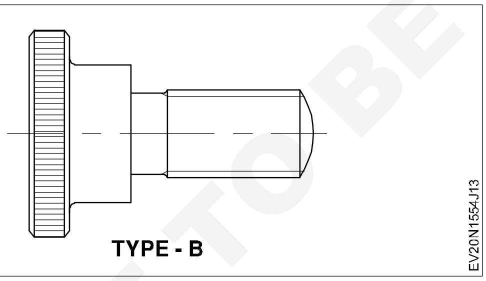


Fig 4

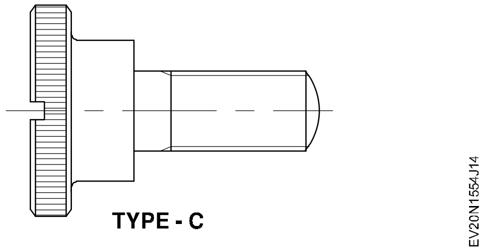


Fig 5

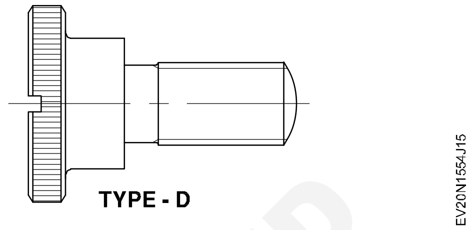
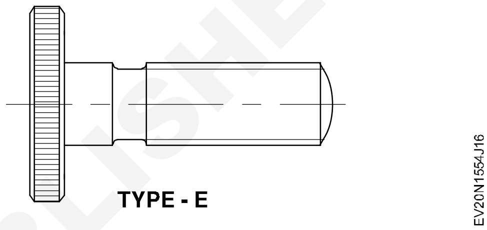


Fig 6



Example

A thumb screw of Type `A', size M6, nominal length 12mm and of property class 4.6 shall be designated as:

Thumb screws A M6 x 12 IS: 3726-4.6

When brass or any other non-ferrous metal is used for the manufacture of thumb screws, the word Brass or the name of the non-ferrous metal used will replace the property class number in the designation.

Types of Nuts

Objectives : At the end of this lesson you shall be able to
- **name the common types of nuts**
- **state the features and uses of the common types of nuts.**

Nuts of different types are used depending on the requirement of the assembly.

Hexagonal nuts (Figs 1 & 2)

This is the most commonly used type of nut in structural and machine tool construction.

Hexagonal nuts are available in different thicknesses. Thin nuts are used as lock-nuts.

Square nut (Fig 3)

Square bolts are provided with square nuts. In bolts for coaches mostly square nuts are used.

Self-locking nuts (Simmonds lock-nut)

This nut has an internal groove cut in which a fibre or nylon ring is inserted. This ring holds the nut tightly on the bolt and serves as a locking device.

Fig 1

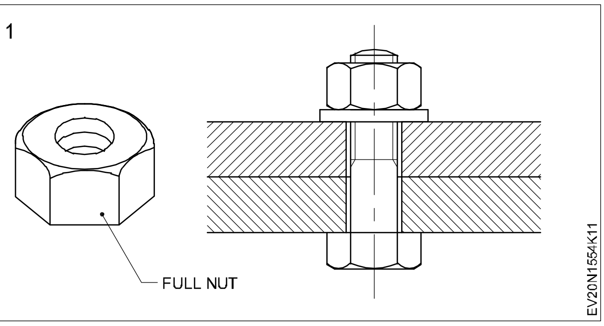


Fig 2

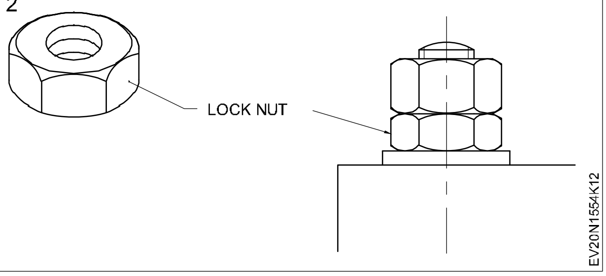
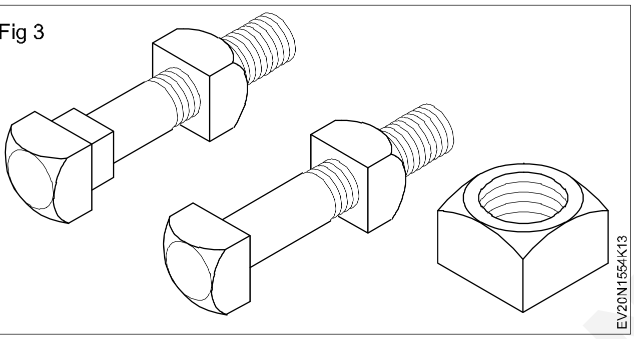


Fig 3



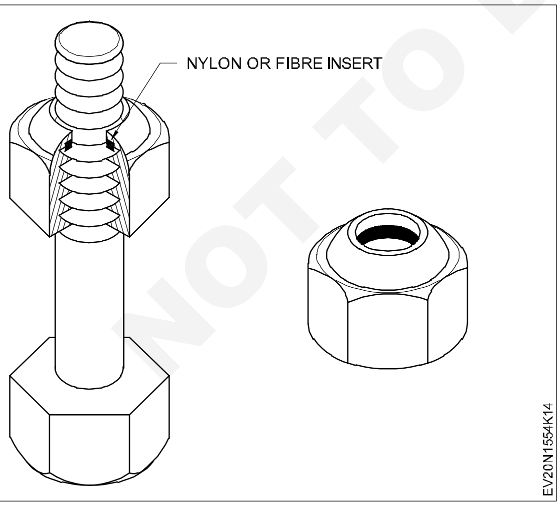
Self-locking nuts are not used with studs.

T-nuts.

T-nuts are used along with studs on machine tools for fixing/holding devices or workpieces.

Slotted and castle nuts (Fig 4)

Fig 4



Round nuts (Fig 5)

Round nuts of different types are available for special applications.

Slotted round nut (Figs 6, 7, 8, 9 & 10)

Slotted round nut for hook wrench.

Fig 5

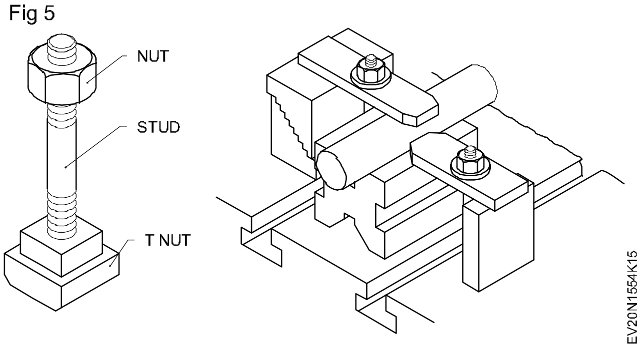


Fig 6

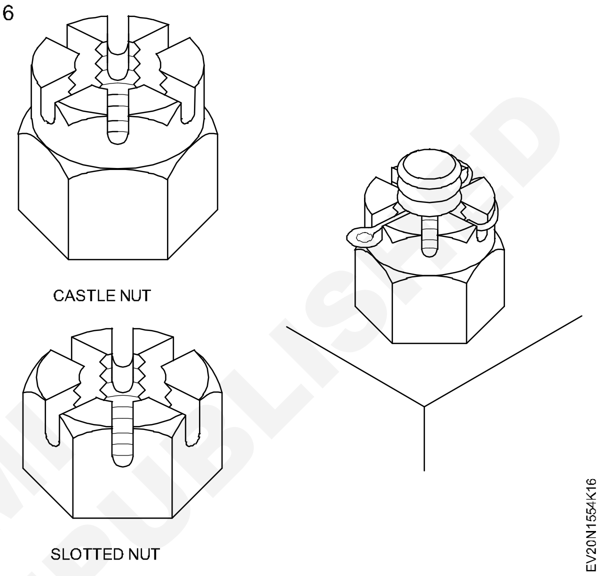


Fig 7

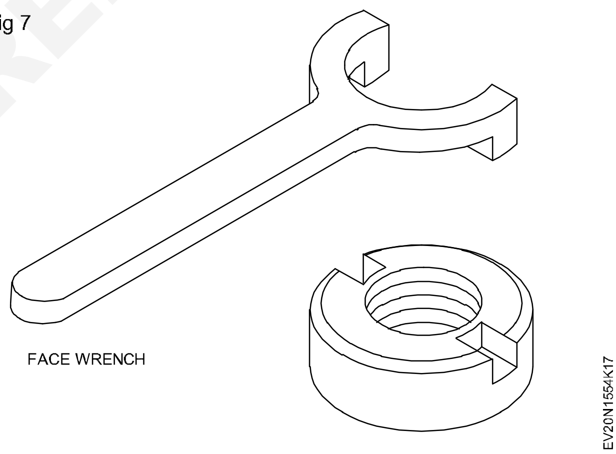


Fig 8

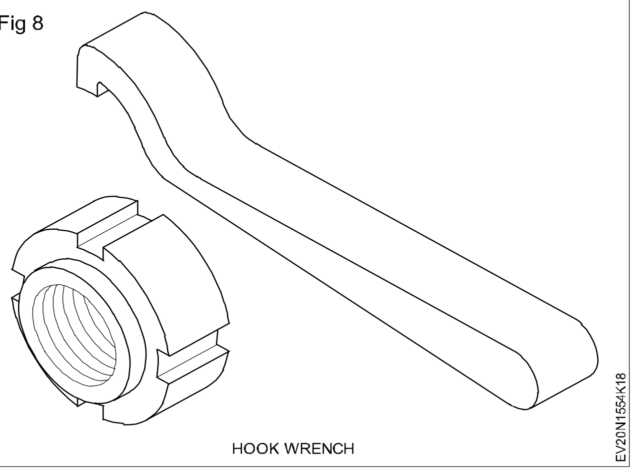
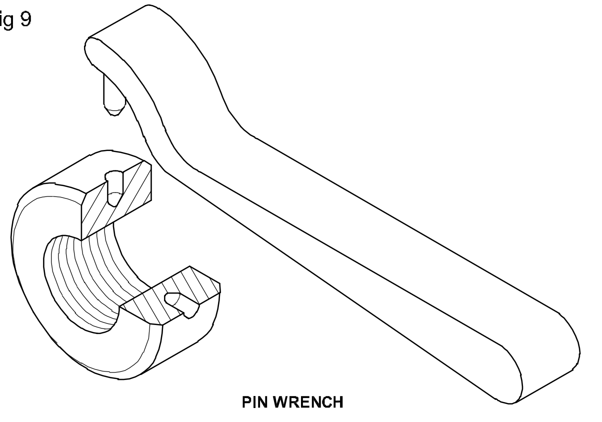


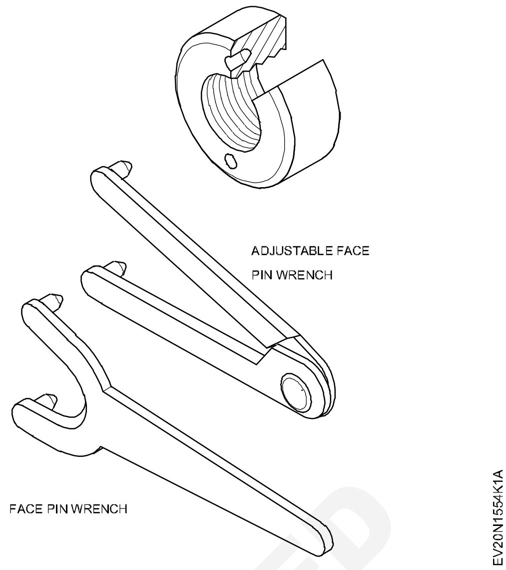
Fig 9



Round nut with set pin holes on sides

Round nut with holes in the face

Fig 10



Bolts and studs

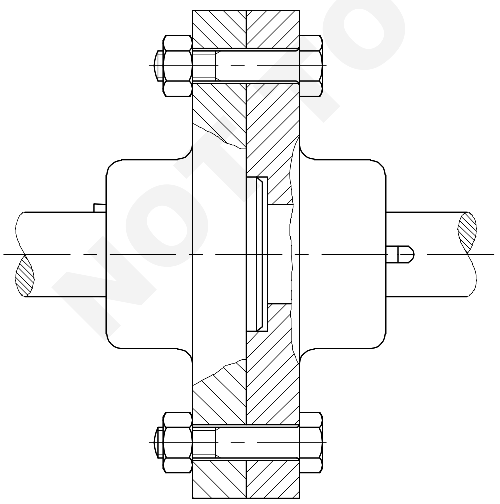
Objectives: At the end of this lesson you shall be able to
- **state the situations in which bolts and nuts are used**
- **state the advantages of using bolts and nuts**
- **name the different types of bolts**
- **state the applications of the different types of bolts**
- **state the situations in which studs are used**
- **state the reason for having different pitches of threads on stud ends.**

Bolts and nuts (Fig 1)

These are generally used to clamp two parts together. When bolts and nuts are used, if the thread is stripped, a new bolt and nut can be used. But in the case of a screw directly fitted in the component. When threads are damaged, the component may need extensive repair or replacement.

Depending on the type of application, different types of bolts are used.

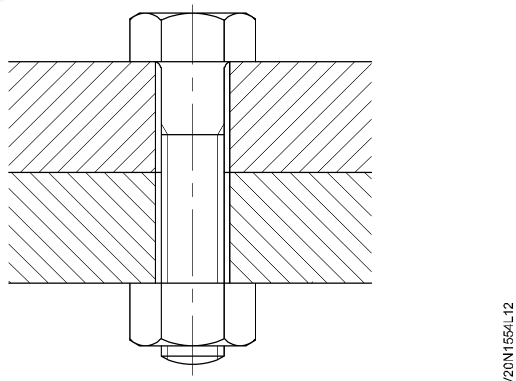
Fig 1



Bolts with clearance hole (Fig 2)

This is the most common type of fastening arrangement using bolts. The size of the hold is slightly larger than the bolt (clearance hole)

Fig 2



Slight misalignment in the matching hole will not affect the assembly.

Body fit bolt (Fig 3)

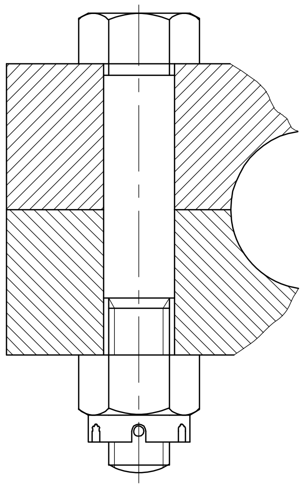
This type of bolt assembly is used when the relative movement between the workpieces has to be prevented. The diameter of the threaded portion is slightly smaller than the shank diameter of the bolt.

The bolt shank and the hole are accurately machined for achieving perfect mating.

Anti-fatigue bolt (Fig 4)

This type of bolt is used when the assembly is subjected to alternating load conditions continuously. Connection rod big ends in engine assembly are examples of this application.

Fig 3



BODY FIT BOLT

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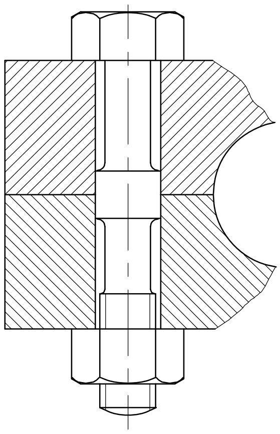
Fig 4



ANTI-FATIGUE BOLT

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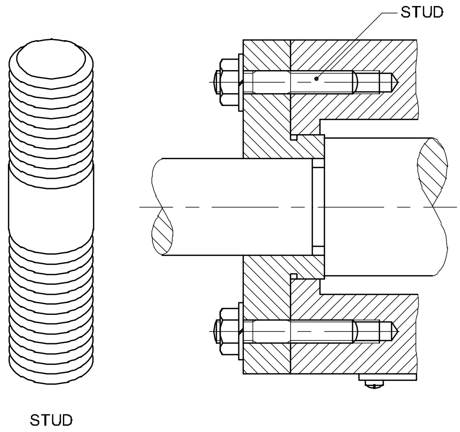
The shank diameter is in contact with the hole in a few places and other portions are relieved to give clearances.

Studs (Fig 5)

Studs are used in assemblies which are to be separated frequently.

When excesssively tightened, the variation in the thread pitch allows the fine thread or nut end to slip. This prevents damage to the casting.

Fig 5



EV20N1554L15

Designation of bolts as per B.I.S. specifications

Hexagon head bolts shall be designated by name, thread size, nominal length, property class and number of the Indian Standard.

Example

A hexagon head bolt of size M10, nominal length 60mm and property class 4.8 shall be designated as:

Hexagon head bolt M10x60 - 4.8-IS: 1363 (Part 1)

Explanation about property class

The Part of the specification 4.8 indicates the property class (mechanical properties). In this case it is made of steel with minimum tensile strength = 40kgf/mm2 and having a ratio of minimum yield stress to minimum tensile strength = 0.8.

NOTE

Indian standard bolts and screws are made of three product grades - A,B, & C, `A' being precision and the others of lesser grades of accuracy and finish.

While there are many parameters given in the B.I.S. specification, the designation need not cover all the aspects and it actually depends on the functional requirement of the bolt or other threaded fasteners.

For more details on the designation system, refer to IS: 1367, Part XVI 1979.

Locking Devices

Objectives : At the end of this lesson you shall be able to
- **state what is a locking device**
- **name the effect, if proper locking devices are not employed**
- **name the various types of locking devices**
- **state the uses of the commonly used locking devices.**

Locking devices

A locking device is a device used to lock the threaded fasteners to prevent them from loosening. Due to vibration in the moving part, there is a tendency for the threaded fastener to get slack and to slip off. Then the assembled part will get loose and cause damages. Some examples are given below to illustrate the importance of the locking device.

In the case of a micrometer, the lock-nut avoids the Movement of the spindle after taking the reading. In the case of boilers and gas cylinders, locking of the nut avoids the leakage of steam or gas.

In automobiles the lock-nut avoids the loosening of the assembled part.

Classification of lock-nuts

Lock-nuts are classified into two categories.

- Positive locking device
- Frictional locking device

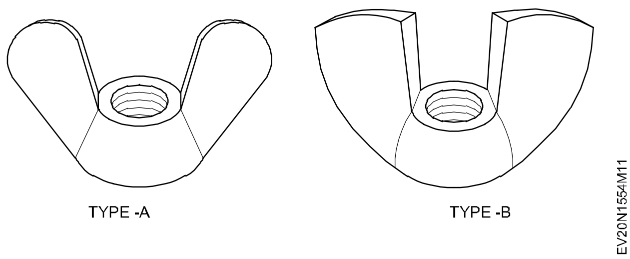
These nuts have special provision in the form of slots for fixing split pins for locking the nuts.

Slotted nuts are hexagonal shaped throughout. In the case of castle nuts, the top part of the nut is cylindrical in shape.

Wing-nuts (Fig 1)

Wing-nuts are used in light duty assembly which require frequent removal and fixing. These are available as hot forged/cast (Type A) and cold forged (Type B).

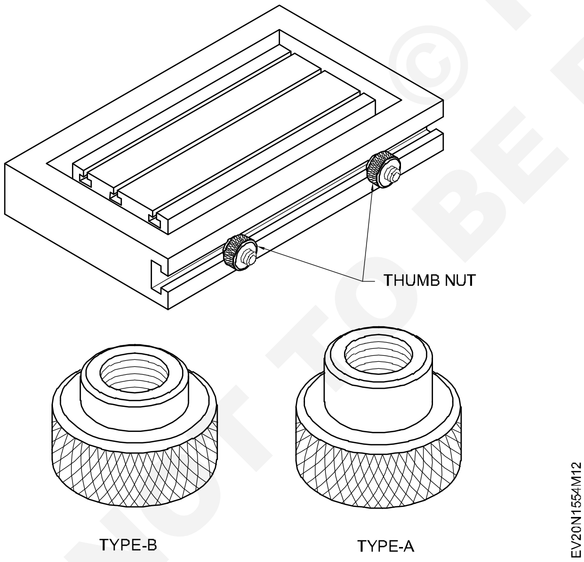
Fig 1



Thumb-nut (Fig 2)

These are used in places where frequent adjustments are required and mere finger tightening enought. They are available in two types - Types A & Type B.

Fig 2



Cap nut (Fig 3)

These are used to protect the bolt end threads from damages and also as a protector for safe working. They serve to provide a decorative appearance.

Hexagonal nuts with collar (Fig 4)

These nuts have a machined collar on one end. This provides additional bearing surface in assembly. The collar acts like a washer and is useful where frequent tightening and loosening is necessary.

Hexagonal weld nuts (Fig 5)

Fig 3

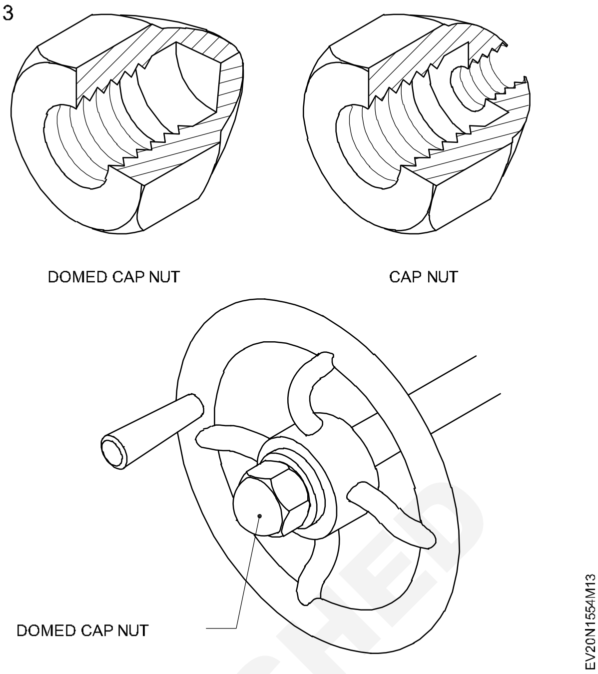


Fig 4

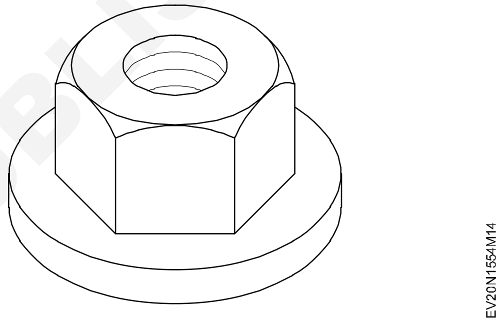
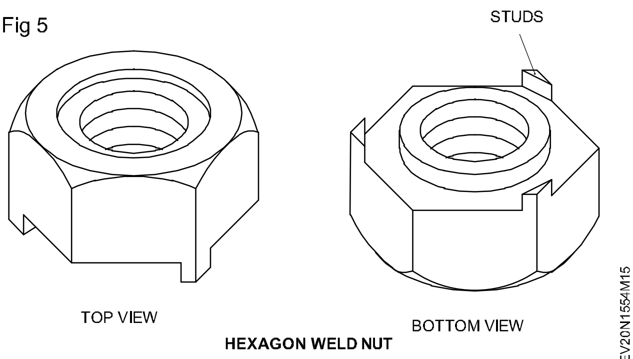


Fig 5



These are nuts used for welding on the plate work. These nuts have:

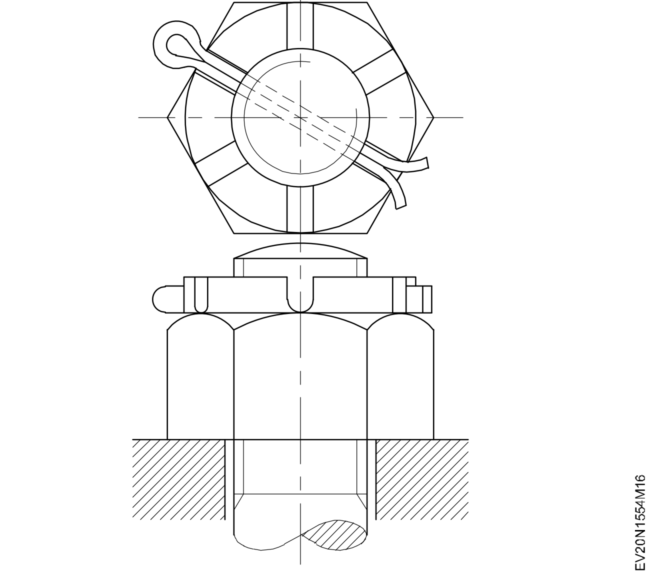
- a spigot ring which fits in the hole of the plate
- three projections to provide a uniform contact on the surface, that is to be welded
- a countersunk hole on one end to protect the thread during welding.

Out. Castle nuts (Fig. 6) are widely used in automobiles and locomotive engines to avoid sudden shock and vibration.

Circlip (Fig 7)

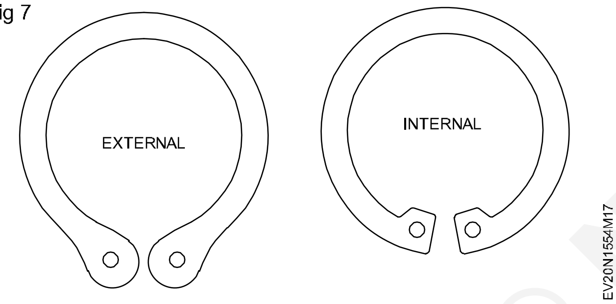
These are widely used to retain the component on a shaft or in a bore. Seating of these circlips in a slot by

Fig 6



using a special type of pliers facilitates rapid assembly and disassembly.

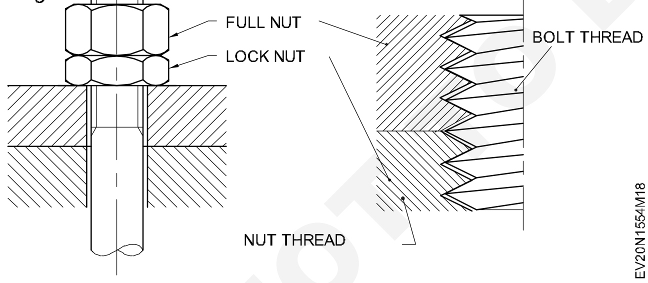
Fig 7



Chuck nut (Fig 8)

This nut is used along with one ordinary nut as shown in the figure.

Fig 8



A chuck nut is also called a lock-nut. The two nuts are thus locked or wedged tightly against each other and against the bolt. This will prevent slackening.

Self-locking nut (Fig 9)

Self-locking nut will have a nylon insert to provent the loosening of the nut from shock, vibration and temperature.

Wire lock (Fig 10)

Wire locks are used for light engineering works. The wire is passed throught the groove.

Nut applied with a sealant

Fig 9

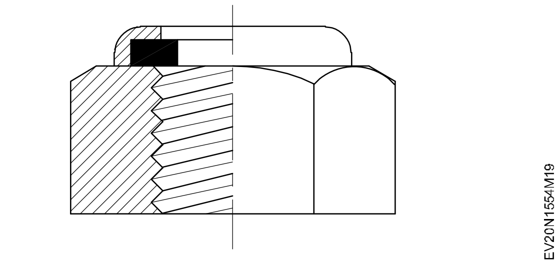
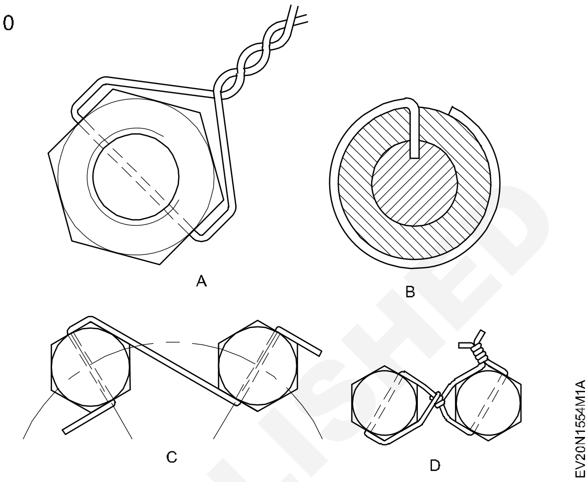


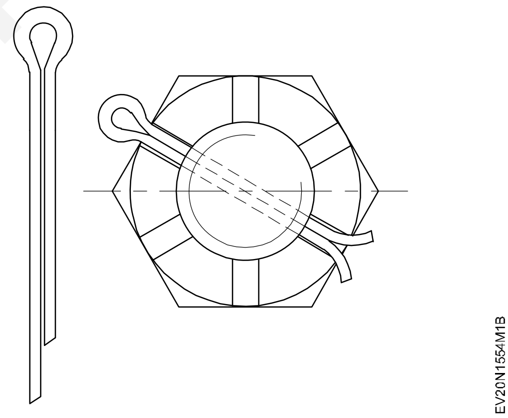
Fig 10



These locking devices are for permanent locking in light works.

Split pin (Fig 11)

Fig 11



A split pin is made from a steel wire of semicircular crosssection, bent as shown in the figure. It is inserted in a hole drilled in the bolt so that it exerts pressure on the top face of the nut to prevent it from turning.

Sawn nut (Wiles nut)

In this locking device, a slot is cut half way across the nut. A screw is fitted with a clearance hole on the top part and a matching thread on the lower part of the nut. Tightening of the nut provides positive locking for the nut.

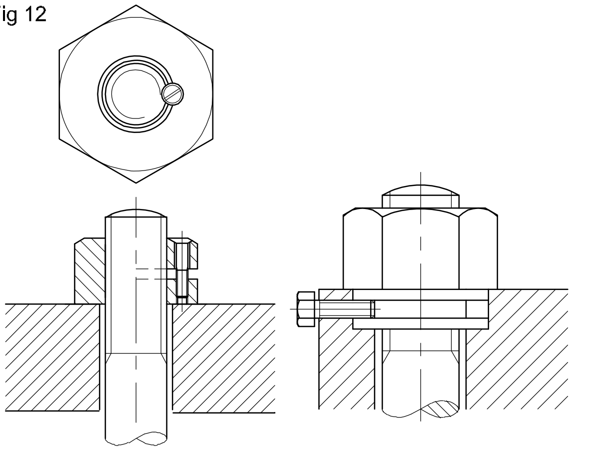
Positive locking device (Fig 12)

Frictional locking device

Positive locking device(Fig 13)

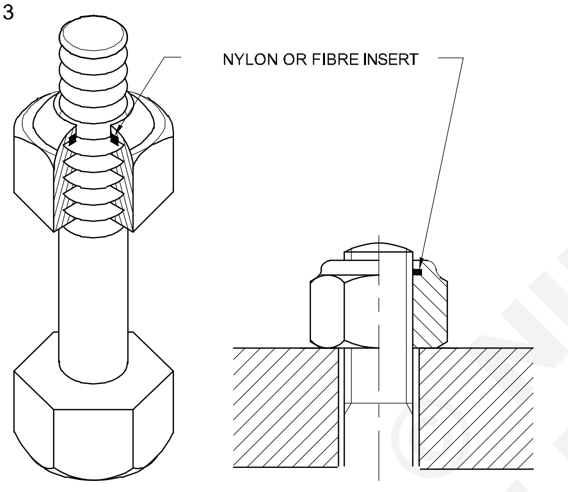
In the positive locking device, the locking action is positive. This locking device is difficult to fit and may take more

Fig 12



time. But it is very essential to use this type of locking device in critical joints where failure could cause serious accidents.

Fig 13



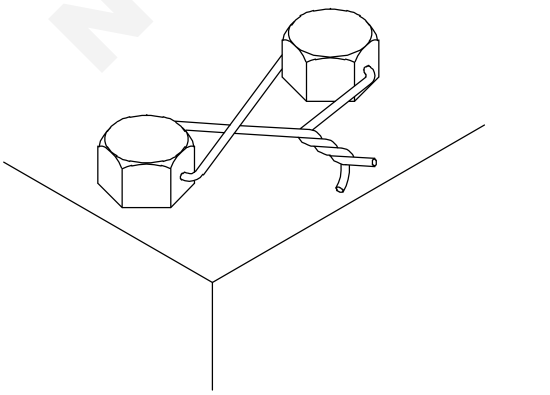
Eg. Clutches, brakes, controls etc.

The positive locking devices are:

- standard hexagonal nut, cross-drilled and pinned
- standard slotted nut
- standard castle nut
- hexagonal nut and locking plate
- wiring bolt heads.

Frictional locking devices

Fig 14



These lock nuts are easy to fit and less time consuming.

The frictional locking devices are:

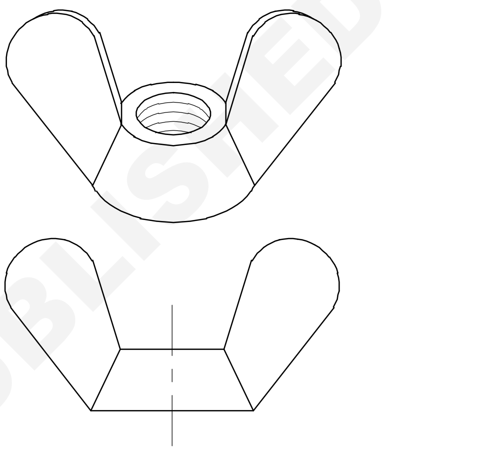
- lock-nut (chuck nut)
- spring washer
- wedge lock bolt
- simmonds lock-nut.

COMMONLY USED LOCKING DEVICES

Wing-nut (Fig 15)

A wing-nut is used where frequent adjustment or removal is necessary. It can be loosened or tightened rapidly without the need of a wrench. These nuts are manufactured with the same material as is used for the bolts.

Fig 15



Thumb-nut

A thumb-nut is used where the movement of the spindle is to be locked, as in a micrometer. Stopping the movement of the spindle is necessary for taking a correct reading.

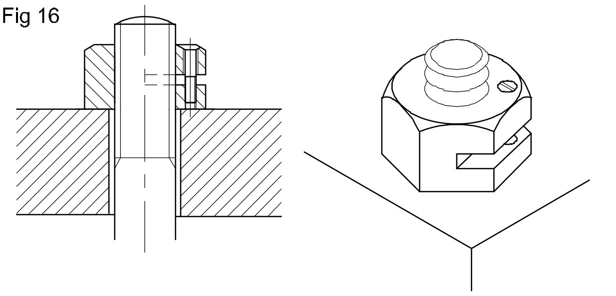
Locking ring

A locking ring is used in taper nose spindles of lathes to lock the chuck.

Castle nut (Fig 16)

Slots are cut in a cylindrical collar provided on the top of the nut, thus overcoming the disadvantage of the slotted

Fig 16



Slotted and castle nut with a split pin

The position of the nut can be locked using the split pin.

Split pins are designated by the nominal size, nominal length, the number of the Indian Standard and the material. (Fig 17 & 18)

Fig 17

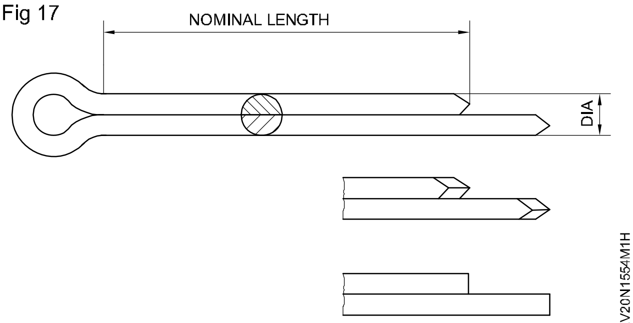
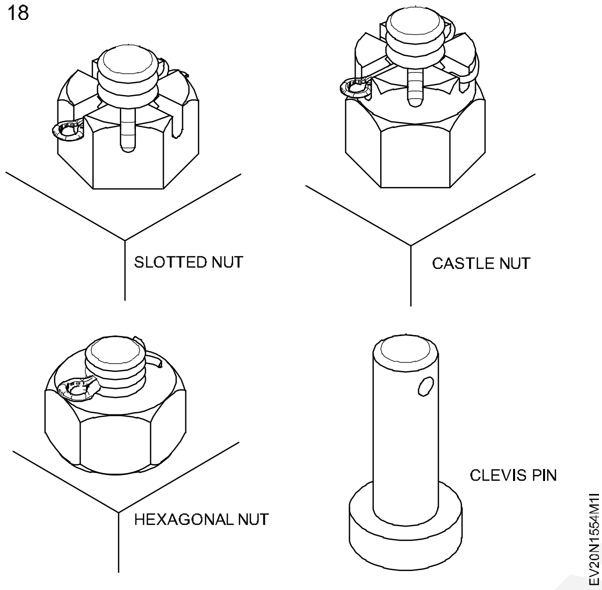


Fig 18



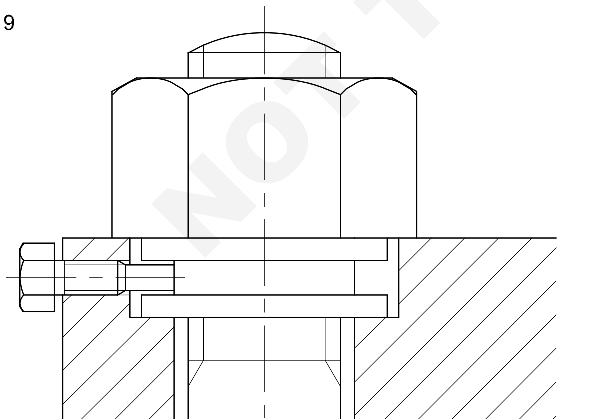
The nominal length is the distance from the underside of the eye to the end of the short leg.

Split pins are used for locking slotted nuts, castle nuts, hexagonal nuts, clevis pins etc. and are used in different ways.

Grooved nut (Penning nut) (Fig 19)

This is a hexagonal nut with the lower part made cylindrical. On the cylindrical surface there is a recessed groove in which a set screw is used to lock the nut.

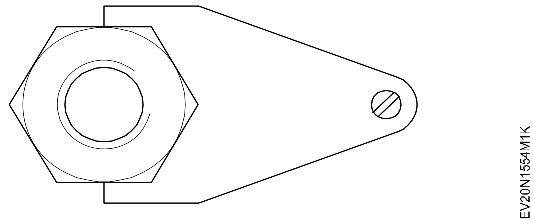
Fig 19



Locking plate (Fig 20)

For preventing the nut from loosening, locking plates are fixed on the outside of the hexagonal nut.

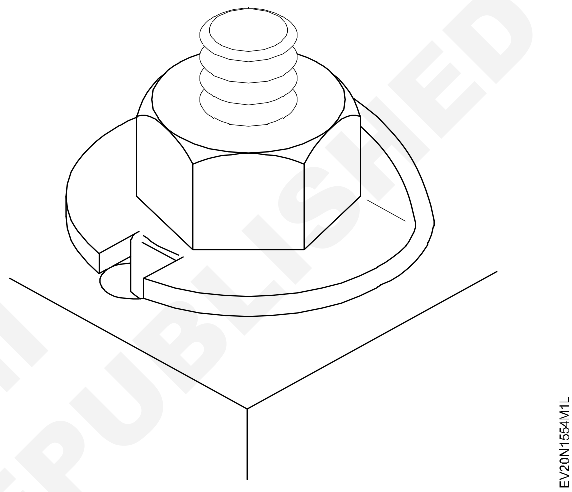
Fig 20



Lock washers with lug (Fig 21)

In this arrangement of locking, a hole is drilled for accommodating the lug.

Fig 21

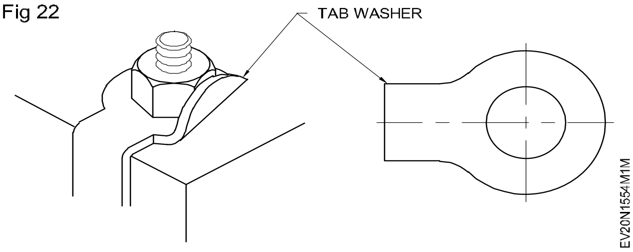


The movement of the nut is prevented by folding the washer against the nut.

Tab washers (Fig 22)

Tab washers can be used for locking the nuts which are located near an edge or corner.

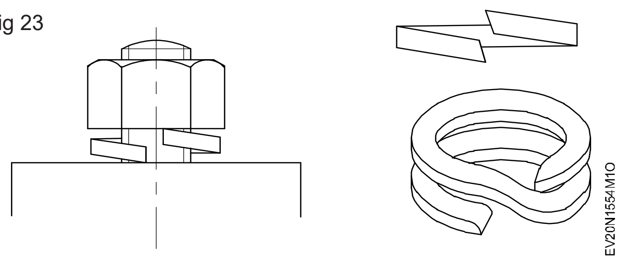
Fig 22



Spring washer (Fig 23)

Spring washers are available with single or double coils. These are placed under a nut in the assembly as washers. The stiff resistance offered by the washer against the surface of the nuts serves to prevent loosening.

Fig 23



Bolts and studs

Objectives: At the end of this lesson you shall be able to
- **state the situations in which bolts and nuts are used**
- **state the advantages of using bolts and nuts**
- **name the different types of bolts**
- **state the applications of the different types of bolts**
- **state the situations in which studs are used**
- **state the reason for having different pitches of threads on stud ends.**

Bolts and nuts (Fig 1)

These are generally used to clamp two parts together. When bolts and nuts are used, if the thread is stripped, a new bolt and nut can be used. But in the case of a screw directly fitted in the component. When threads are damaged, the component may need extensive repair or replacement.

Depending on the type of application, different types of bolts are used.

Bolts with clearance hole (Fig 2)

This is the most common type of fastening arrangement using bolts. The size of the hold is slightly larger than the bolt (clearance hole) Slight misalignment in the matching hole will not affect the assembly.

Studs (Fig 3)

Studs are used in assembiles which are to be separated frequently.

When excessively tightented, the variation in the thread pitch allows the fine thread or nut end to silp. this prevents damage to the casting. Designation of bolts as per B.I.S specifications Hexagon head bolts shall be designated by name. thread size, nominal lenth, property class and number of the indian standrad. Example A hexagon head bolt of size M10, nominal length 60mm and property class 4.8 shall be designated as: Hexagon head bolt M10x60 - 4.8-IS: 1363 (Part 1) Explanation about property class The Part of the specification 4.8 indicates the property class (mechanical properties). In this case it is made of steel with minimum tensile strength = 40kgf/mm2 and having a ratio of minimum yield stress to minimum tensile strength = 0.8. NOTE Indian standard bolts and screws are made of three product grades - A,B, & C, 'A' being precision and the others of lesser grades of accuracy and finish. While there are many parameters given in the B.I.S. specification, the designation need not cover all the aspects and it actually depends on the functional requirement of the bolt or other threaded fasteners. For more details on the designation system, refer to IS: 1367, Part XVI 1979.

Fig 1

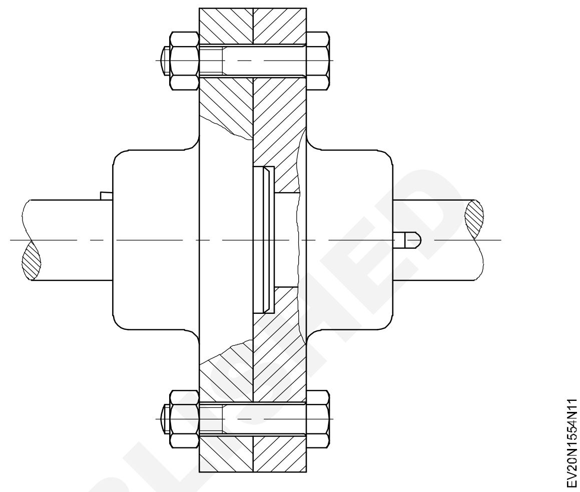


Fig 2

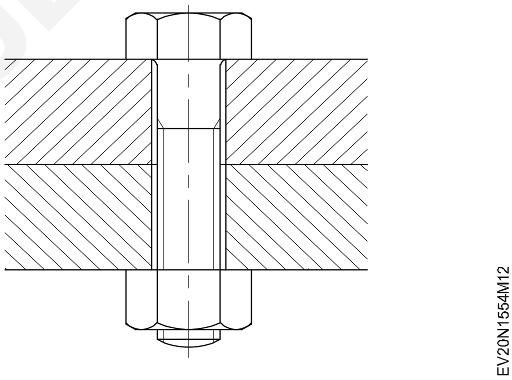
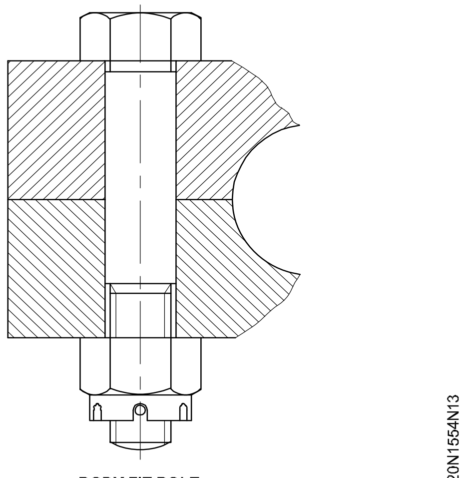


Fig 3



BODY FIT BOLT

Locking devices

Objectives: At the end of this lesson you shall be able to
- **state what is a locking device**
- **name the effect, if proper locking devices are not employed**
- **name the various types of locking devices**
- **state the uses of the commonly used locking devices.**

Locking devices

A locking device is a device used to lock the threaded fasteners to prevent them from loosening. Due to vibration in the moving part, there is a tendency for the threaded fastener to get slack and to slip off. Then the assembled part will get loose and cause damages. Some examples are given below to illustrate the importance of the locking device.

In the case of a micrometer, the lock-nut avoids the Movement of the spindle after taking the reading. In the case of boilers and gas cylinders, locking of the nut avoids the leakage of steam or gas. In automobiles the lock-nut avoids the loosening of the assembled part.

Classification of lock-nuts

Lock-nuts are classified into two categories.

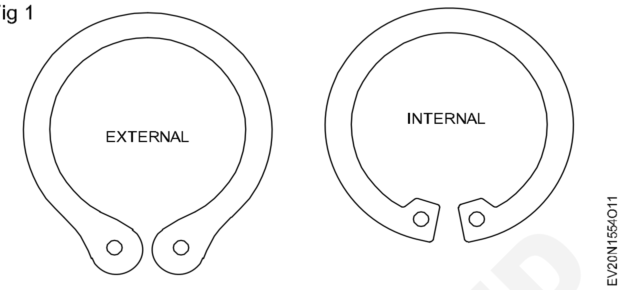
- Positive locking device
- Frictional locking device

These nuts have special provision in the form of slots for fixing split pins for locking the nuts. Slotted nuts are hexagonal shaped throughout. In the case of castle nuts, the top part of the nut is cylindrical in shape.

Circlip (Fig 1)

These are widely used to retain the component on a shaft or in a bore. Seating of these circlips in a slot by using a special type of pliers facilitates rapid assembly and disassembly.

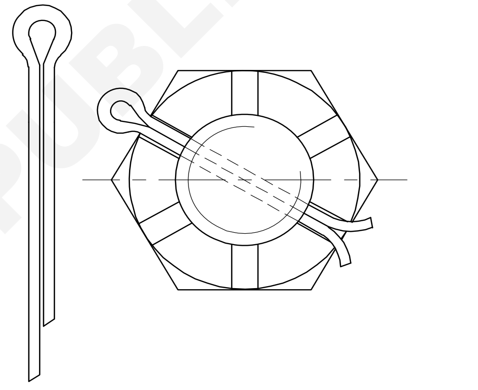
Fig 1



Split pin (Fig 2)

A split pin is made from a steel wire of semicircular cross section, bent as shown in the figure. It is inserted in a hole drilled in the bolt so that it exerts pressure on the top face of the nut to prevent it from turning.

Fig 2



Keys

Objectives: At the end of this lesson you shall be able to
- **name the different types of keys used in transmission**
- **state the features of each type of keys.**

Keys

Keys are used for transmitting torque from a rotating shaft to a hub/wheel or from a hub/wheel to the shaft. (Fig 1)

Keys of different types are used depending on the requirements of transmission.

Hollow saddle key

One face of this key has a curvature to match with that of the shaft surface. It has a taper of 1 in 100 and is driven in through the keyway. (Fig 2)

The hub is held on the shaft due to friction. This key is useful only for light duty transmission.

Flat saddle key

This key has a rectangular cross-section. For fitting this key in the assembly a flat surface is machined on the shaft. (Fig 3).

The key is placed between the flat surface of the shaft and the keyway on the hub. This is considered to be stronger than the hollow saddle key. This is not suitable for heavy duty transmission.

Circular taper key

In this case both the shaft and the hub have semicircular keyways cut on them (Fig 4).

The taper key is driven in while assembling. This key is suitable only for light transmission.

Sunk key (Fig 5 & 6)

This key has a rectangular cross-section and its fits into the keyway cut on both the shaft and the hub. Sunk keys are either parallel or tapered.

Fig 1

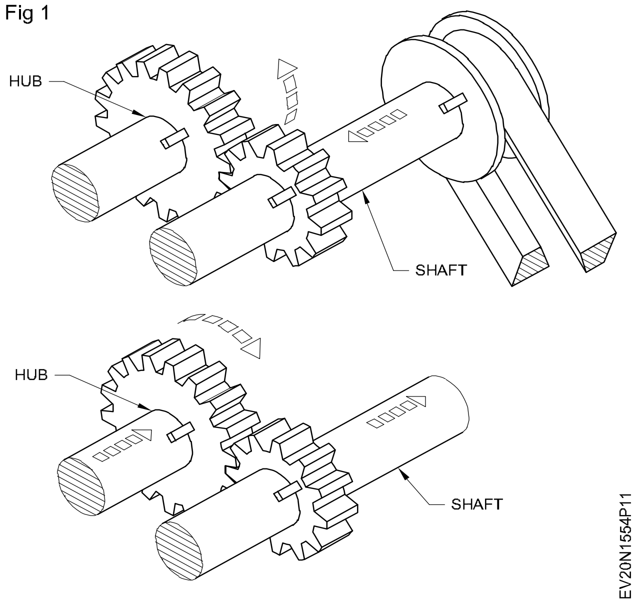


Fig 2

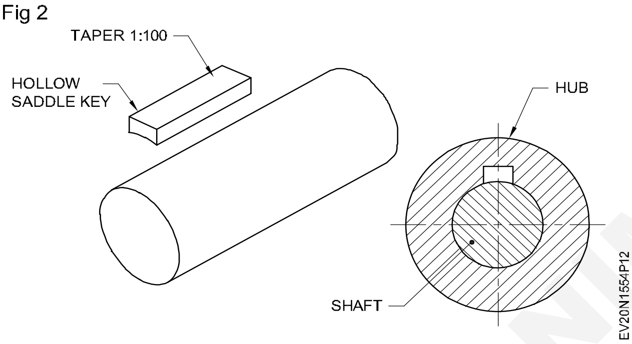


Fig 3

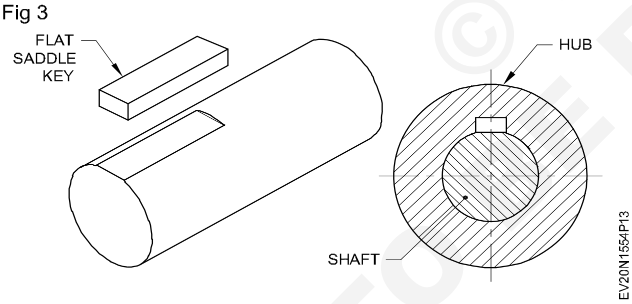
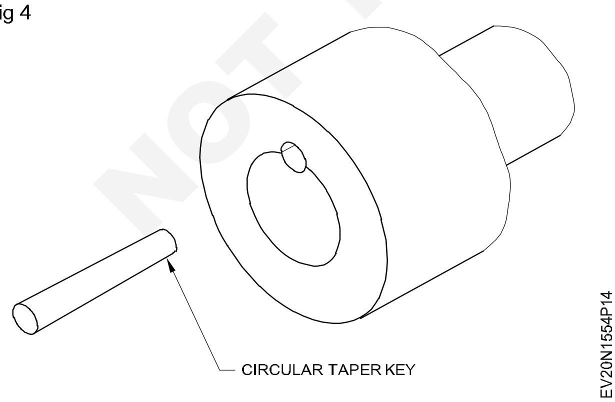


Fig 4



Gib-head key (Fig 7)

This is another type of sunk key. This has a gib-head to assist in fixing and removing the keys. (Figs 7a and b)

Fig 5

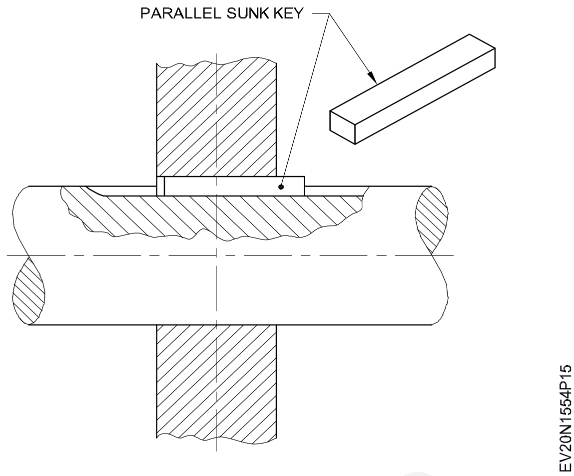


Fig 6

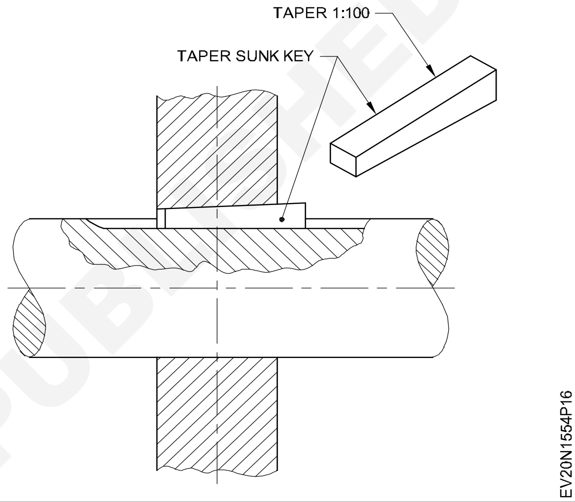
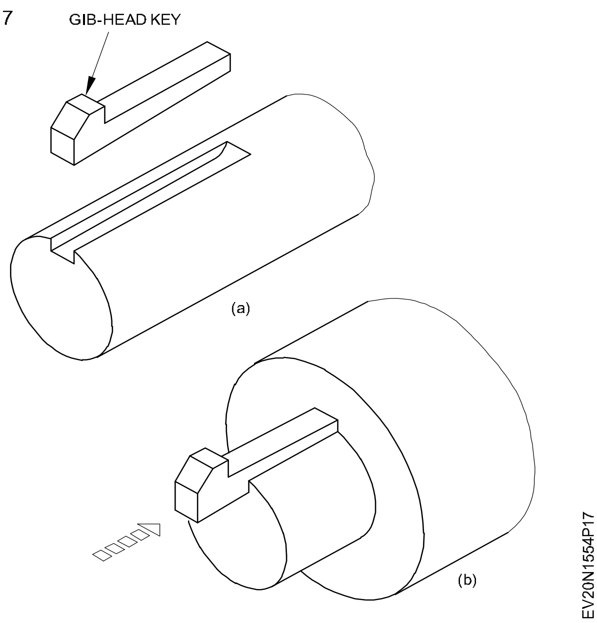


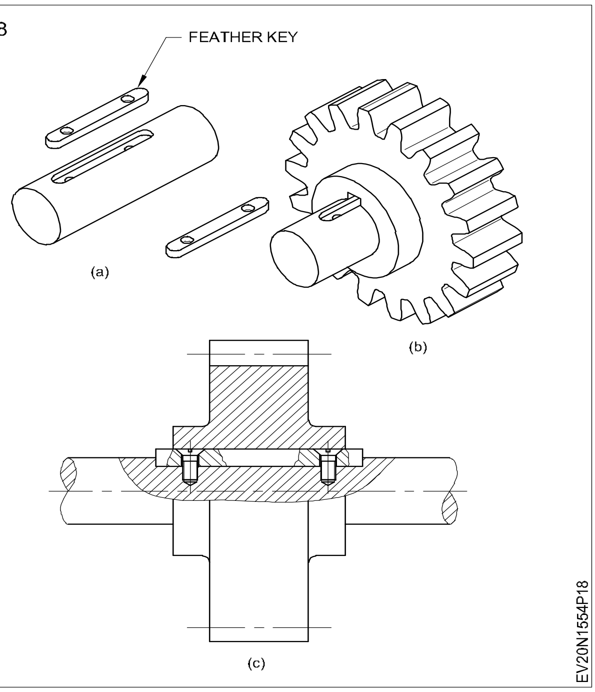
Fig 7



Feather key (Fig 8)

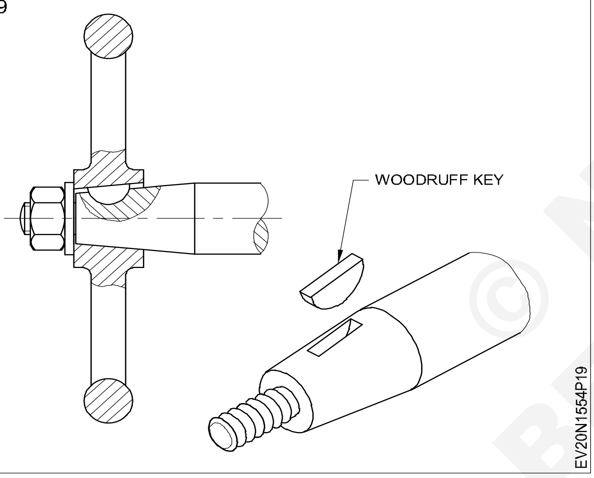
This is a parallel key with rounded ends. This is useful when the hub/pulley has to slide axially on the shaft to some distance. (Figs 8a,b and c) This key may be either tightly fitted in the keyway or screwed in.

Fig 8



Woodruff key (Fig 9)

Fig 9



This is semicircular key and it fits on to the shaft on which matching recesses are cut. The top portion of the key projects out and fits in the keyway cut on the hub. (Fig 9)

This key is particularly useful on tapered fittings of shafts Splined shaft & serrated shaft Splinded shafts along with splined hubs are used particularly in the motor industry. The splined hub can also slide along the shaft, wherever necessary. (Figs 10a and b) In certain assemblies, serrated shafts are also used for transmission. (Figs 11a and b)

Fig 10

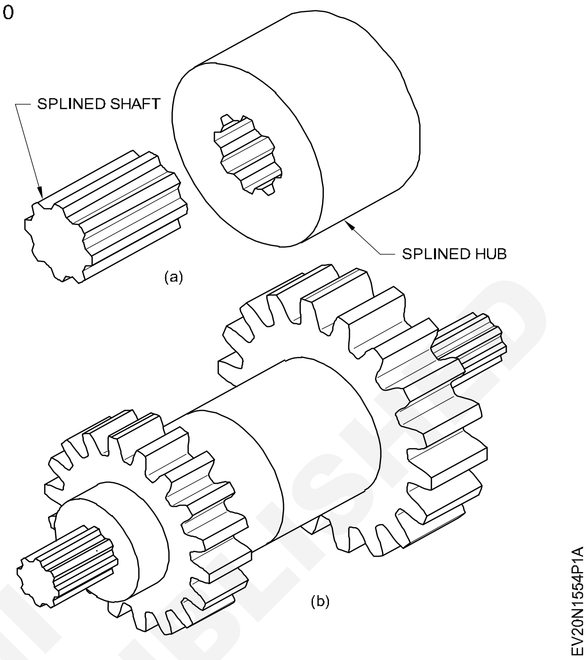
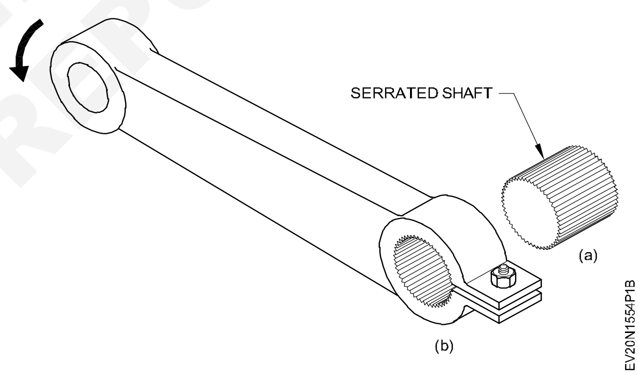


Fig 11



Circlips

Objectives: At the end of this lesson you shall be able to
- **state the functions of circlips**
- **state the different types of circlips**
- **state the advantages of circlips over other fastening devices**
- **state the materials used for circlips.**

Circlips are fastening devices used to provide shoulders for positioning or limiting the movement of parts in an assembly (Fig 1) Circlips are also called 'Retaining rings. The rings are generally made of materials having good spring properties so that the fastener may be deformed elastically to a considerable degree and still spring back to its original shape. This permits the circlips to spring back into a groove or other recess in a part or they may be seated on a part in a deformed conditional so that they grip the part by functional means. Circlips are manufactured from spring steel with high tensile and yield strength.

Types

There are two types. Internal circlips (Fig 2) This type of rings are assembled in holes, bores or housing.

External circlip (Fig 3) This type of rings are installed on shafts, pins, studs and similar parts. Both types offer a number of advantages over other types of fasteners.

Fig 1

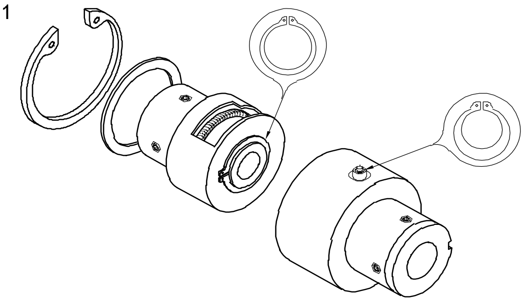
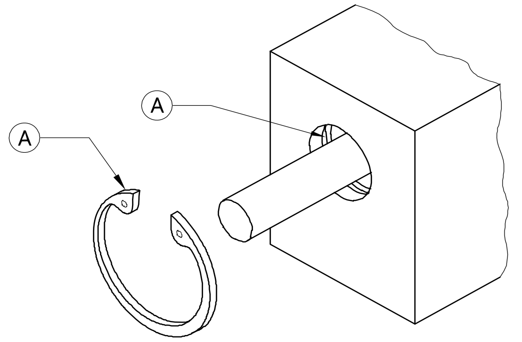


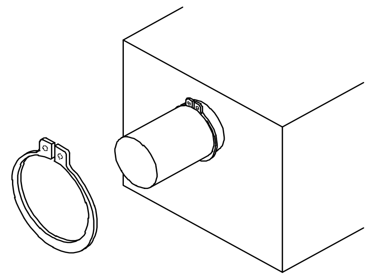
Fig 2



INTERNAL CIRCLIP

- Their cost is relatively low when compared with other types of fasteners.

Fig 3



EXTERNAL CIRCLIP

- Their use often results in savings in raw material and simplified machining operations for other parts in the assembly.
- One circlip often can replace two or more parts.
- Assembly toolings developed for circlips usually permit very rapid assembly of the fasteners, even by unskilled workers.

Material

Because retaining rings depend for their function largely on their ability to be deformed elastically during assembly and disassembly, the materials must have good spring properties. Circlips are manufactured from spring steel with high tensile and yield strength.

Washers - types and uses

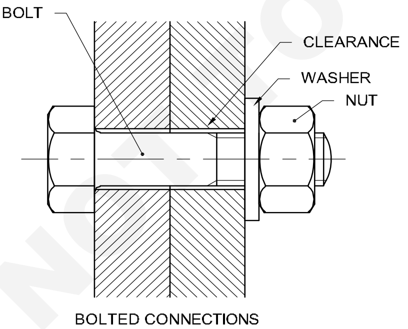
Objectives: At the end of this lesson you shall be able to
- **state the purpose of washers**
- **name the types of washers**
- **state the uses of each type of washers**
- **specify the washers as per B.I.S.**

Purpose

It is a common practice to provide washers under the nuts in bolted joints.

Washers help to (Fig 1)

Fig 1



BOLTED CONNECTIONS

- increase the frictional grip
- prevent loosening of nuts due to vibration
- prevent damage to the work piece and
- distribute force cover a larger area.

Types of washers

There are different types of washers available. They are

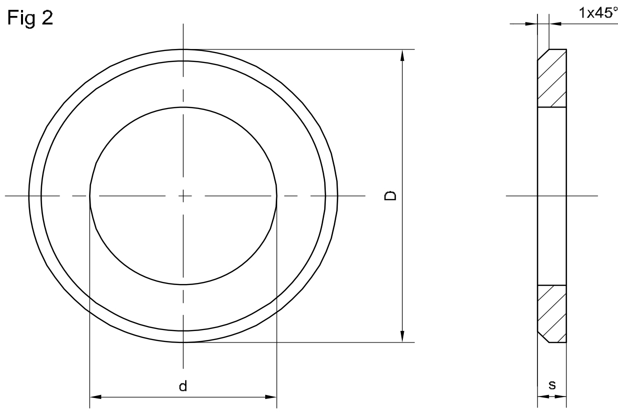
- plain or flat washers
- taper washers
- spring washers
- tab washers
- toothed lock washers.

Plain or flat washers (Fig 2)

These washers are used for bolting assemblies with flat surfaces. The diameter thickness and the bore diameter are proportional to the diameter of the bolt. (I.S. 2016)

Plain washers are available as machined or punched washers.

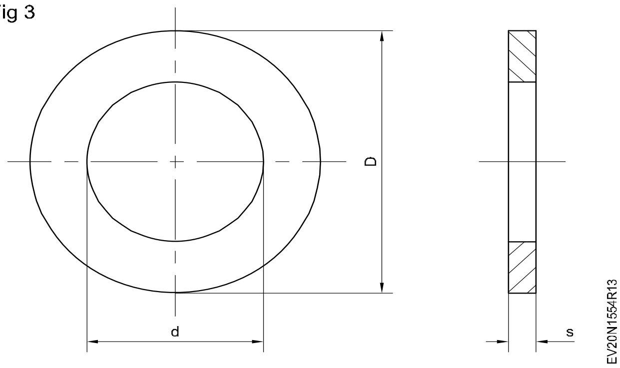
Fig 2



Machined washers (Fig 3)

These washers are used for assemblies using machined components. These washers are available with chamber on one side or on both sides. They are heat treated and ground.

Fig 3



Punched washers

These do not have chamfers and are commonly used in structural fabrication work.

Tapered washers (Figs 4 & 5)

These are used in structural assemblies with tapered surfaces like the inside of beams, channels etc. These washers help bolt head or nut to seat square to the hole.

Fig 4

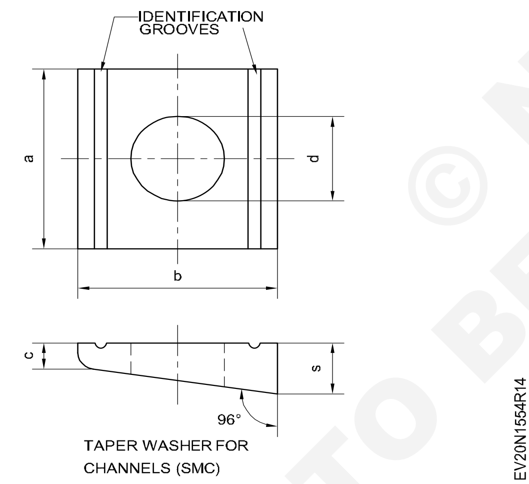
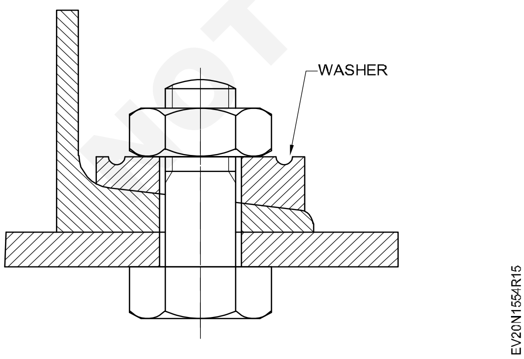


Fig 5



Spring washers (Figs 6 & 7)

Spring washers are used under the nuts to prevent slackening of the nuts due to vibrations. They are made of spring steel, and when compressed they create tension between the bolt and the nut.

Fig 6

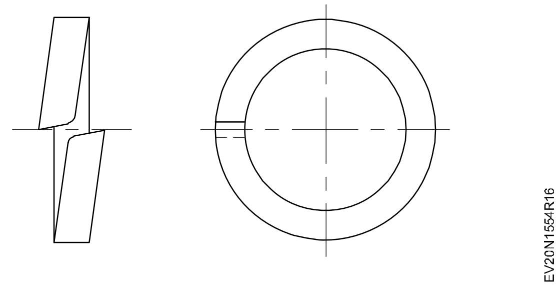
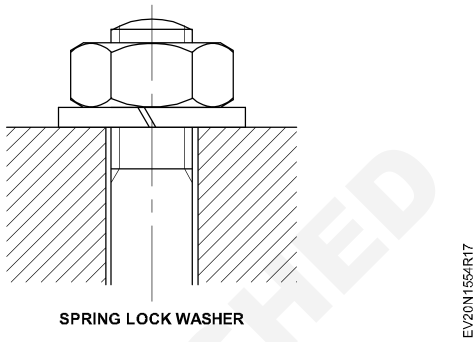


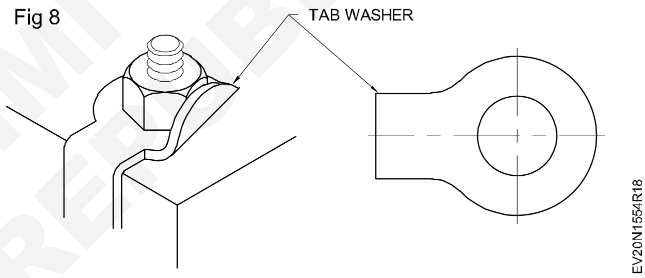
Fig 7



Tab washers (Fig 8)

These washers are used for locking the nuts.

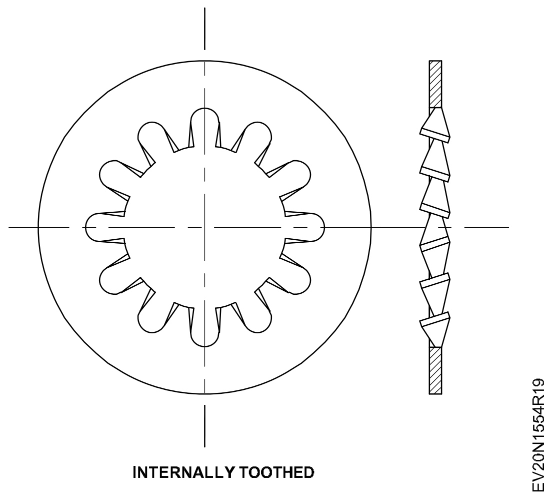
Fig 8



Toothed lock washers (Fig 9)

These washers have serrations, cut and twisted. When placed between the nut and the assembly, this washer exerts friction on both the contacting surfaces. This prevents the nuts from slackening.

Fig 9



Specifications

The Indian standard Is:2016-1967 designates a washer by name, type size and number of the standard and material.

Example A machined washer of size 10.5 mm made of brass shall be designated as machined washer 10.5 IS:2016 Brass.

Note

For detailed specification of different types of washers refer to the following IS specifications.

Taper washer - IS: 5374 and IS: 5372

Tab washer - IS: 8068

Toothed lock washer - IS: 5371

Plain washer - IS: 2016

Screwdrivers

Objectives: At the end of this lesson you shall be able to
- **classify the hand-held screwdrivers and state the features of standard screwdrivers**
- **list out the different types of special screwdrivers and their specific uses**
- **specify standard screwdrivers.**

Screwdrivers are used to tighten or loosen screws which are fixed in the machine element.

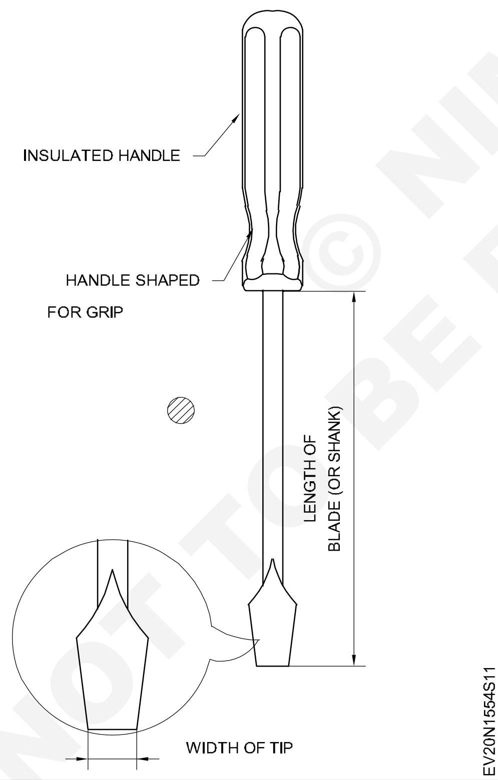
Classification

- Standard type with tips to suit recessed head screw slots.
- Special type with tips to suit recessed head screws

Features of Standard screwdrivers (Fig 1)

Screwdrivers must have:

Fig 1



- tips (1) of turn screws with slotted heads
- handles of metals, wood or moulded insulating material(2), shaped to give a good grip for turning (3).
- blades of hardened and tempered carbon steel or alloy steel
- round or square blade with length (4) ranging from 40mm to more than 350mm.
- flared tips which vary in length and thickness with the length of the blade.

Standard Screwdrivers

Standard screwdrivers are classified as:

- heavy duty screwdrivers
- light duty screwdrivers
- stumpy screwdrivers

Heavy duty screwdrivers (Fig 2 & 3)

This screwdriver has a square blade for applying extra twisting force with the end of the spanner. Heavy duty screwdrivers of London pattern have a flat blade and are mostly used by carpenters.

Fig 2

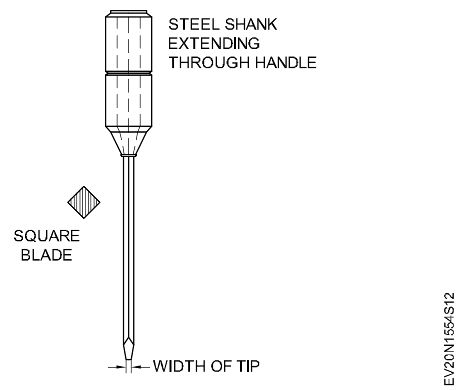
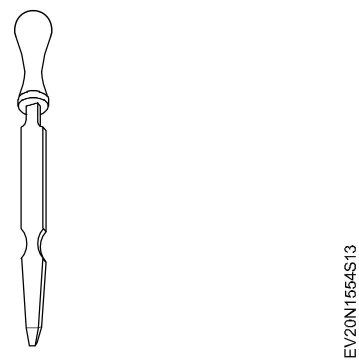
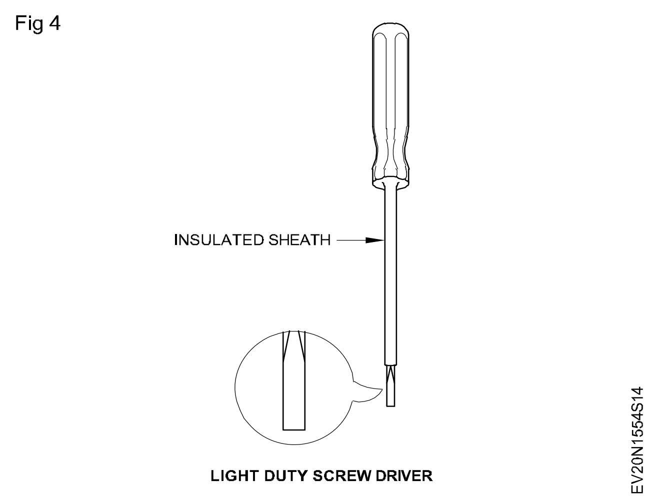


Fig 3



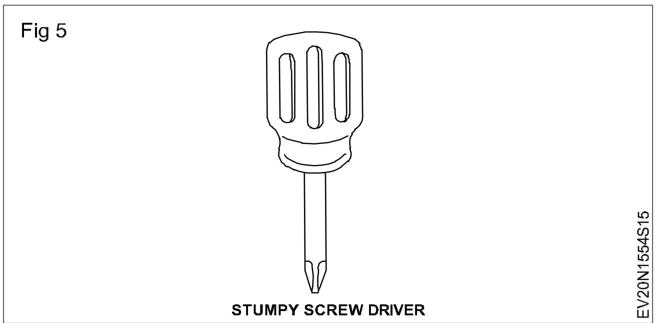
Light duty screwdrivers (Fig 4)

This screwdriver has a round blade with parallel tips. This screwdriver is used by electricians. The blades are sheathed in insulation to avoid short circuiting live parts.



LIGHT DUTY SCREW DRIVER

Stumpy screwdrivers (Fig 5)



STUMPY SCREW DRIVER

These are small sturdy screwdrivers. They are used when other types of screwdrivers cannot be used due to the space limitations.

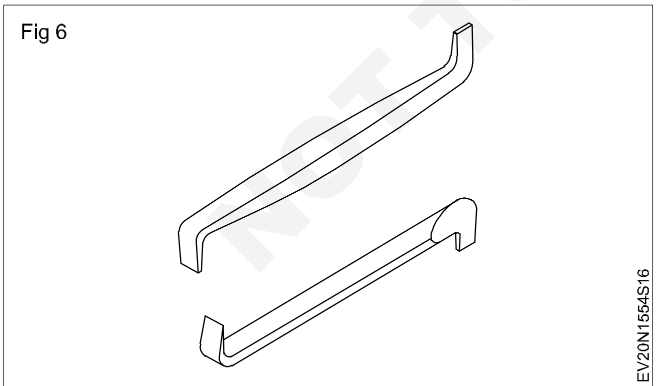
Special screwdrivers and their uses

Offset screwdriver (Fig 6)

Offset screwdrivers are used on screws which are placed in blind spaces.

They are made with short blades and with the tips at right angle.

Greater turning force can be applied on screws by these screwdrivers because of their leverage.



Ratchet screwdriver (Fig 7)

The following are the features of ratchet screwdrivers.

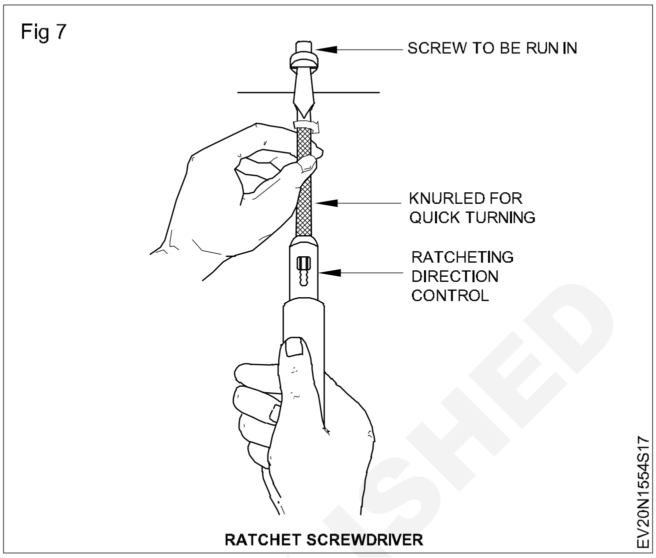
These screwdrivers are made with a three-position ratchet control for screwing, unscrewing of a screw and also providing a neutral position.

They are used for tuning screws in confined spaces.

They can be operated without changing the hand grip.

They are used for slackening or tightening with a medium force.

They are used in mass production.



RATCHET SCREWDRIVER

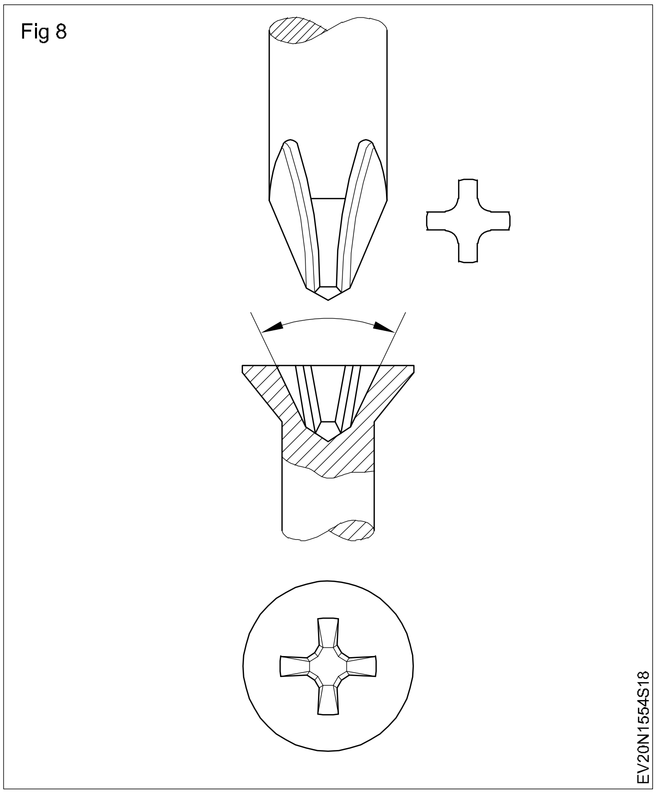
Phillips (cross-recess) screwdrivers (Fig 8)

Phillips screwdrivers have cruciform or cross-shaped tips that are unlikely to slip from the cruciform slots in Phillips recessed head screws.

The end of the four flats is tapered to an angle of 53o

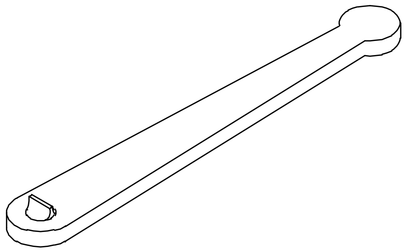
The extreme end is ground to 110°.

Four different sizes to cover the full range of screws are available. These are specified by point sizes 1,2,3 & 4 which correspond to the size of the Phillips screw heads.



For quicker application ratchet offset screwdrivers are also available with renewable tips. (Fig.9)

Fig 9

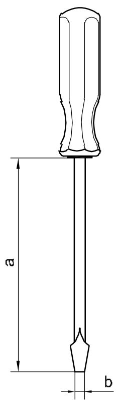


Specification

Screwdrivers are specified (Fig 10) according to the

- length of the blade (a)
- width of the tip (b).

Fig 10



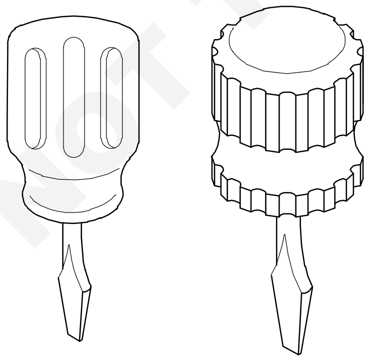
Normal blade length : 45 to 300mm. Width of blade : 3 to 10mm.

The blades of screwdrivers are made of carbon steel or alloy steel, hardened and tempered.

Screwdrivers for special uses

Small sturdy screwdrivers (Fig 11) are available for use where there is limited space.

Fig 11



Screwdrivers with blades sheathed in insulation are available for the use of electricians (Fig 12)

Precautions

Use screwdrivers with tips correctly fitting into the screw slot. (Fig 13)

Fig 12

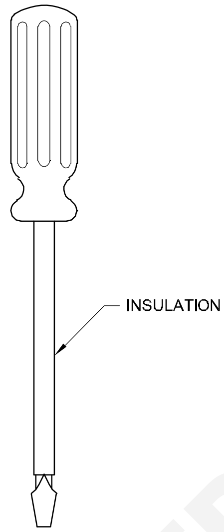
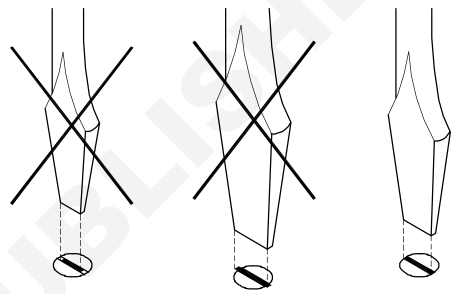


Fig 13



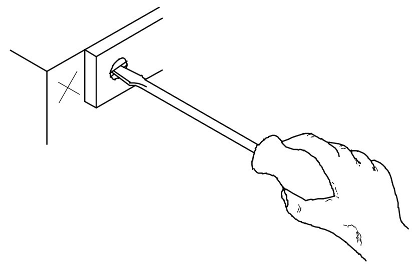
Make sure your hand and the handle are dry.

Hold the screwdrivers axis in line with the axis of the screw.

While using a Philips screwdriver apply more downward pressure.

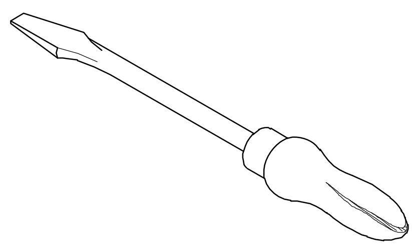
Keep your hand away to avoid injury due to slipping of the screwdriver. (Fig 14)

Fig 14



Do not use screwdrivers with split or defective handles. (Fig 15)

Fig 15



In the case of damaged screwdrivers, the blades can be ground (the faces will be parallel with the sides of the screw slot) and used. While grinding ensure the end of the tips is as thick as the slot of the screw.

While using screwdrivers on small jobs, brace the job on the bench or hold them in a vice.

Specification of a screwdriver

Screwdrivers are specified according to the

- length of the blade
- width of the tip

The normal blade length varies from 45mm to 300mm and the width of the blade varies from 3mm to 10mm.

Screw driver (Fig.16): There are several different size of screw drivers of the standard, reed & prince & phillips types.

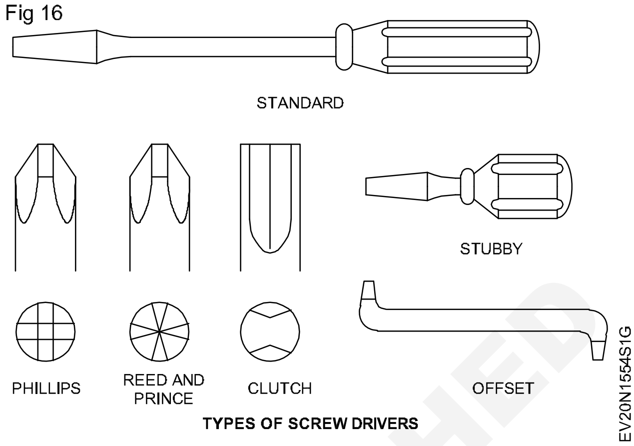
The offset screw driver is useful in tight quarters where even a “Stubby” cannot be used.

Safety

1 Always use correct type and size screw drivers.

2 Don’t do repair work by holding the job on the hand with the help of screw driver, if may slips it pierce the hand.

Fig 16



TYPES OF SCREW DRIVERS

Allen keys

Objectives: At the end of this lesson you shall be able to
- **state the features and uses of hexagon socket screw keys**
- **specify hexagon socket screw keys.**

Hexagon socket screw keys/Allen keys are made from hexagonal section bars of chrom vanadium steel.

These are hardened and tempered. These are bent to `L’ shape. The size of an Allen key is identified by the size across the flat of the hexagon.

Uses

They are used to tighten or loosen screws having internal hexagon sockets. (Fig.1)

Allen keys, available in different sets in plastic wallets, surprise of a set of 8 (2 to 10mm)

2,3,4,5,6,7,8 and 10mm

Sizes of Allen keys (Fig 1)

Individual pieces are available as follows 1, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 14, 17, 19, 22, 24, 27, 32 and 36.

Designation of Allen keys (Fig 2)

A hexagonal socket screw key of width across flat 8 mm shall be designated as Key 8 IS:3082. \

Fig 1

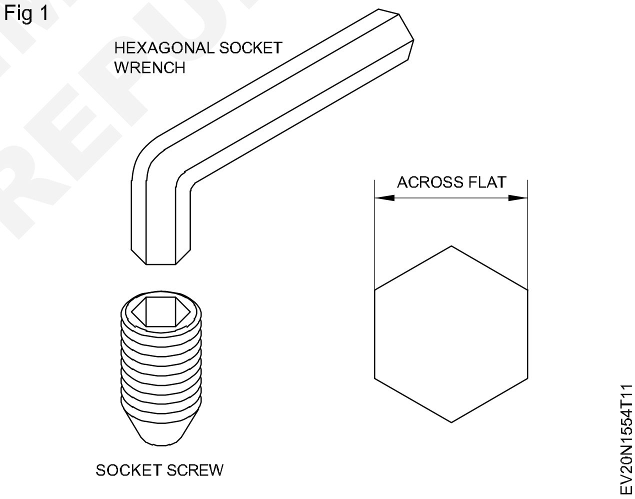
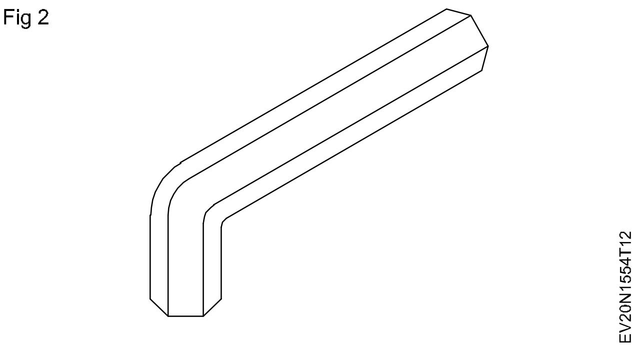


Fig 2



Bench vice

Objectives: At the end of this lesson you shall be able to
- **name the parts and uses of a bench vice**
- **specify the size of a bench vice**
- **state the uses of vice clamps.**

Vices are used for holding workpieces. They are available in different types. The vice used for bench work is called as bench vice or (Engineer's vice)

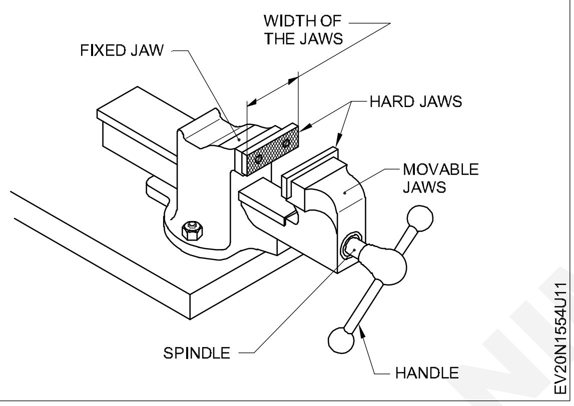
A bench vice is made of cast iron or cast steel and it is used to hold work for filling, sawing, threading and other hand operations.

The size of the vice is stated by the width of the jaws.

Parts of a bench vice (Fig.1)

The following are the parts of the vice

Fig 1



The Vice is generally bolted and secured in a wooden work table, and is useful for operations like filing, chipping, hacksawing, bending sheet metal etc.

Fixed jaw, movable jaw, hard jaws, spindle, handle, box-nut and spring are the parts of vice.

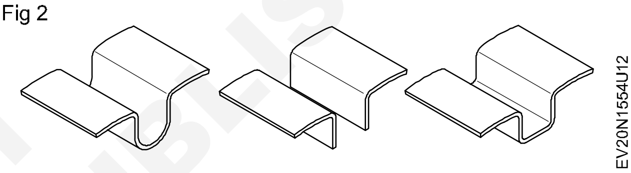
The box-nut and the spring are the internal parts.

Vice clamps or soft jaws (Fig.2)

The hold a finished work use soft jaws (vice clamps) made of aluminium over the regular jaws. This will protect the work surface from damage.

Do not over-tighten the vice as, the spindle may get damaged.

Fig 2



Types of vices

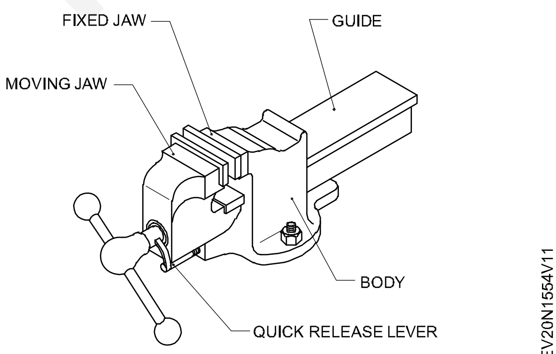
Objectives: At the end of this lesson you shall be able to
- **state the construction and advantages of a quick releasing vice**
- **state the uses of pipe vice, toolmakers vice, hand vice and pin vice.**

There are different types of vices used for holding workpieces. They are quick releasing vice, pipe vice, hand vice pin vice and toolmaker's vice.

Quick releasing vice (Fig 1)

A quick releasing vice is similar to an ordinary bench vice but the opening of the movable jaw is done by using a trigger (lever). If the trigger at the front of the movable jaw is pressed, the nut disengages the screw and the movable jaw can be set in any desired place quickly.

Fig 1

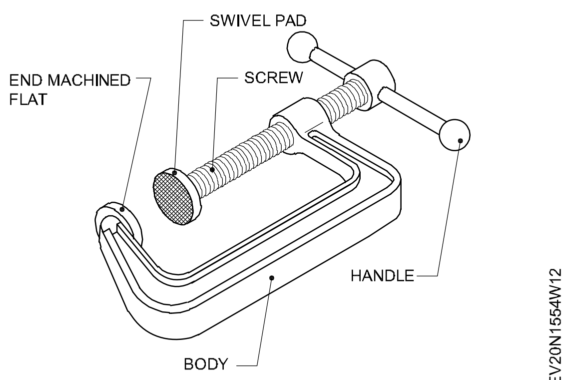


Pipe vice (Fig 2)

A Pipe vice is used for holding round sections of metal, and pipes. In this vice, the screw is vertical and movable. The jaw works vertically.

The pipe vice grips the work at four points on its surface. The parts of a pipe vice are shown in Fig. 2.

Fig 2

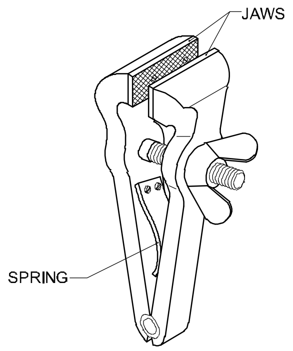


Hand vice (Fig 3)

Hand vices are used for gripping screws, rivets, keys, small drills and other similar objects which are too small to be conveniently held in the bench vice.

A hand vice is made in various shapes and sizes. The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm.

Fig 3

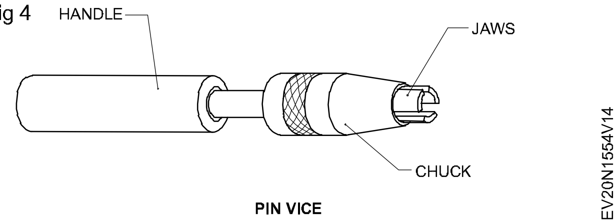


The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg, and passes through the other.

Pin vice (Fig 4)

The pin vice is used for holding small diameter jobs. It consists of a handle and a small collect chuck at one end. The chuck carries a set of jaws which are operated by turning the handle.

Fig 4

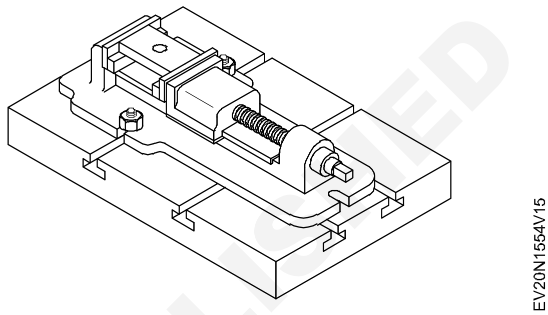


Toolmaker's vice (Fig 5)

The toolmaker's vice is used for holding small work which required filing or drilling and for marking of small jobs on the surface plate. This vice is made of mild steel.

Toolmaker's vice is accurately machined.

Fig 5



C - Clamps and toolmaker's clamps

Objectives: At the end of this lesson you shall be able to
- **state the purpose of using clamps**
- **specify the requirements of the clamping devices**
- **state the features and uses of 'C' clamps**
- **state the features of Toolmaker's clamps.**

Purpose of using clamps: Clamps are used for preventing the movement of work, and for holding the job tight.

Requirements of clamping devices

Should be able to manipulate for easy loading.

Should provide the required clamping force.

Should be capable of locking with minimum movement.

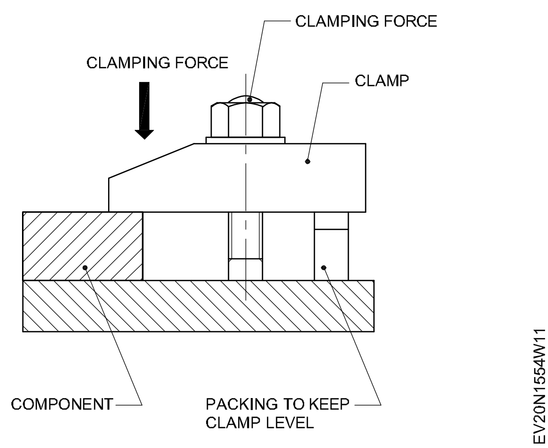
Should accommodate a range of sizes of jobs.

(Fig.1) shows a typical clamping device, employing a screw and nut to provide the clamping force.

'C' Clamps

These clamps are in the shape of a 'C'. The 'C' clamp has its body forged or cast. One end of the clamp is machined flat. The other end is drilled and threaded to accommodate a screw-rod which is operated by a handle. The screw-rod carries a swivel pad which is free to revolve. The clamp is hardened and the face is serrated. (Fig 2)

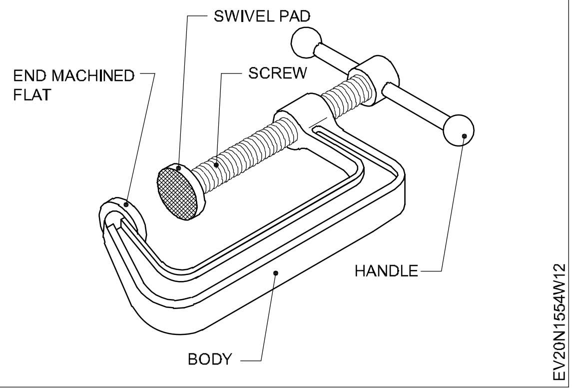
Fig 1



These clamps are used to hold work, on an angle plate or a drill press table, and also, for holding two or more workpieces together.

The swivel pad on the end of the clamping screw helps in clamping surfaces which are not parallel. 'C' clamps are available for light and heavy duty work.

Fig 2

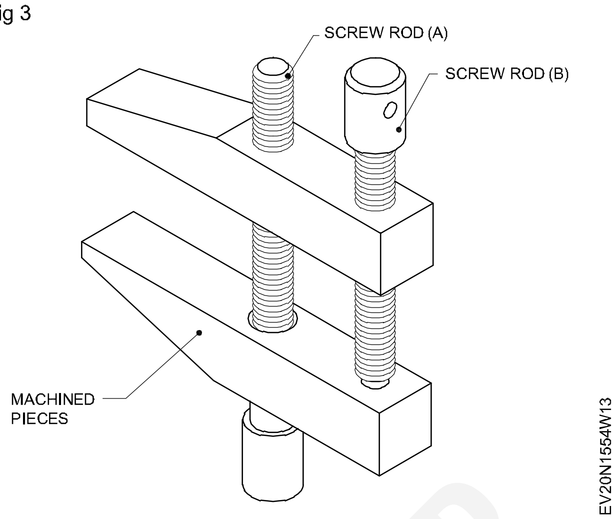


Toolmaker's clamps: This is the type most commonly used by toolmakers for holding small, machined, flat pieces for further operations. They have two rectangular pieces of steel perfectly machined. The inner faces which come in contact with the workpiece are perfectly parallel.

They are assembled by means of two threaded rods. The screw-rod (A) is rotated in one direction to adjust the gap between the two holding faces. The other screw (B) when tightened maintains the required pressure. (Fig 3)

The head of the screw-rod (B) is provided with a hole through which a cylindrical pin may be passed for tightening purposes. The toolmaker's clamps are for holding a previously machined work which is flat and parallel.

Fig 3



The toolmaker's clamp is not suitable for doing any heavy operations on the workpiece since the contacting and holding area of the clamp is limited. It is meant for holding light jobs. It is also called as parallel clamp.

'U' Clamps:These are clamps used along with 'V' Blocks as an accessory. These clamps serve the purpose of holding the round work securely in the 'V' groove for layout operations as well as for machining operations.

Spanners and their uses

Objectives: At the end of this lesson you shall be able to
- **state the necessity of spanners**
- **identify the different types of spanners**
- **specify the spanners**
- **list out the parts of adjustable spanners**
- **state the features of 'C' spanners and their uses.**

Spanners are used for operating threaded fasteners, bolts and nuts. They are made with jaws or opening that fit square on hexagonal nuts and bolts and screw heads. They are made of high tensile or alloy steel. They are drop-forged and heat-treated for strength. Finally they are given a smooth surface finish for ease of gripping.

Spanners are considerably in shape to provide ease of operation under different conditions.

The basic types of spanners are (Fig 1)

- Open end spanners (1)
- tube or tubular box spanners (2)
- Socket spanners (3)
- Ring spanners (4)

The correct spanner fits exactly and allows room for use. They should also permit the job to be done in a shorter time.

The following are the points to be noted for using spanners in a safe way. (Fig.2)

Use open end and ring spanners by pulling on the shank. It is safest to pull as there is less chance of hitting your knuckles if the spanner or nut slips suddenly. If you are forced to push the spanner, use the base of your hand and keep your hand open.

Use both hands for large spanners.

Keep yourself balanced and firm to avoid slipping yourself, if the spanner slips suddenly, Hold on to some support, if there is any chance of falling.

Use both hands as shown in the figure, when using tubular box spanners. (Fig. 2)

Use two spanners as shown in the figure to stop the head of the bolt rotating as the nut is operated. (Fig. 2)

Socket spanners may be turned by accessories which have square driving ends. (Fig. 2)

Size and identification of spanners

The size of a spanner is determined by the nut or bolt it fits. The distance across the flats of a nut or bolt varies both with the size and the thread system. (Fig 4)

In the British system the nominal size of the bolt is used to identify the spanner. (Fig. 3)

Fig 1

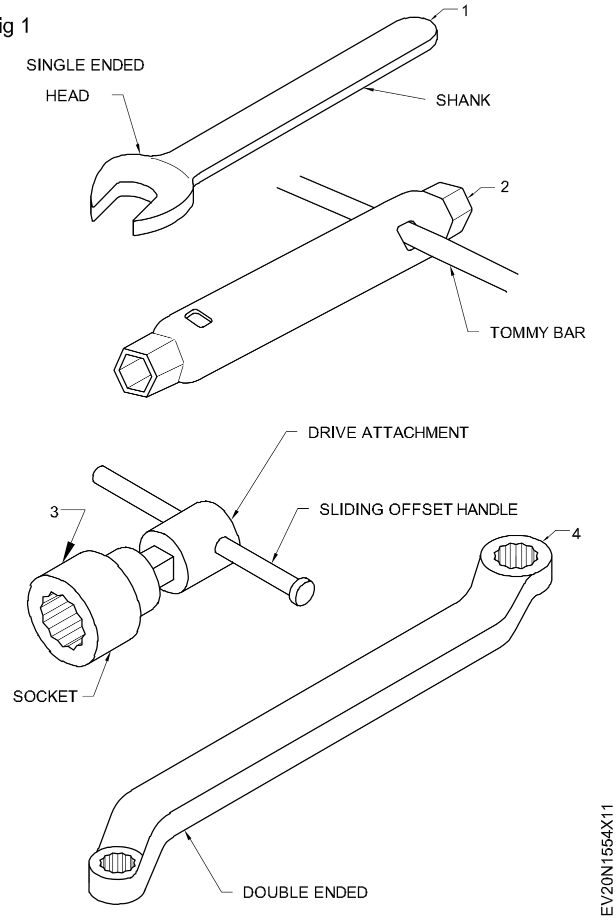
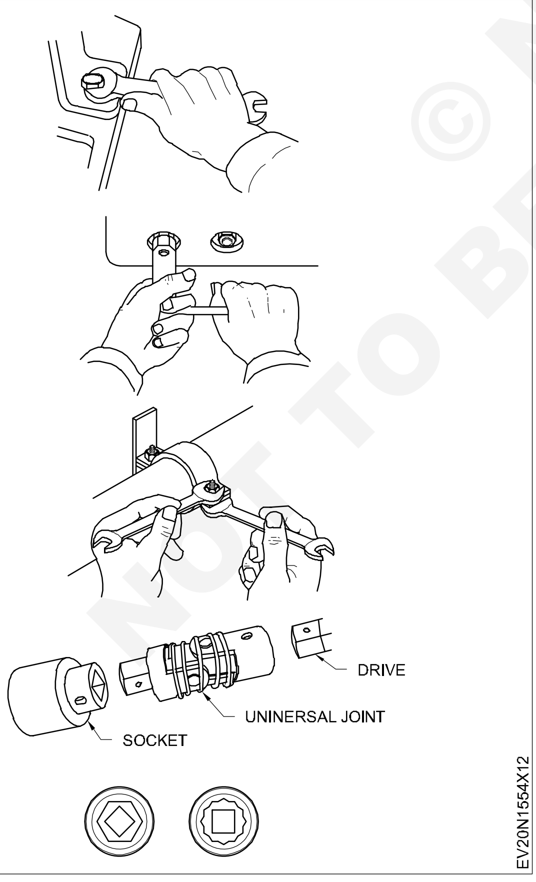


Fig 2



In the unified standard system (Fig.3), the spanners are marked with a number based on the gas requirement decimal equivalent of the nominal fractional size across the flats of the hexagon, following the sign A/F or with

Fig 3

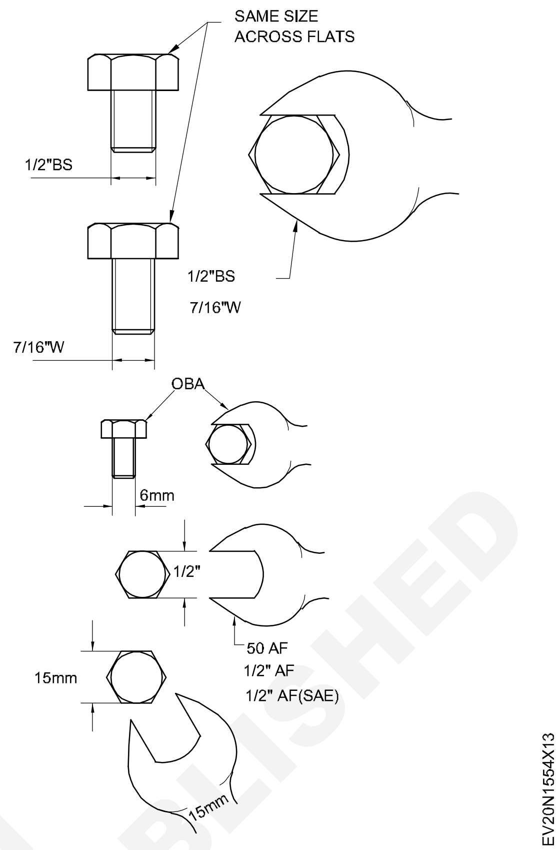
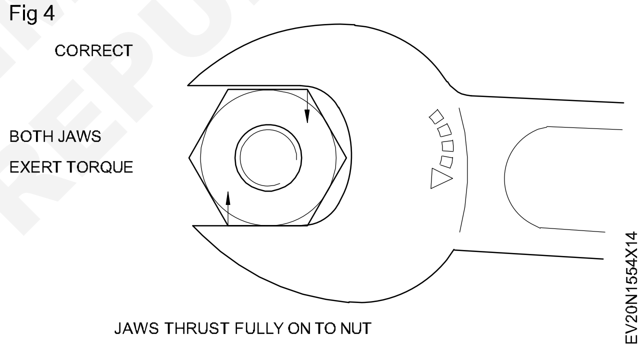


Fig 4



the fractional size across the flats following the sign A/F. In the metric system, spanners are marked with the size across the jaw opening followed by the abbreviation 'mm'.

To fit exactly, a spanner must be:

- of the correct size
- placed correctly on the nut
- in good condition.

Spanners have their jaws slightly wider than the width of the nut so that they can be placed into position easily. Any excess more than a few hundredths of a millimeter clearance could cause the spanner to slip under pressure.

Place the spanner so that its jaws bearfully on the flats of the nut.

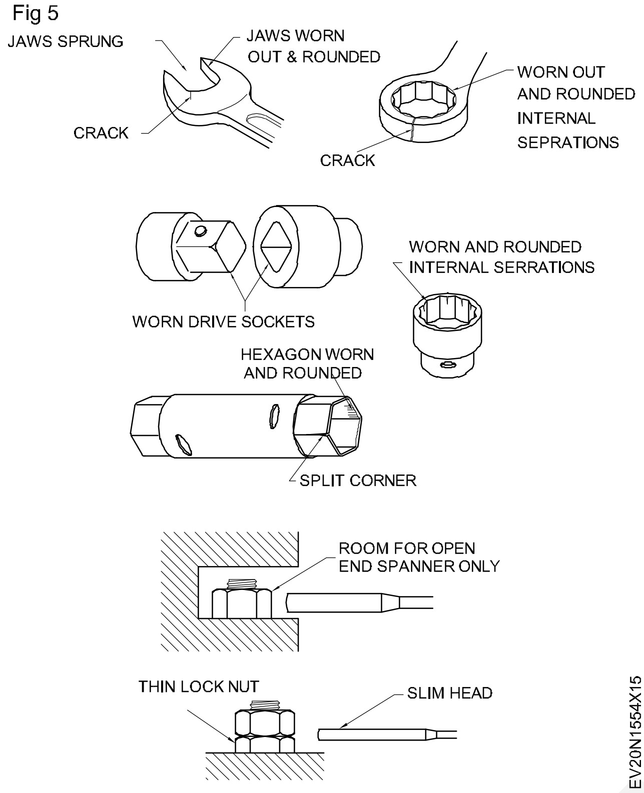
Incorrect use damages the spanners & the nuts too.

Discard any defective spanners. The spanners illustrated here are dangerous for use.

Choose spanners that allow room for use.

Nuts in inaccessible positions may be reached with socket spanners, with special drawing accessories. (Fig 5)

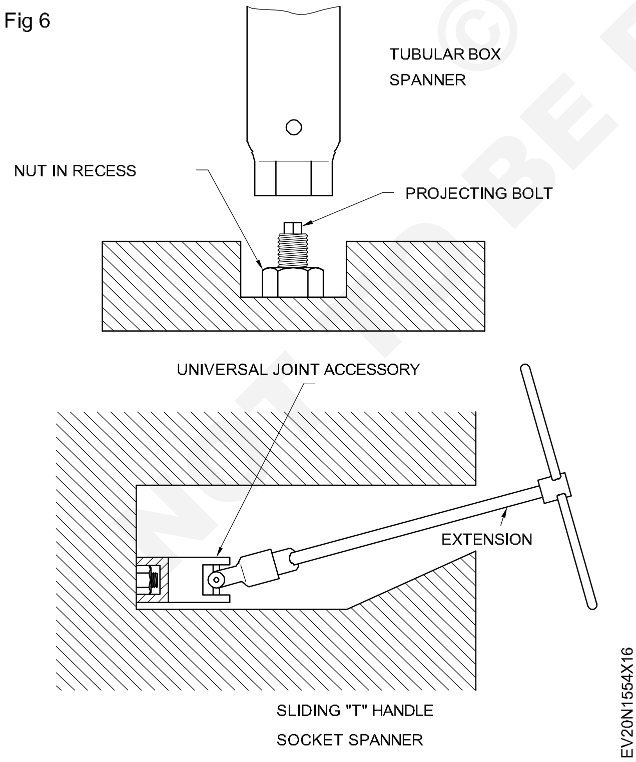
Fig 5



Length of spanners (Fig 6)

Normally spanners have a length that is about ten times the width of the jaw opening.

Fig 6



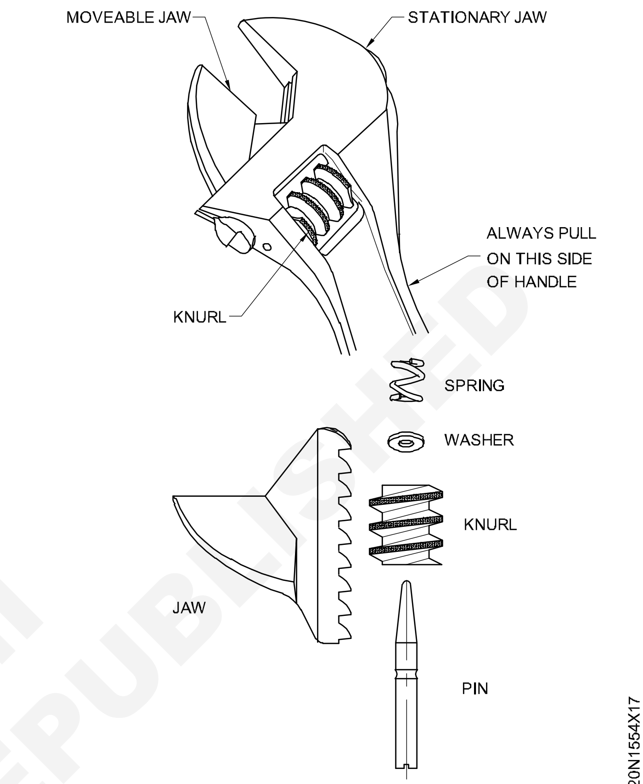
Never exert excessive pull on a spanner, particularly by using a pipe to extend the length of a spanner.

Excess turning effect of the spanner could result in:

- striping the thread
- shearing the bolt
- straining the jaws of the spanner
- making the spanner slip and cause an accident.

Adjustable spanners (Figs 7 & 8)

Fig 7



REPLACE WORN PARTS WITH SPARES

Most common types of adjustable spanners are similar to open and spanners, but they have one movable jaw. The opening between the jaws of a typical 250 mm spanner can be adjusted from zero to 28.5 mm. Adjustable spanners may range in length from 100 mm to 760 mm. the type illustrated has its jaws set an angle of 22 1/20 to the handle. Adjustable spanners are convenient for use where a full kit of spanners cannot be carried about. They are not intended to replace fixed spanners which are more suitable for heavy service. If the movable jaw or knurled screw is cracked or worn out, replace them with spare ones.

When using the adjustable spanner follow the steps given below.

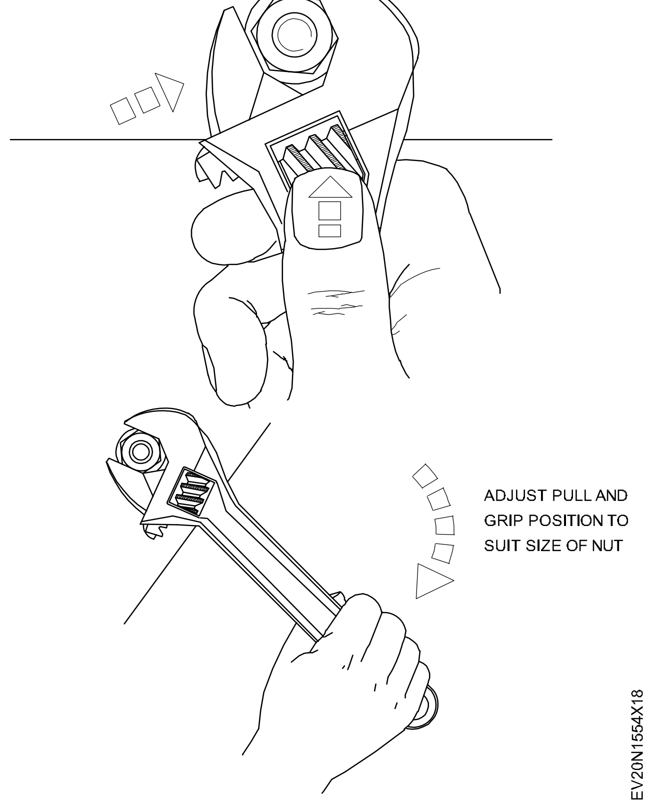
Place it on the nut so that the jaw opening points in the same general direction the handle is to be pulled. In this position the spanners are less liable to slip and the required turning force can be exerted without damage to the moving jaw and knurl.

Push the jaws into full contact with the nut.

Use the thumb to tighten the adjusting knurl so that the jaws fit the nut strongly.

Pull continuously. The length of the handle is designed to suit the maximum opening of the jaws. With small nuts, a very small pull on the handle will produce the required torque.

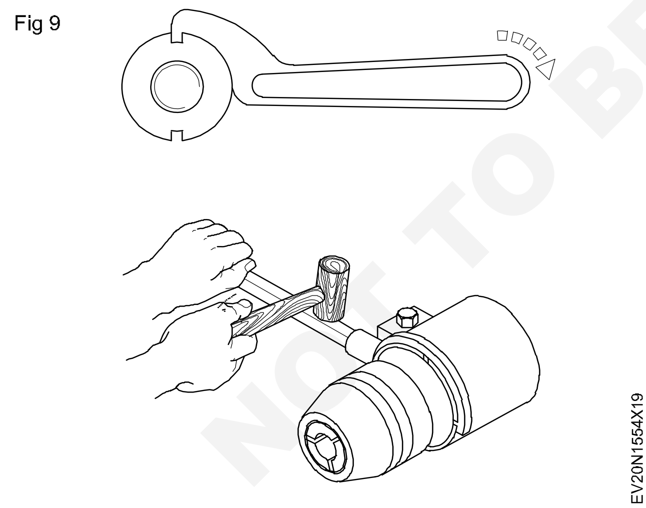
Fig 8



'C' spanners (Hook spanners) (Fig.9)

It has a lug that fits in a notch, cut in the outer edge of a round nut. The 'C' section is placed around the nut in the direction in which it is to be turned. In adjustable hook wrenches, part of the 'C' section pivots to fit nuts with a range of diameters. A set of three spanners is needed to cover diameters from 19 mm to 120 mm.

Fig 9



The applications of 'C' spanners are shown in the figure.

C' Spanners are also used for zero - setting of micrometer.

With socket spanners (Fig 10), use the reversible ratchet handle for doing fast work, where turning space is restricted.

Ring or box spanner (Fig 11): For critical tightening and loosening of nuts. For multi contact on bolts and nuts.

Fig 10

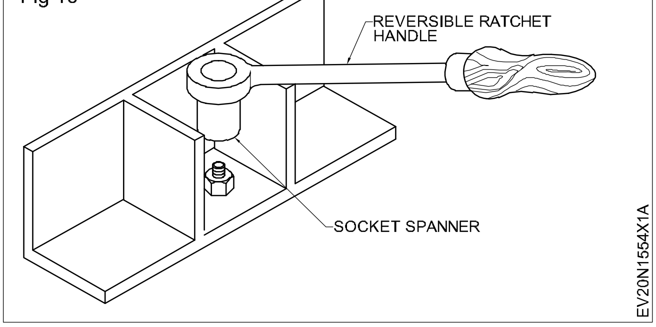
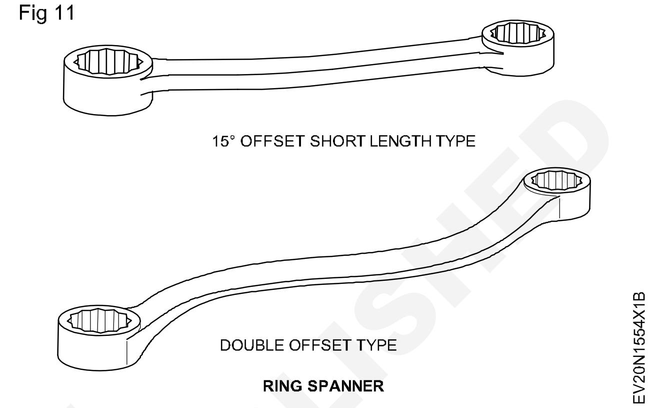
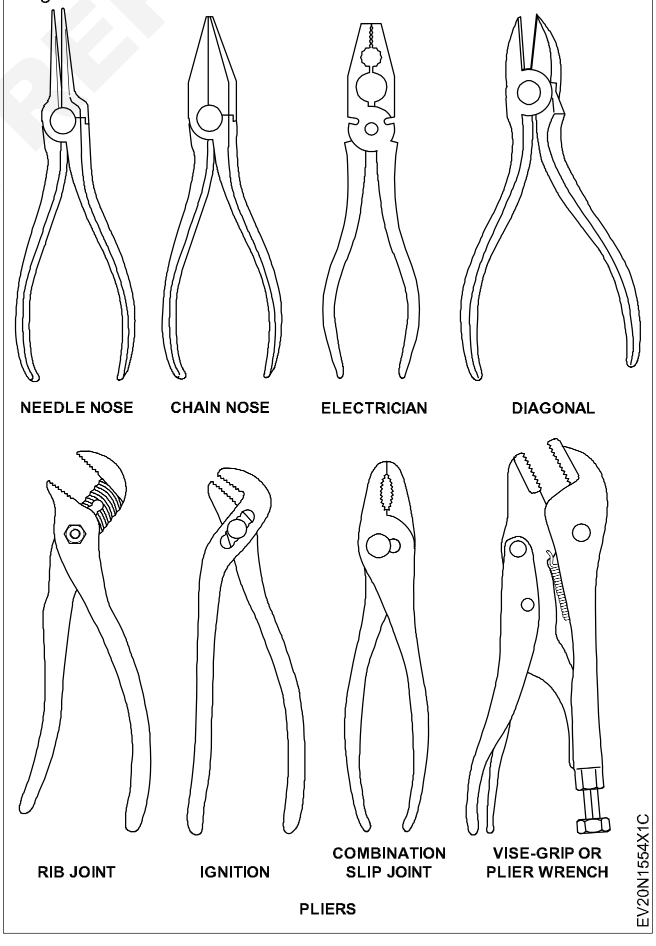


Fig 11



Pliers (Fig.12): Pliers are commonly used for cutting wires, holding parts, crimping electrical connections and bending cotter pins.

Fig 12



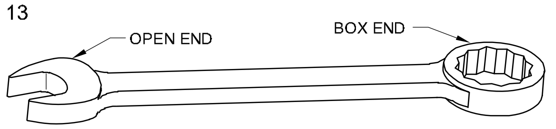
Safety

1 Avoid cutting hardened objects.

2 Never use pliers to turn nuts, bolts or tubing fitting.

Combination of ring and open end spanner (Fig 13): This tool has a box end on one end and an open end on the other. Both ends are of the same size.

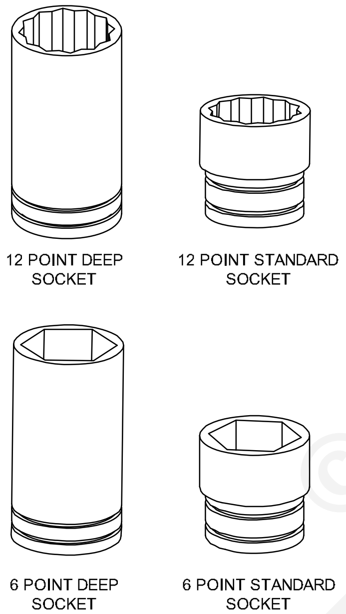
Fig 13



COMBINATION OF RING AND OPEN END SPANNER

Socket spanners (Fig 14): The socket is one of the fastest and most convenient of all the spanners. Sockets come in two sizes; standard and deep.

Fig 14

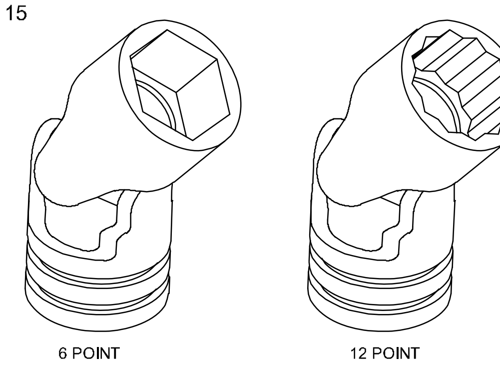


SOCKET SPANNER

Standard sockets will handle the most of the works, while the extra reach of the deep socket is occasionally needed.

Swivel socket (Fig 15): The swivel socket allows the user to turn fasteners at an angle.

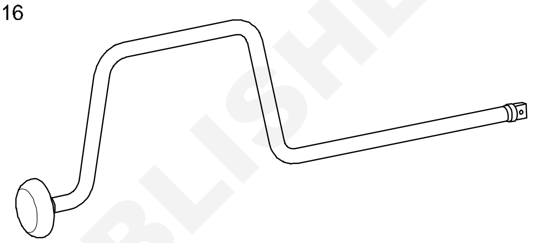
Fig 15



SWIVEL SOCKETS

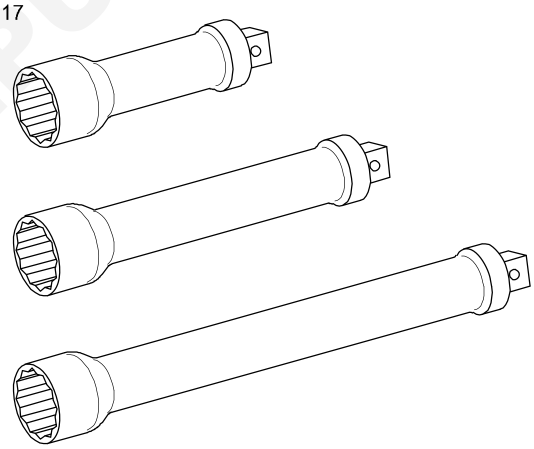
Socket handles: Several different drive handles are used. The speed handle (Fig 16 & 17) is used whenever possible as it can be turned rapidly. and socket extension bar is used with ratchet handle.

Fig 16



SOCKET SPEED HANDLE

Fig 17



SOCKET EXTENSION BARS

Pliers

Objectives: At the end of this lesson you shall be able to
- **state the features of pliers**
- **state the uses of pliers.**

Features

Pliers have a pair of legs joined by a pivot, hinge or fulcrum pin. Each leg consists of a long handle and a short jaw.

Elements of pliers with two joint cutters (Fig. 1)

(Combination pliers)

- Flat jaw
- Pipe grip
- Side Cutters
- Joint cutters
- Handles

Features

Flat jaw tips are serrated for general gripping.

Pipe grip is serrated for gripping cylindrical objects. (Fig 2)

Cutters are provided for cutting off soft wires. (Fig 3)

Two joint cutters are provided for cutting or shearing off steel wires (Fig 4)

Fig 1

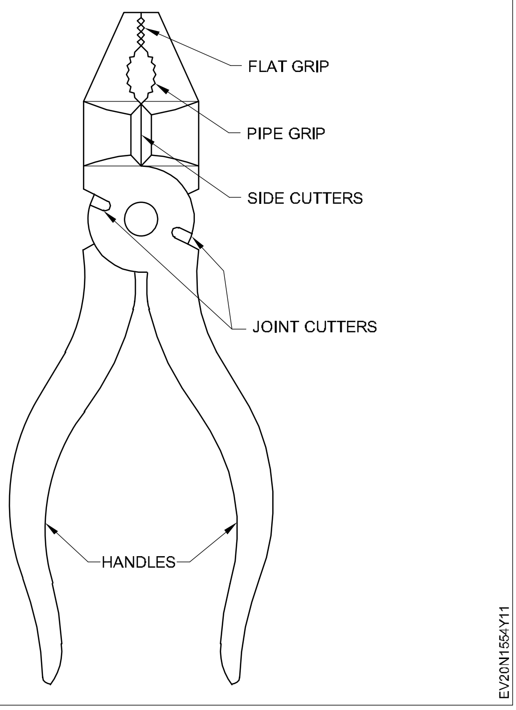


Fig 2

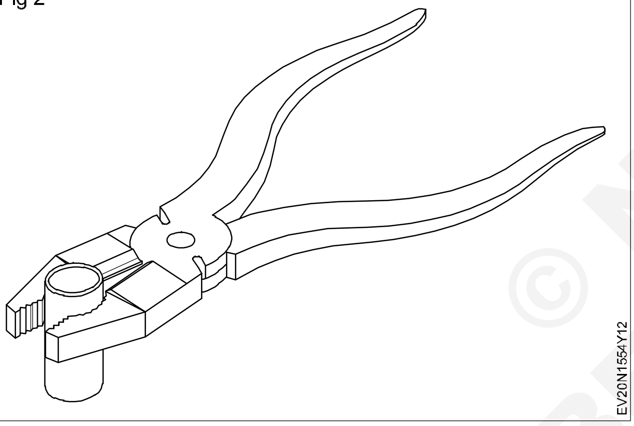
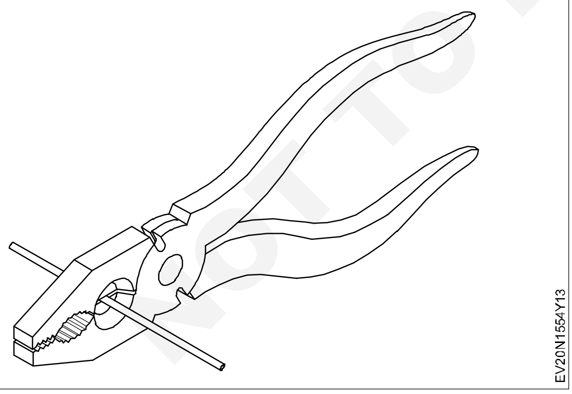


Fig 3



Handles are used for applying pressure by hand.

Pliers are available in sizes from 150 mm to 230 mm. (Size = Overall length)

Other types of pliers

Flat nose pliers

It has tapered wedge jaws with flat gripping surfaces which may be either smooth or serrated. (Fig 5)

Fig 4

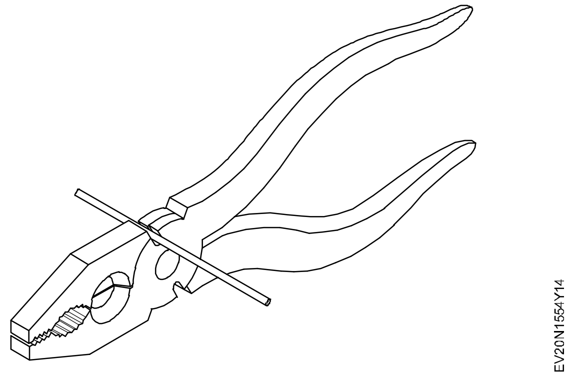
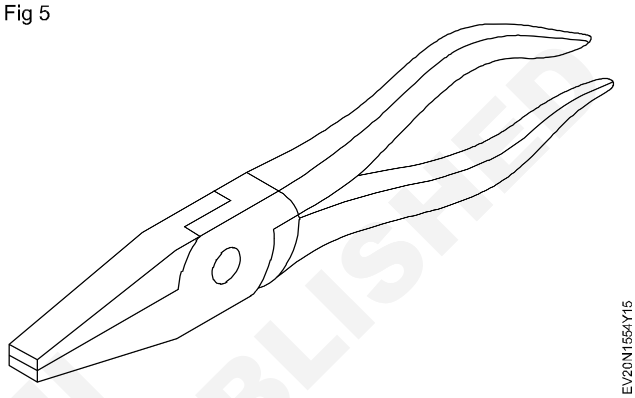
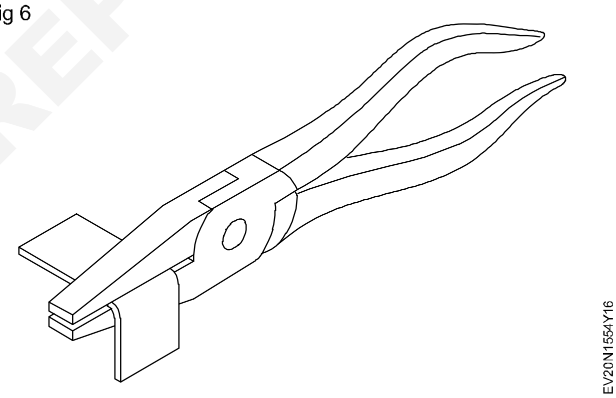


Fig 5



It is used for bending and folding narrow strips of thin (Fig.6)

Fig 6



Roundnose Pliers

This type of pliers is made with tapered round shaped (Fig 7) They are used to shape loops in wires and the form curves in light metal strips (Fig.8)

Fig 7

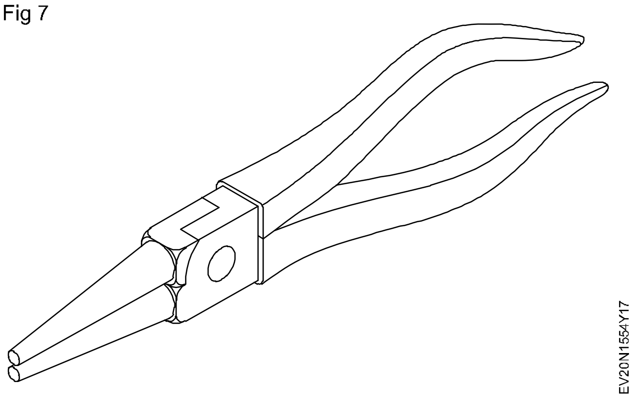
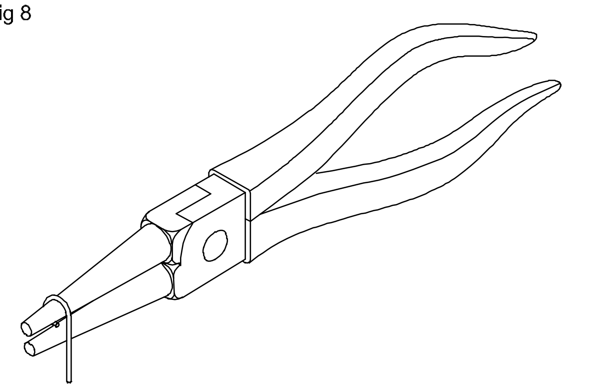


Fig 8

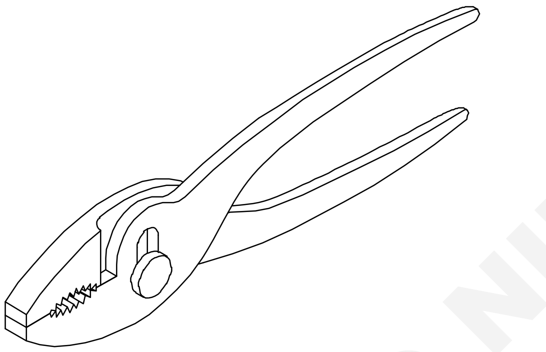


Slip-joint pliers

These pliers are available in various ranges of positions with different shapes of pivot pins so that they have various ranges of jaw opening.

Mainly used for gripping. (Fig 9)

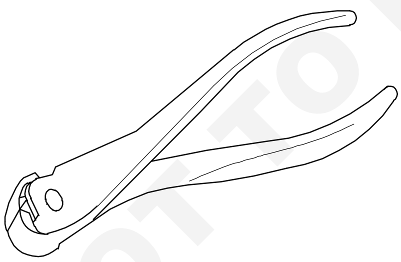
Fig 9



End cutting pliers

These pliers have the same uses as the side cutting pliers. (Fig 10)

Fig 10



Circlip pliers

Circlip pliers are used for fitting and removing circlips in assembly works.

Internal circlip plier

It is used to fit and remove the internal circlip in the groove of the bore. (Fig 11)

Slip-joint, multi-grip pliers

It is similar to the grip pliers but has more openings in the legs. It gives a range of jaw openings. It allows parallel gripping by the jaws in a number of positions. (Fig 12)

Fig 11

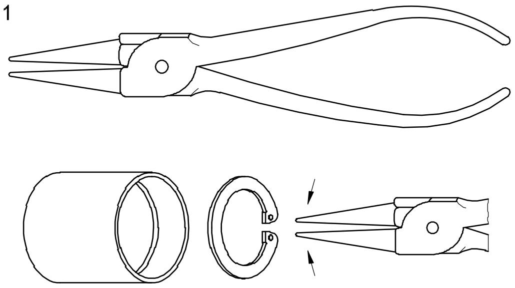
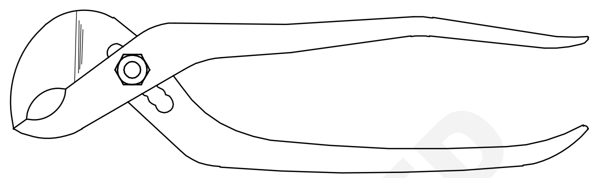
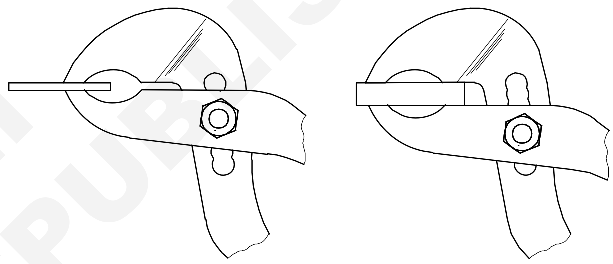


Fig 12



The shape and length of the leg are different from those of the slip-joint pliers. (Fig 13)

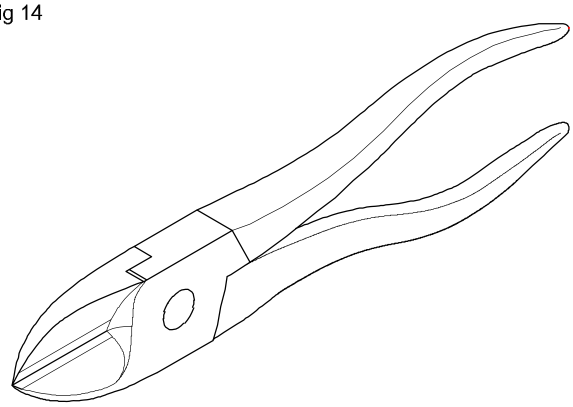
Fig 13



Side cutting pliers

It is made with jaws set at an angle. (Fig 14)

Fig 14



They are used for shearing off wires in confined spaces and cutting off wires close to the surface level. (Fig.15)

They are also used for spreading the cotter pin. (Fig 16)

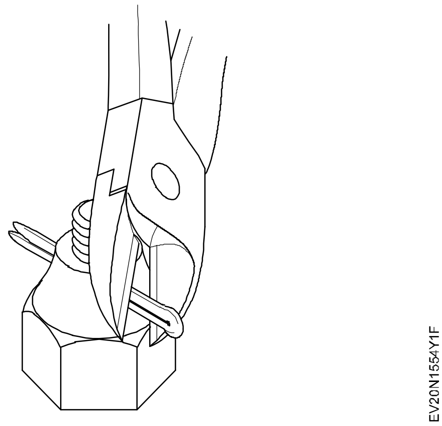
External circlip pliers.

External circlip pliers are used to fit and remove the external circlip in the grooves of the shafts.

Locking pliers

The locking lever of the locking pliers is attached with a movable handle which clamps the jaws on to an object of any shape.

Fig 15



It has high gripping power.

The screw in the handle enables adjustment of the lever action to the work size.

SNIPS (Straight & Bent)

Objectives: At the end of this lesson you shall be able to
- **state the uses of straight and bent snips**
- **state the features and use of lever shears**
- **state the uses of circle cutting machines.**

A snip, also called a hand shear and it is used like a pair of scissors to cut thin, soft metal sheets. Snips are used to cut sheet metal upto 1.2mm thickness.

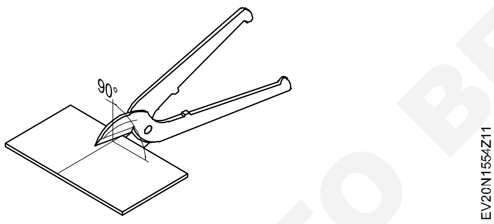
Types of snips (shears)

There are several types of snips available for making straight or circular cuts, the most common being straight snips and curved snips.

The choice of shears (snips) depends on the shape and type of the cut required.

Straight snips (Figs 1& 2)

Fig 1

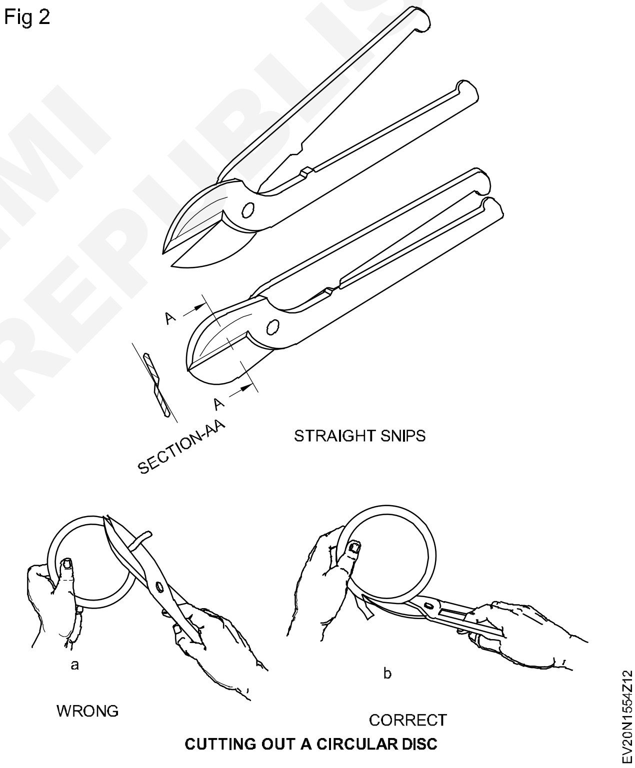


These are used for making straight cuts and large external curves.

Straight snips have thin blades which are only strong on a vertical planes. They are, therefore, only suitable for straight cuts and external curves when surplus waste has to be removed.

While cutting, the blade of the snips should not cover the marking.

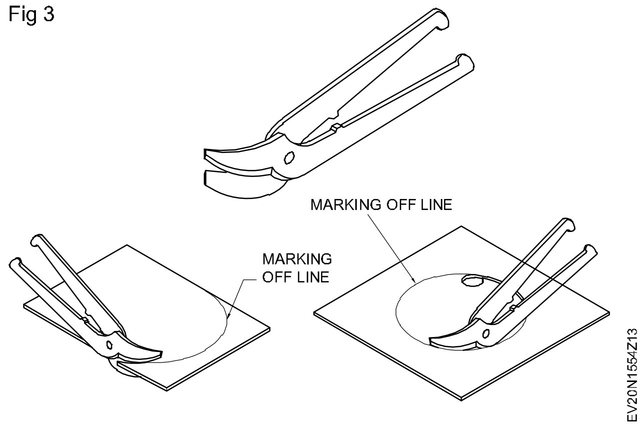
Fig 2



Bent snips (Fig 3)

These snips have curved blades for making circular cuts. They are also used for trimming cylindrical or conical work in sheet metal.

Fig 3



Snips are specified by the overall length and the shape of the blade.

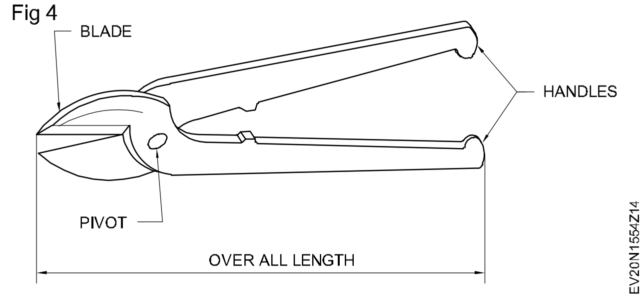
Example

200mm straight snip (Fig 4)

Screw Extractor: is a tool for removing broken or seized screws. There are two types one is spiral flute another is straight flute structure. It is made of hard, brittle steel, while applying twisting torque with screw extractor upon the broker screw, enter and bring out.

Nipper is a tool to 'nip' or remove small amount of hard material such as pieces of tiles which need to be fitted around an odd or irregular shape. Nipper is used to in railway line.

Fig 4



Wrenches

Objectives: At the end of this lesson you shall be able to
- **name the different wrenches used**
- **state the features of each type of wrenches.**

Types of wrenches

- Stillson pipe wrench
- Footprint pipe wrench
- Tension wrench
- Hexagon socket wrench

Stillson pipe wrenches (Fig 1 & 2)

Fig 1

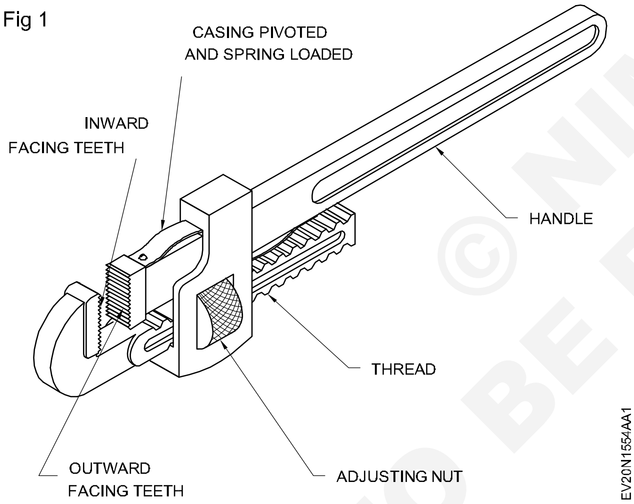
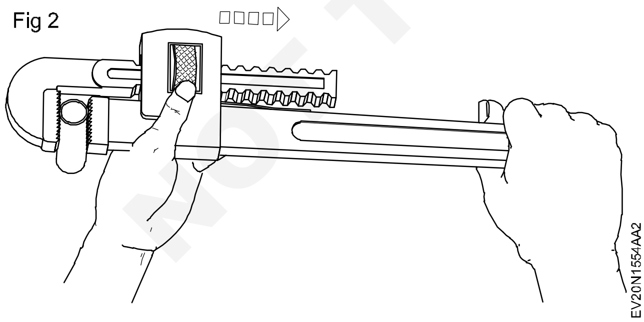


Fig 2



These are used for gripping and turning pipes of a wide range of diameters.

The parts and their names are shown in the

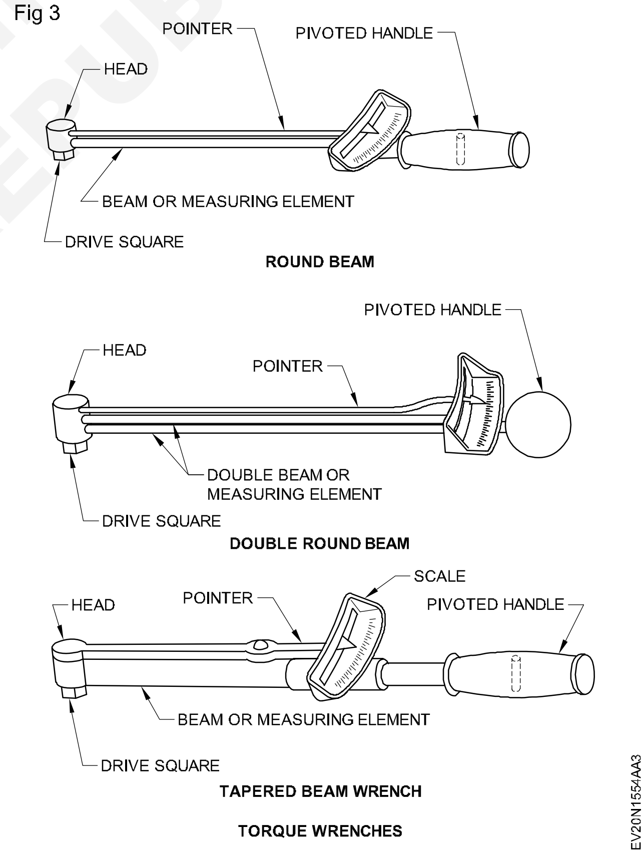
A jaw is fixed to the handle with outward facing teeth. Attached to the handle by a pivot pin is a spring-loaded casing that carries a knurled adjusting nut. This engages with a thread on the adjustable arm of a jaw with inward facing teeth.

Once the jaws are adjusted, the spring loading keeps them in contact with the work, and the toggle action causes the hardened serrations to bite into the work.

The jaws will mark the work. File off any burrs. Never use them on polished or plated surfaces. Never grip hardened materials with this type of wrench as this will damage the serrations.

Torque wrench (Fig 3)

Fig 3



A torque wrench is necessary to tighten bolts, nuts etc. To the exact torque as specified by the manufacturers. Excessive tightening may lead to breakage of the fast tener/parts and loose tightening will lead to leakage/ breakage during operation. Torque wrenches are available in special shapes and sizes. Selecting the torque wrench of the appropriate size and range is very important. Torque wrenches are available in pound feed (lb-ft), pound inch (lb-in), kilogram metre (Kg-m) kilogram - centimetre (Kg-cm) and Newton metre (N-m). Newton metre is the preferred metric unit, although others are still used by the manufactures.

To convert pound feet to kilogram-metres by 0.138 and to convert to Newton-metres multiply the pound feed by 1.35.

Dial type

It has a scale and the torque can be read directly.

Brake over (Micrometer)

It contains a micrometer scale (1) on the handle and a ratchet head (2). In this the torque can be set on the micrometer scale (Ref.job sequence). (Both pound-feet and metric scales are marked on the graduated barrel). The wrench makes a metallic 'click' that is heard and felt on the handle when fasteners are tightened at the correct.

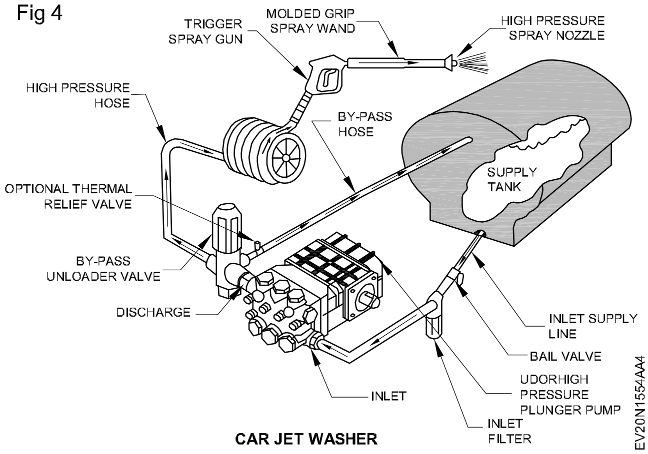
Torsion bar torque wrench

Its gauge is a simple pointer (3) that moves across a graduated scale (4) which shows the amount of torque being applied.

Digital read out torque wrenches are also available.

Car jet washer (Fig 4)

Fig 4



CAR JET WASHER

- Car jet washer is used to clean the interior and exterior of motor vehicle different type of car washer are available in the market
- It is also used for pressure wash the auto mobile employments in workshop
- Car jet washer is used for cleaning the dirty floor and wall of floor mates
- It is also used is ear service station for commercial purpose

Flaring, flare fittings and testing the joints

Objectives: At the end of this lesson you shall be able to
- **illustrate necessity, types of flaring methods**
- **list the types and applications of flare fittings**
- **pressures the joint system and test for leaks.**

Flaring necessity: When connecting tubing to fittings, it is common practice to flare the end of the tube and to use fittings designed to grip the flare for a vapour tight seal. Special tools are used for making flares.

Types of flaring: There are two types of flaring

Single thickness flare

Double thickness flare

Single thickness flare: It can be made on smaller size copper tubing (Fig.1)

Double thickness flare: Double thickness flares are recommended for only the larger size tubing 5/16 inch (9mm) OD and over. Such flares are not easily formed on smaller tubing. The double flare makes a stronger joint than a single flare.

Pressurising the joint on tubing: A flared joint or brazed joint needs to be tested for its firm. If it leaks while working it will put the whole system into problem. Before putting the joint into a system after it is made pressure test must be done.

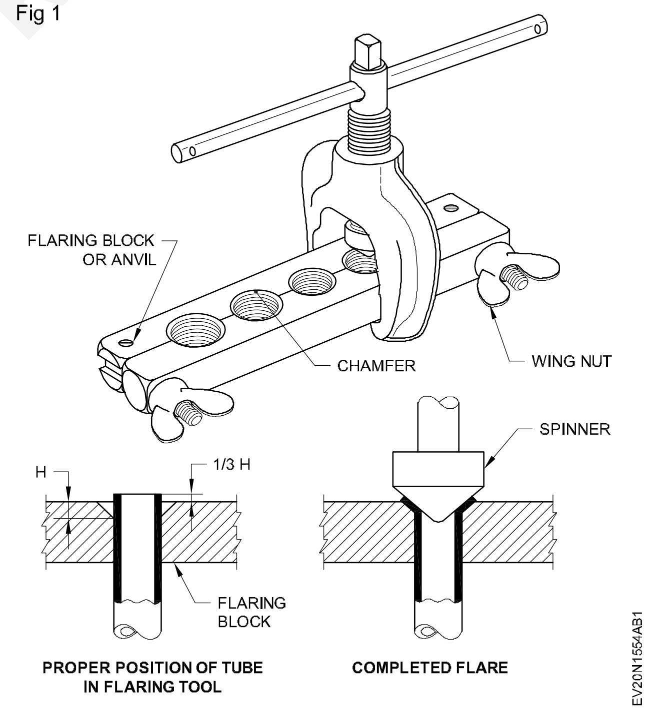
Air pressure from

Air compressor - 150 PSI

or - 10Kg/cm2

The gas which is employed can be used for testing.

Fig 1



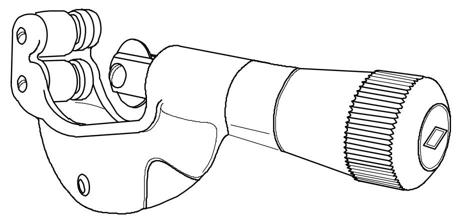
Leak can be detected with the use of soap solution. There are also other methods for leak detection.

Pressure tests are usually made on the joints above the working pressure.

A pipe cutter is more convenient and better than a saw when cutting pipes and metal tubing. (Fig. 2)

The sharpened wheel does the cutting as the tool turns around the pipe, the screw increases the pressure, driving the wheel deeper and deeper through the pipe until it finally cuts right through.

Fig 2



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Puller

Objectives: At the end of this lesson you shall be able to
- **state the function of puller**
- **state the types of puller.**

Puller

The puller is a General Workshop tool which is used to remove Gears, bearings pulleys, flanges, bushes.

The puller is made out of steel material, generally with two or three legs and they are adjusted to hold the outside of the gears or bearing sleeves while the central threaded shaft is screwed forward exerting force on the gear/bearing. This enables to remove the bearing without damaging the shaft.

Pullers are classified according to the application and the number of leg.

Another classification is based on the power utilized i.e. Mechanical puller and Hydraulic puller.

Two legs puller is generally used for removing the gears. Where as puller with three legs are for removing pulleys. flanges and bearings. It is also called gear puller. Special pullers: These are mainly used for specialised application such as crank shaft bearing removal brake drum, removal pilot bearing removal.

Hydraulic puller: These pullers eliminate time consuming and unsafe hammering, heating or prying. Damage to past is minimised through the use of Hydraulic. pullers.

Safety

To avoid personal injury during system operation,

Always wear proper PPE gear

never use a tool to strike a puller

make sure that items are pulled is well and adequately supported

do not apply heat to a puller

before every use lubricate the centre bolt threads, with graphite - based lubricant

use puller only with recommended attachment

do not over load a pulley which may cause to break

> **Important: Always keep the guide parts of the lifting plate greased.**

Hydraulic pullers are designed to help you extend bearing life in your applications through proper installation, removal and service.

Hydraulic pulling systems are available with capacity ranging from 4 tons to 30 tons, and are ideal for removing all kinds of shaft filled parts.

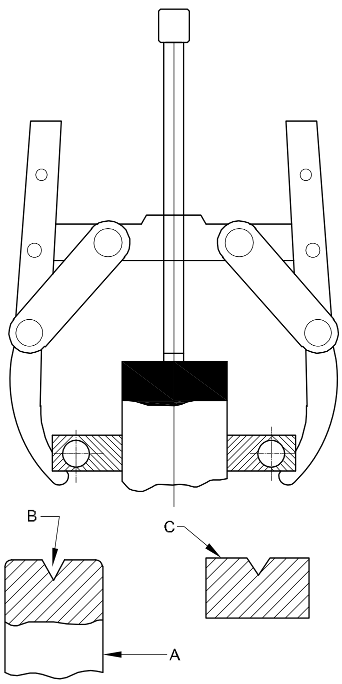
Hydraulic pulling system comprises of integrated pump. cylinder, hose, puller with safety-release valve. The pullers have self-contained hydraulic pump and are compact, handy. There are ideal for pulling variety of press-fit parts including bearing, wheels bushings, gears, pulleys.

In Automobiles Hydraulic Puller especially used for marine engine liner from the cylinder block during engine Reconditioning Work.

Mechanical Puller Operation (Fig 1)

1 Ensure that the spindle is clean and applied grease before use.
2 The Shaft (A) must have a center hole (B) as shown in the figure. If it does not, use a shaft protector (C) as shown in (Fig.1)
3 Tighten strap bolts to hold jaws lightly in place
4 Position the puller that the spindle as shown in fig 2.

Fig 1



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5 Tighten the spindle slightly by turning the spindle nut with proper wrench

6 Check that the jaws are fully contacting the part to be pulled.

7 Tighten the strap bolts.

8 Apply pulling force by turning the spindle.

Post lock puller operation (Manual pullers) (Fig 2)

1 Make sure that all items being pulled are supported by a means other than the puller. NO LOOSE PIECES!!!

2 Before each use, lubricate the center bolt of the puller with a graphite-based lubricant.

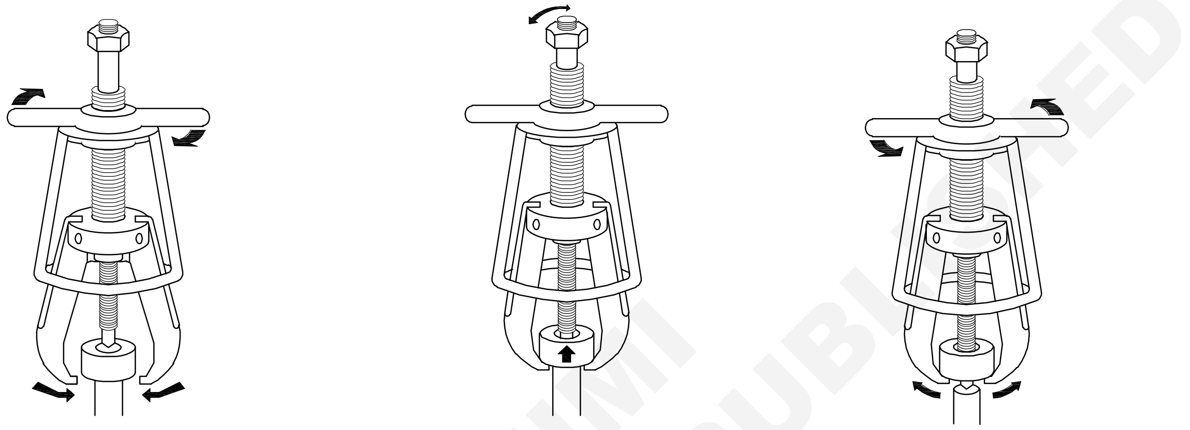
3 To operated the puller, grasp the puller with one hand and turn the T-handle counter-clockwise with the other hand until the jaw opening is big enough to fit over the component to be pulled.

4 Turn the T-Handle clockwise with the other hand until the jaw firmly onto the component. (Fig.2A)

5 Make sure that the center of the puller is aligned with the center of the component to be pulled. Using hand tools only, tighten the center bolt to pull the component off of its shaft. Never exceed the maximum torque ratings of the puller's drive bolt. (Fig.2B)

6 Turn the T-handle counter-clockwise to remove the puller from the component. (Fig.2C)

Fig 2



Air impact wrench, air ratchet and other power tools

Objectives: At the end of this lesson you shall be able to
- **explain the use of air impact wrench**
- **explain the working principle of air impact wrench**
- **state the features of power tools.**

Air powered wrenches: Air-powered wrenches involved threaded fasteners can be done faster and easer with air powerd wrench. There are two types of wrenches. (1) Impact wrench (2) Air ratchet wrench.

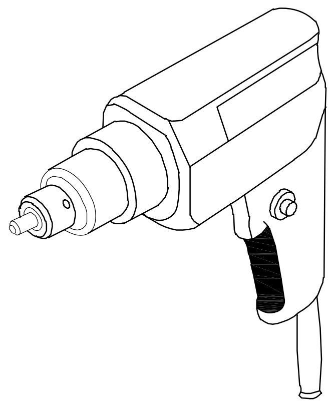
Impact wrenches: An impact wrench is a portable hand held reversible air powered tool for rapid turning of bolts and nuts impact wrench output shaft spins freely over 2000 rpm. The socket snaps over the sqyare drive head and shaft when using an impack wrench, it is important that only impact sockets and adopters be used. Air impact wrenches work regularly well for tightening and loosening. The rotation of wrench is controlled by a switch or two way trigger. Remember not to change the direction of rotation while the trigger swtich is ON.

Air impact wrench (Fig 1)

Air Impact Wrench (also known as an impact or, Air Rattle Gun windy gun), Air wrench is a socket wrench power tool, which is used to deliver high torque. It works by storing energy in rotating mass and suddenly delivering it to output shaft.

Compressed Air is commonly used as the power source. Electric power can also be used as the source of power. cordless Electric devices are also used, and are very popular due to ease of working.

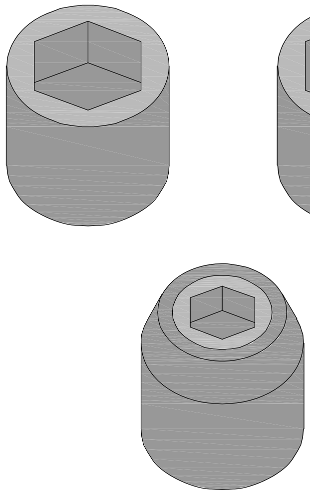
Fig 1



The Air impact wrench is to be used along with a specially hardened impact socket extension and joints to withstand sudden force.

Generally a special 6 inch pin socket is used with air impact wrench. (Fig 2)

Fig 2



Air Ratchet

Air ratchet wrenches: It is like the hand ratchet its angle drive reaches in and spins fasteners where other hand or power wrenches just cannot work. The air ratchet looks like and ordinary ratchet but it has a thicker hand grip that contains the air vane motor and drive mechanism.

An Air Ratchet is a quite identical to General ratchet wrench.

It is also having square drive at different sizes.

The socket drive is turned by a Air Motor. When we pull the trigger, Air motor gets activated it turns the socket drive.

The direction of socket drive can be changed to clockwise (or) anti clockwise as per the user requirement.

Air Ratchet operates with more speed unless torque. In case where more torque is required we should use Air impact wrench.

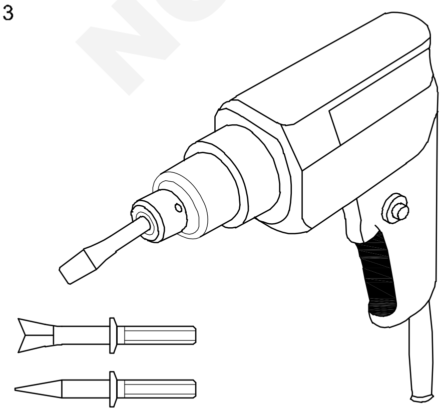
Air Chisel (Fig 3)

Air chisel is used for cutting the bolts to nuts of vehicle body sheet.

The compressed Air provides more force and much efficient than a hand chisel and Hammer.

Air chisel can be used with different types of chisel kit, depending upon the job.

Fig 3



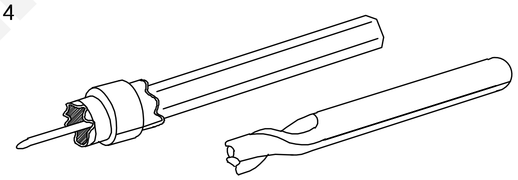
Maintenance of pneumatic tools: Air tools maintenance is need to up keep the air tools in service.

- Lubricate the air tools periodically (Don't use motor oil)
- Squirt a couple of drops of oil into the oil inlet holes on the tool before and after use. This will prevent repid wear and rusting of the tools.
- Runs the tool after lubricate the oil
- Wipe the excess oil off to the tool to keep it from the body parts.
- Use in-line oiler attachment that will automatically meter the oil into air lines for air tools.
- Don't use the inline oiler's in the paint area.
- Don't use excess lubrication oil on air tools that excess oil could be spoiled the vehicle's surface with oil.

Air drill: Air drill is used an air pressure to spin a drill bit. Air drills are smaller and lighter than electric drills. It is very easier to use for most tasks, especially for drilling operations in auto body repair works.

Spot weld remover air drill (Fig 4): Air drill attachment that are used for cutting out spot welds. When cutting out the spot weld the drill can be fastened to the weld are a with a clamp attachment that makes operation easier. The cutter drill bit will not deviate from the weld center during cutting. These are two types of spot cutters available that can be mounted in an air drill for cutting out spot welds. So work finishing is easy and very smooth as desired.

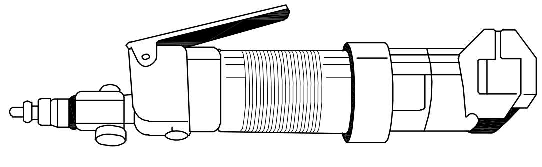
Fig 4



SPOT WELD CUTTER

Spot weld cutter drill hole saw type (Fig 5): Air drill hole saw type cutting depth can be adjusted. So that the bottom panel is not damaged. It is necessary to sand off the remaining portion the weld.

Fig 5



AIR BENCH

Vacuum cleaner: Vacuum cleaner is used for removing dust and debris from the vehicle interior. It is the first tool used when a vehicle comes in for refinishing work. Vacuum cleaner will greatly reduce the chance of dirt getting into the complete refinishing job.

Power washer: Power washer can be used in exterior cleaning, under carriage, shop degreasing and cleaning of the vehicle. Before using a power washer, check the personal and machine safety.

Hydraulically powered shop equipment: These type of equipment are used on oil like liquid called hydraulic fluid. These equipments operate by hydraulic oil pressure achieved by manually pumping on a handle or lever to build up the fluid pressure or motor by electrically provides the fluid pressure needed to force the hydraulic fluid to the equipment cylinder. The cylinder then causes the tool to operate when a button or lever is turned ON.

Never work under vehicle supported by hydraulic Jack place the jack stands under the vehicle before working under chassis of the vehicle.

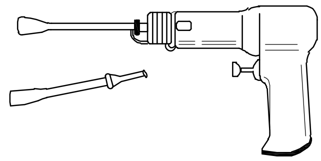
Hand or bottle Jacks: It is tubular shaped and perform a variety of functions and range from 1 1/2 tons of lifting capacity. They are useful when a service jack is too much.

Service jacks: It is a four wheeled jack with a pump handle are by far the most commonly used jack in the body shop. Its lifting capacity is 1 ½ ton to 5 ton these jacks are easily dollied around the shop. This jack is intermediate, compact to use.

Air chisel (Fig 6): Air chisel is used for various driving and cutting operations of auto body repair. Different types of chisels or blade can be installed in the air chisel body to complete various auto body repair tasks.

When you are using the air chisel, position the tool by starting slowly, then increasing power. Avoid running into hardware frames and so forth, with sheet metal cutting tools. Check the chisel shanks periodically and keep the cutting sharp when you are using a air chisel wear thick gloves, a face mask/shield and hearing protection during power cutting metal.

Fig 6



AIR CHISEL

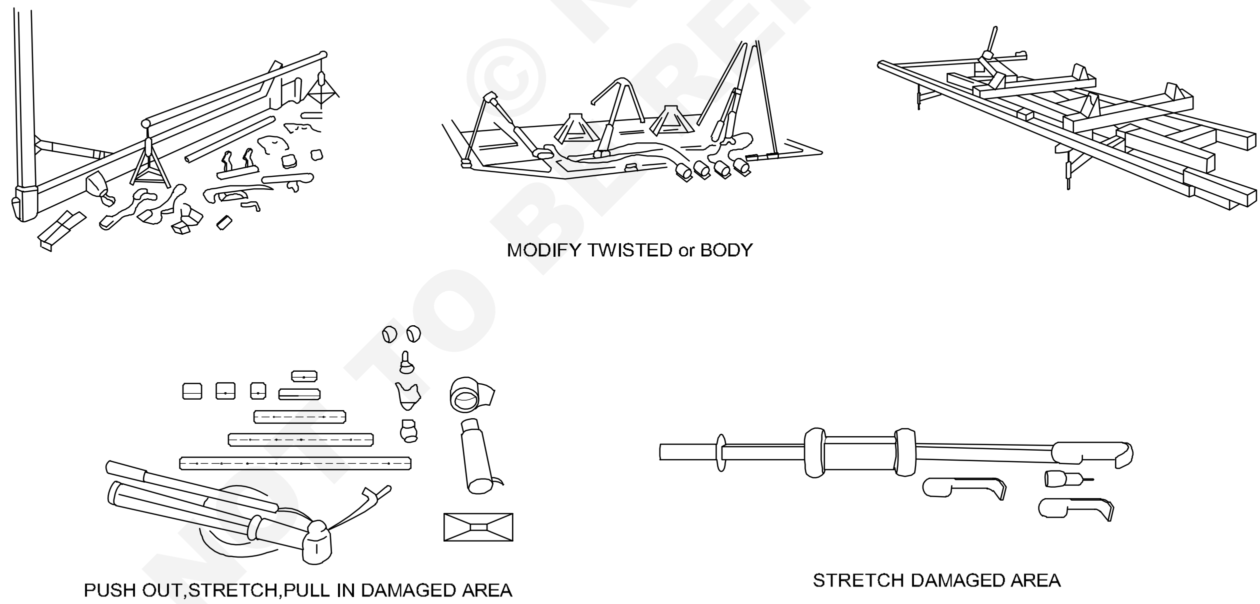
Transmission jacks: It is used to remove the transmission, engine or drive train from the unibody before servicing a repair. This jacks lifting capacity ranges from ¼ to 1 ton. (Fig 7)

Frame jacks: Power portable frame jack is a hydraulic hand pump and ram the minor body and frame straightening operations. These jacks are used to perform the many different straightening operations involving pushing pulling or holding a panel to align metal, a large assortment, of attachments can be obtained.

Hydraulic tool maintenance: Hydraulic tools preventive maintenance. Avoid failure at a critical moment.

- Hydraulic tools should be lubricate properly.

Fig 7



FRAME JACKS

- Use the SAE 30 - lubricate oil the moving parts include the moving mechanism, pump roller, universal joint, handle socket, pivot pins, wheels and bearings.
- Be sure to grease the fittings and sliding points used in pumping.
- Avoid over filling a hydraulic oil in a tool.
- Make sure the system and ram are fully retracted so oil pressure has been released.
- Remove air spongy effect in hydraulic system.
- Maintain the correct level of fluid in hydraulic tools circuit.
- Arrest the leaks under fluid pressure and air pressure in the circuit.
- Check and ensure the proper function of valves provided in the air and hydraulic circuit.
- Ensure the proper function of hydraulic tool operating system.

Hydraulic lifts: It is used to raise the whole vehicle in the air for easier working. The traditional stationary in the ground unit is used in car service station, dealers, repair shops and auto body repair shop. Hydraulic lifts are used lift off the vehicle from ground to estimate and repair the vehicle easier.

There are several ways to get a vehicle off the ground by four post and two post hoists. The using of lifts is a much less physical and mental task on the body of technicians. The quality of lifts provides the number of safety devices on each model, makes them safe to operate.

Maintenance on above ground lifts is minimal, but important depending on the lift, pulling, pivoting lift, links and wheels should be greased. Bearings, pins, and other moving parts should be oiled, and cables and chains should be checked for worn or frayed areas following the manufactures directions.

General maintenance on lifts includes inspecting the lift pods and bumbor cushions regularly and replacing them if of necessary.

Engine crane: An engine crane uses hydraulic power to raise heavy power trains from a vehicle during major repairs. The engine and transmission may have to come out to replace frame rails or other structural panels. The engine crane has a large lift arm that can be raised by pumping the handle on the hydraulic cylinder. The ram will then extent to lift the aim and any assembly attached to engine.

Power tools

Air powered tools: Air power tools are driven by compressed air supplied by an air compressor. Pneumatic tools can also be driven by compressed carbon dioxide (Co2) stored in small cylinders allowing for potability.

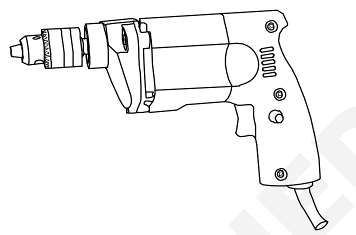
Advantages of air powered tools: Pneumatic tools have many benefits, which have contributed to their rise in popularity. The advantage and disadvantages of using compressed air to power tools are

Advantages	Disadvantages
Inexpensive	Air power tools required larges up front cast
Safe to use	Air tools themselves are usually less expensive than their counter parts
Easy to operate	Air compressors are an expensive and unavoidable up front cost for pneumatic tools
Portable	Pneumatic tools are lighter and stranges
Low theft rate Low maintenance cost	Pneumatic tools are lighter and stranges

Air drill (Fig 8): Air drills are used the shop air pressure to spin a drill bit. They can be adjusted to any speed and are more commonly used than electric drills. They are usualy available in many sizes. Air drills are smaller and lighter than electric drills. Their compactness makes them a great deal easier to used for most tasks, especially for drilling operations in auto body work. Drill bits of different sizes for into the chuck on drills for making holes in parts drill bits comes in various sizes. The drill size is usually stamped on the upper part or shank of each drill bit.

A key is used to tighten the chuck. The chuck has movable jaws that close down and hold the bit. The key has a small gear that turns a gear on the chuck. Never leave a key in a drill when not tightening. Always unhook the air hose when installing a bit to prevent injury.

Fig 8

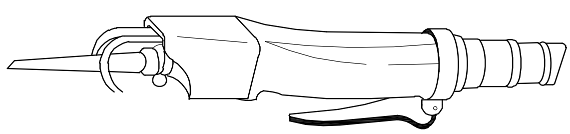


Air screw driver: Air screw driver is a portable, hand held, reversible air powered tool for effective rapid turning of screws and nuts. When triggered the output shaft spins freely over high rpm. When using an air screw driver it is important that only suitable screw driver be used make certain air screw drivers are clearly marked or labeled for use with air screw drivers. An adjustable air regulator is part of most penumatic impact screw driver. Turning the air control knob allows to adjust the tools speed and torque. To remove conventional threaded fasteners set the switch for left hand counter clock wise rotation place a screw driver over the fastener screw head. Exert forward pressure on the screw driver, while deprassing the trigger switch. As soon as the fastener screw becomes loosened, relax the forward pressure on the wrench to let it spin the fastener screw free, do not use and air impact screw driver for final torque fasteners. When important fluid torque should be done by hand. This will prevent broken fasteners. Air screw driver run cool will not burn out even under constant use. They are designed to perform will in wide variety of applications.

- machine screws in tapped holes
- soft tapping screw in plastic
- sheet metal screws
- self drilling screw and thread forming screw in blend die-cast holes

Air saw (Fig 9): An air saw uses a reciprocating action and hacksaw type blade used to quickly cut through metal. An air saw is handly, when using an air saw, do not apply to much pressure to the blade. Otherwise it will heat the saw teeth and dull the black.

Fig 9



AIR SAW

Electrical terms

Objectives: At the end of this lesson you shall be able to
- **describe electrical charge, potential difference, voltage, current, resistance**
- **explain about DC and AC circuit**
- **explain single phase and 3 phase A.C. system**

Electric charge

Charge is the basic property of elementary particles of matter. **charge** is taken as the basic electrical quantity to define other electrical quantities such as voltage, current etc.

According to modern atomic theory, the nucleus of an atom has positive charge because of protons. Generally, when the word **charge** is used in electricity, it means excess or deficiency of electrons.

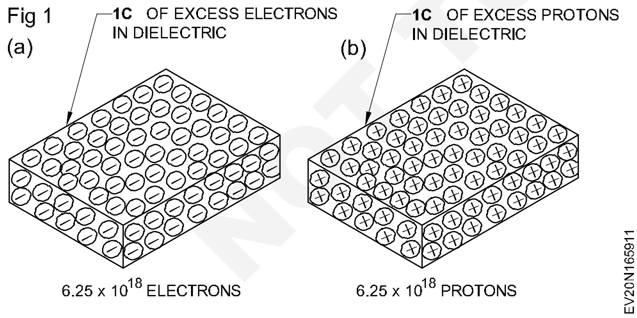
Charges may be stationary or in motion. Stationary charges are called **static charge.** The analysis of static charges and their forces is called **electrostatics.**

Example: If a hard rubber pen or a comb is rubbed on a sheet of paper, the rubber will attract paper pieces. The work of rubbing, resulted in separating electrons and protons to produce a charge of excess electrons on the surface of the rubber and a charge of excess protons on the paper. The paper and rubber give evidence of a s**tatic electric charge** having electrons or protons in a static state i.e. if it is not in motion or stationary charges.

The motion of charged particles in any medium is called **current**. The net transfer of charge per unit time is called current it is measured in **ampere.**

Charge of billions of electrons or protons is necessary for common applications of electricity. Therefore, it is convenient to define a practical unit called the **coulomb** (C) as equal to the charge of 6.25 x 1018 electrons or protons stored in a dielectric, as shown in Fig 1.

Fig 1



The symbol for electric charge is Q or q. A charge of 6.25 x 1018 electrons is stated as Q = 1 Coulomb = 1C. This unit is named after Charles A. Coulomb (1736-1806), a French physicist, who measured the force between charges.

NEGATIVE AND POSITIVE POLARITIES

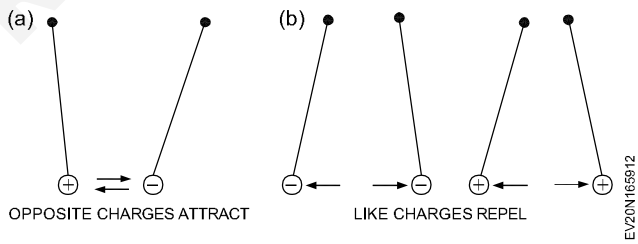
Negative polarity has been assigned to the static charge produced on rubber, amber, and resinous materials in general. Positive polarity refers to the static charge produced on glass and other vitreous materials. On this basis, the electrons in all atoms are the basic particles of negative charge because their polarity is the same as the charge on rubber. Protons have positive charge because the polarity is the same as the charge on glass.

Positive charge is denoted by +Q (deficiency of electrons) and Negative charge is denoted by -Q (excess of electrons). A neutral condition is considered zero charge.

Opposite polarity/charges attract each other

If two small charged bodies of light weight are mounted so that they are free to move easily and are placed close to each other, they get attracted to each other when the two charges have opposite polarity as shown in Fig 2a. In terms of electrons and protons, they tend to be attracted to each other by the force of attraction between opposite charges. Furthermore, the weight of an electron is only about 1/1840 of the weight of a proton. As a result, the force of attraction tends to make electrons move towards protons.

Fig 2



Same polarity/charges repel each other

In Fig 2b, it is seen that when the two bodies have an equal amount of charge with the same polarity, they repel each other. The two negative charges repel, while two positive charges of the same value also repel each other.

Electric potential difference

The electrical potential difference is defined as the amount of work done to carrying a unit charge from one point to another in an electric field of the two charged bodies. In otherwords, the potential difference is defined as the difference in the electric potential.

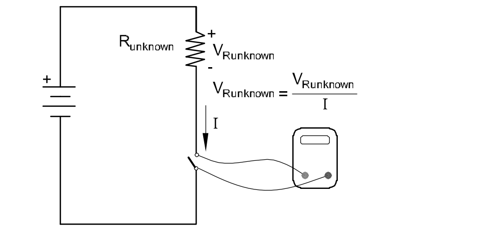
When a body is charged to a different electric potential as compared to the other charged body, the two bodies are said to be potential difference. Both the bodies are under stress and strain and try to attain minimum potential.

Unit: The unit of potential difference is volt.

Resistance (Fig 3)

Resistance is the measure of opposition to electric current. A short circuit is an electric circuit offering little or no resistance to the flow of electrons. Short circuits are dangerous with high voltage power sources because the high currents encountered can cause large amounts of heat energy to be released.

Fig 3



A.C. Circuits

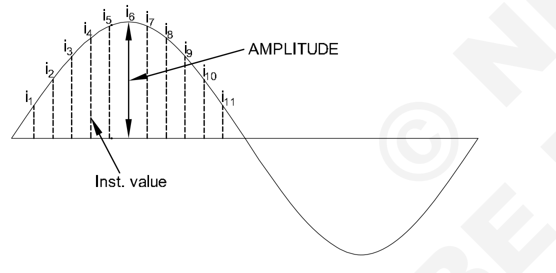
Cycle: A complete change in value and direction of alternating quantity is called cycle. Fig.3 shows a cycle.

Period: Time taken to complete one cycle is called period.

Amplitude: It is the highest value attained by the current of voltage in a half cycle.

Instantaneous value: Value at any instant is called instantaneous value. Fig.4 shows this value by i1,i2.

Fig 4



Frequency: It is defined as the number of cycles per second. In India 50 c/s frequency is common.

Frequency $\frac{NP}{120}$ where N is the speed in r.p.m and P is no.of poles of a machine.

R.M.S. Value: Root mean square value of an alternating current is given by that steady d.c. current which produces the same heat as that produced by the alternating current in a given time and given resistance. It is also called the virtual or effective value of A.C.

$$I_{r.m.s.} = 0.707\ I_{max}$$

$$V_{r.m.s} = 0.707\ V_{max}$$

All A.C. voltmeters and ampere meters read r.m.s. value of voltage and current.

Symmetrical Alternating Quantity: The ratio of the value to the mean period

Instantaneous value: The value of a variable quantity at a given instant. It is the value of an alternating quantity (AC Voltage ac current or AC Power) at a particular instant time in a power cycle. The Instantaneous value of any variable quantity is designated by the smaller case letter of its symbol For Example 'V' for voltage 'i' for current 'r' resistance. 'p' for power 't' for time etc.

Peak value: The maximum of the values of quantity during a given interval.

Basic of DC circuit

This flow of electrical charge is referred to as electric current. There are two types of current, direct current (DC) and alternating current (AC). DC is current that flows in one direction with a constant voltage polarity (Fig.5) while AC is current that changes direction periodically along with its voltage polarity (Fig 6). But as societies grew the use of DC over long transmission distances became too inefficient. With AC it is possible to produce the high voltages needed for long transmissions.Therefore today, most portable devices use DC power while power plants produce AC.

Fig 5

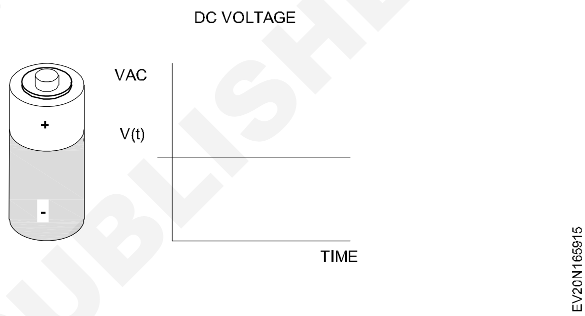
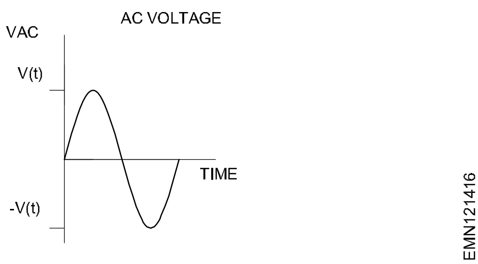


Fig 6



Voltage

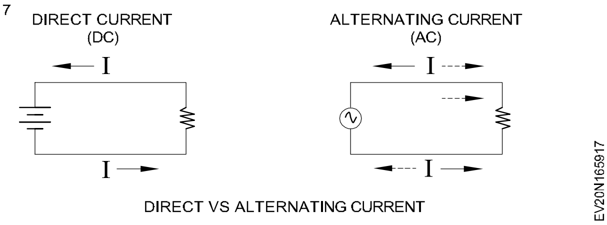
We define voltage as the amount of potential energy between two point on a circuit. One point has more charge than another. This difference in charge between the two points is called voltage. It is measured in volts. Techinally, it is the potential energy difference between two points that will impart one joule of energy per coulomb of charge that passes through it. The unit “volt” is named after the Italian physicist Alessandro Volta who invented what is considered the first chemical battery. Voltage is represented in equations and schematics by the letter “V”.

Basics of AC circuit

As useful and as easy to understand as DC is, it is not the only “kind” of electricity in use. Certain sources of electricity (most notably, rotary electro-mechanical generators) naturally produce voltages alternating in polarity reversing positive and negative over time. Either as a voltage switching polarity or as a current switching direction back and forth, this “kind” of electricity is known as Alternating Current (AC):as shown in figure (7)

Whereas the familiar battery symbol is used as a generic symbol for any DC voltage source, the circle with the wavy line inside is the generic symbol for any AC voltage source.

Fig 7



DIRECT VS ALTERNATING CURRENT

One might wonder why anyone would bother with such a thing as AC. It is true that in some cases AC holds no practical advantage over DC. In applications where electricity is used to dissipate energy in the form of heat, the polarity or direction of current is irrelevant, so long as there is enough voltage and current to the load to produce the desired heat (power dissipation). However, with AC it is possible to build electric generators, motors, and power distribution systems that are far more efficient than DC, and so we find AC used predominately across the world in high power applications.

General overview of single phase and three phase AC system

Both single phase and three phase systems refer to units using alternating current (AC) electric power. With AC power, the flow of current is constantly in alternating directions. The primary difference between single phase and three phase AC power is the constancy of delivery.

In a single phase AC power system the voltage peaks at 90° and 270°, with a complete cycle at 360° is shown in Fig 8. With these peaks and dips in voltage, power is not delivered at a constant rate. In a single phase system, there is one neutral wire and one power wire with current flowing between them. The cyclical changes in magnitude and direction usually change flow in current and voltage about 60 times per second, depending on the particular needs of a system.

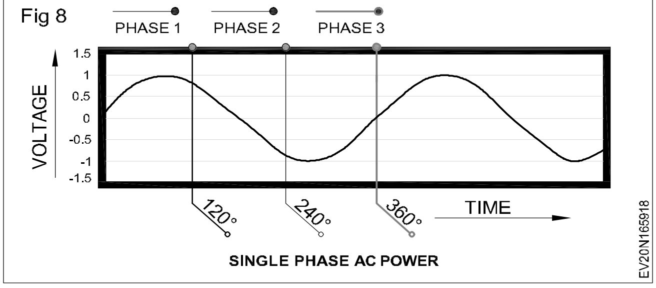
Benefits and uses of a single phase AC power supply

Single phase power supply units have a broad array of applications. Units that have a limited power need up to 1000 watts typically make the most efficient use of a single phase AC power supply. Generally, benefits of selecting a single phase system include:

- Broad array of application uses
- Most efficient AC power supply for up to 1000 watts
- Fewer design costs
- Less complex design

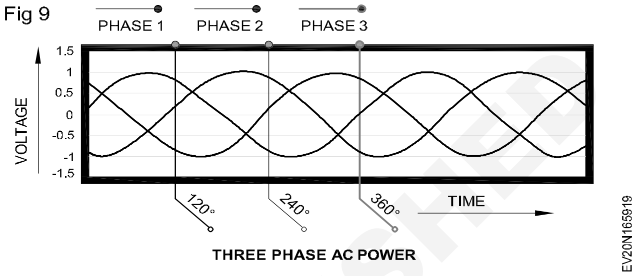
In a 3 phase system there are three power wires, each 120° out of phase with each other. Delta and wye are the two types of circuits use to maintain equal load across a three phase system, each resulting in different wire configurations. In the delta configuration, no neutral wire is used. The wye configuration uses both a neutral and a ground wire. (Note: In high voltage system, the neutral wire is not usually present for a three phase system.) All three phases of power have entered the cycle by 120°. By the time a complete cycle of 360° has completed, three phases of power each peaked in voltage twice as shown in Fig 9. With a three phase power supply, a steady stream of power is delivered at a constant rate, making it possible to carry more load.

Fig 8



SINGLE PHASE AC POWER

Fig 9



THREE PHASE AC POWER

Benefits and uses of a three phase AC power supply

Typical applications for 3 phase systems include data centers, mobile towers, power grids, shipboard and aircraft, unmanned systems, and any other electronic with a load greater than 1000 watts. Three phase power supplies offer a superior carrying capacity for higher load systems. Some of the benefits include:

Reduction of copper consumption

Fewer safety risks for workers

Lower labor handling costs

Greater conductor efficiency

Ability to run higher power loads

Additionally, three phase systems in delta configuration with a 208 volt load requires less circuit breaker pole positions than that of a wye configuration. In these cases, a three phases system yields further savings in installation, maintenance, and cost of production materials due to the reduction of required wires. However, in most cases, the wye configuration is preferable. Wye is more flexible so that it can power devices that require 3 phase, 2 phase, or 1 phase power. For example, a data center's warehouse of servers may only require three phase power, however the technician monitory the series will likely need single phase power to operate his/her computer, tools and lights.

Line voltage and phase voltage

Line voltage is the voltage measured between any two lines in a three-phase circuit. Phase voltage is the voltage measured across a single component in a three-phase source or load.

Line current and Phase current

Line current is the current through any one line between a three- phase source and load. Phase current is the current through any one component comprising a three phase source or load. In balanced "Y" circuits, line voltage is equal to phase voltage times the square root of 3, while line current is equal to phase current.

Conductor, and semiconductor properties

Objectives: At the end of this lesson you shall be able to
- **define conductor and insulator**
- **explain about types of cables**
- **explain about types of wires**

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

Some materials are better conductors of electricity than others. The more free electrons in a material has the better it will conduct. Silver, copper, aluminium and most other metals are good conductors.

Insulators: Materials that have only a few free electrons (if any), and they are capable of not allowing the current to pass through them are known as insulators.

Wood, rubber, PVC, porcelain, mica, dry paper, fibre glass are some examples of insulating materials.

Non-conducting materials (insulators) are also called DIELECTRIC.

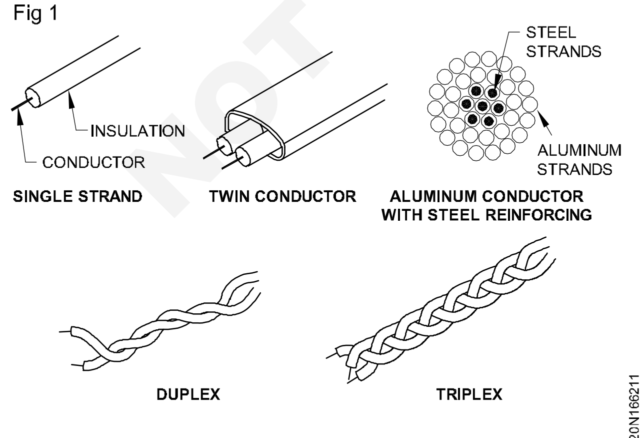
Conductors make up the main conducting path of electric current, and insulating materials prevent current flow through unwanted paths and minimises electrical hazards.

Conductors: The use of conductors and their insulation is regulated by I.E. regulations and I.S.Code of practice.

Regulations and I.S. code cover electrical conductors listing the minimum safety precautions needed to safe-guard people, buildings and materials from the hazards of using electricity.

Wires and cables are the most common forms of conductors. They carry electric current through all kinds of circuits and systems. Wires and cables are made in a wide variety of forms suited to many different applications. (Fig 1)

Fig 1



VARIOUS FORMS OF CONDUCTOR

Conductors form an unbroken line carrying electricity from the generating plant to the point where it is used. Conductors are usually made of copper and aluminium.

A conductor is a wire or cable or other form of metal, suitable for carrying current.

All wires are conductors, but all conductors are not wires. For example copper bus bar are conductors but not wires. They are rigid rectangular bars.

Current passing through a conductor generates heat. The amount of heat depends on the value of current and the potential difference between its ends.

The rate of heat production in the conductor equals the amount of power lost by the electricity in passing through the conductor.

The cross-sectional area of the conductor must have a large enough area to give it a low resistance. But the cross-sectional area must also be small enough to keep the cost and weight as low as possible.

The best cross-sectional area depends on how much current the conductor must carry.

The rate of heat production in a conductor increases with the square of the current. As heat is produced the conductor gets hotter and the temperature rises until the rate at which the conductor releases heat to the surroundings equals the rate at which the heat is produced. The temperature of the conductor then remains steady. This steady temperature is called equilibrium temperature.

There is a limit to the temperature each kind of insulation can safely withstand. There is also a limit to the temperature the surroundings can withstand.

I.E. regulations specify the maximum current considered safe for conductors of different sizes, having different insulation and installed in different surroundings.

Size of conductors: The size is specified by the diameter or the cross-sectional area. Typical sizes are 1.5 sq mm, 2.5 sq mm, 6 sq mm etc.

A common measure of wire diameter is the standard wire gauge (SWG), commonly used in our country. The resistance of a material increases as the length of the conductor increases, and the resistance decreases as the cross-sectional area of the conductor increases. We can compare one material with another by measuring the resistance of samples.

Classification of Conductors

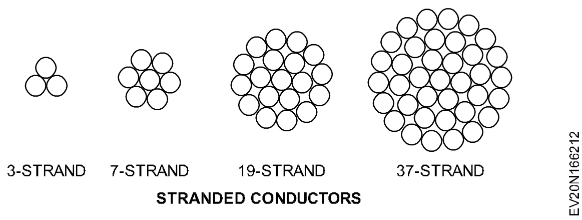
Wires and cables can be classified by the type of covering they have.

Bare conductors: They have no covering. The most common use of bare conductor is in overhead electrical transmission and distribution lines.

Insulated conductors: They have a coating of insulation over the metals. The insulation separates the conductor electrically from other conductors and from the surroundings. It allows conductors to be grouped without danger. Additional covering over the insulation adds mechanical strength and protection against weather, moisture and abrasion.

Stranded conductors: They consist of many strands of fine wires as shown in Fig 2. The wires in stranded conductors are usually twisted together. Stranded conductors are more flexible and have better mechanical strength.

Fig 2



Properties of electrical Conductors ;-

- A Conductor always allows the movement of electrons and ions through them
- The electric field inside a conductor is zero allowing electrons to flow within them
- The charge density inside a conductor is zero only on the surface of the conductor do free charges exist.
- All points of a conductor are at the same pottential.

Cable: A length of insulated conductor. It may also be of two or more conductors inside a single covering. The conductors in a cable may either be insulated or bare. Cables are available in different types. There are single core, twin core, three core, four core and multi-core cables.

Properties of insulation 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: It is the electrical resistance of the insulation against the flow of current. Mega-ohmmeter(Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megaohms 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 breakdown is called the breakdown voltage of the insulation.

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

– high dielectric strength

– resistance to temperature

– flexibility

– mechanical strength

– Non hydroscopic.

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

Insulating tapes

Various tapes are used for insulating electrical equipment, conductors and components. Some of these are adhesives. The tapes commonly used include friction, rubber, plastic and varnished cambric tapes.

Semiconductors: A semiconductor is a material that has some of the characteristics of both the conductor and an 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.

Properties of Semi Conductor :-

- The resistivity of a semi conductor is less than an insulator but higher than a conductor.
- Semi Conductors show a negative temperature coeffcient of resistance in simple words the resistance of the semi conductors descress as the temperature increases.
- At zero kelvin semi conductors behave as insulator. As the temperature is increased it woks as a conductor.
- The Conductivity of the semi conductor increases when impurities are added. The process of adding impurities to semi conductors is called doping.

Electrical cable types (Fig 3)

- Coaxial cable - used for radio frequency signals, for example in cable television distribution systems.
- Communications cable
- Direct-buried cable
- Flexible cables
- Heliax cable
- Non-metallic sheathed cable (or non metallic building wire, NM, NM-B)
- Metallic sheathed cable (or armored cable, AC, or BX)

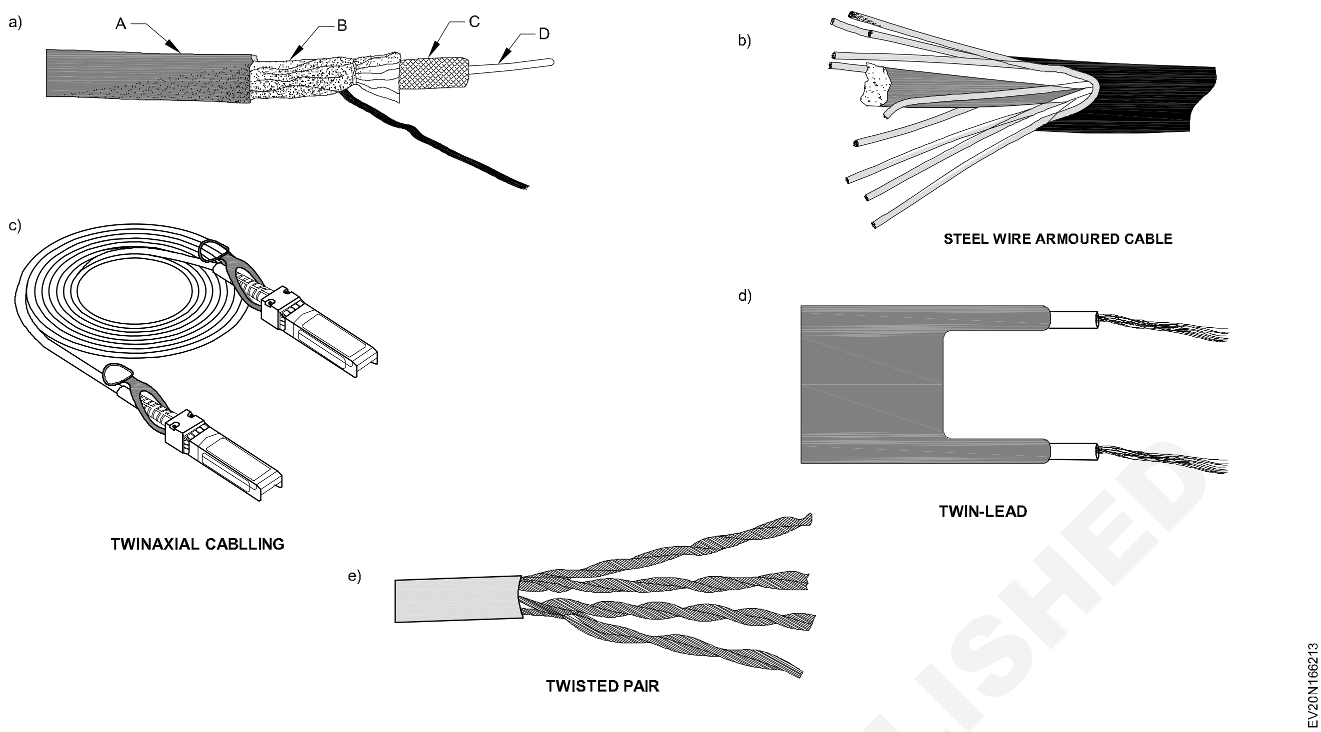
Steel wire armoured cable

Twinaxial cabling

Twin-lead

Twisted pair

Fig 3



A comparison of the most commonly used metals as conductors in wires is given below:

PROPERTIES	TYPES OF METALS USED AS CONDUCTORS			
	Silver	**Copper**	**Gold**	**Aluminium**
Ability to be drawn into thin wires	Very good	Very good	Very good	Not good
Flexibility (ability to bend without breaking).	Very good	Good	Very good	Not good
Conductivity.	Very good (100%)	Very good (94%)	Good (67%)	Good (56%)
Resistivity in W m at 20°C	$1.6x10^{-8}$	$1.7x10^{-8}$	$2.4x10^{-8}$	$2.85x10^{-8}$
Ability to withstand extreme atmospheric conditions.	Good	Good	Very good	Bad
Cost	Expensive	Cheap	Very expensive	Very cheap

Eletrical cable and wire :-

A wire is single conductor and cable is a multiple conductor or group of wires encased in shieding. Electric wires are typically made of aluminum or copper. Cables contain a neutral wire, ground wire and hot wire that are twisted or bonded together. depending on the purpose of the cable it may be contain more wires. The wires in cable are insulated in their own color coded layer of thermoplastic. The group of wires encased in an outer sheath to make up the single cable.

Conductors used in common types of wires are always drawn to thin circular forms (bare wires). A few reasons why the wires are drawn in circular form are given below.

1 Drawing a conductor in the circular shape is cheaper and easier than drawing in any other form.

2 Round shape of the conductor ensures uniform current flow through the conductor.

3 Uniform diameter of wire can be maintained.

4 Insulation can be uniformly covered.

Conductor(s) of wires are covered with insulating material or an insulating coating(enamel). Some of the reasons for covering the conductor of wires with an insulator are given below:

1 Bare conductors carrying high voltage/current when touched accidentally will give electrical shock, which can be hazardous to life.

2 When two or more conductors carrying different types of current are laid side by side, the current flow through the wires should not get mixed.

3 To protect the conductor from moisture and destructive atmospheric conditions.

Any non-conductor of electricity can be used as an insulator. However the insulators used with wires should have elastic properties so that the insulation does not get cut or tear off when wires are bent.

CURRENT CARRYING CAPACITY OF WIRES

A wire is used to carry electric current. The amount of current that can flow through a wire depends on, how good is the conductivity of the conductor used (silver,copper,aluminum etc) physical dimension (diameter) of the conductor(s).

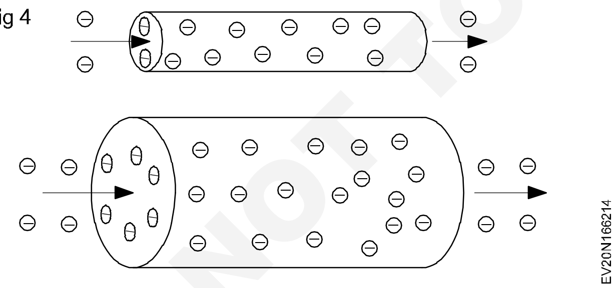
Larger the diameter of the conductor, higher is the current that can flow through it, as shown in Fig 4.

The maximum current that flows through a wire of a particular diameter without heating up the wire is called the maximum current carrying capacity or generally the **current carrying capacity** of a wire. Hence the current carrying capacity of a wire is directly proportional to the conductor's diameter.

STANDARD WIRE GAUGE

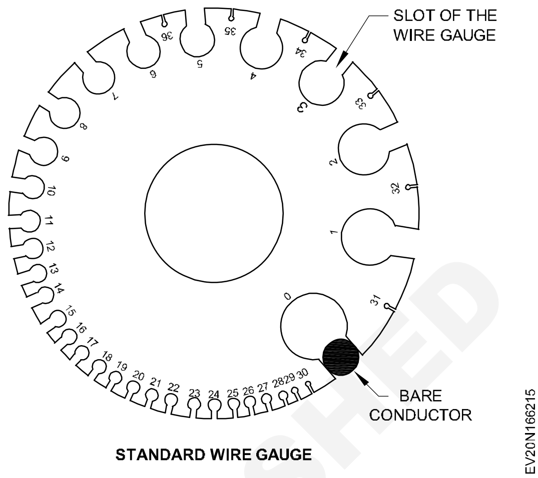
Size of a wire means the diameter of the conductor used in that wire. To measure the size of a wire, an instrument called standard wire gauge (SWG) is used as shown in Fig 5.

Fig 4



Standard wire gauge is a circular metal disk with varying slot sizes on its circumference. Each slot size corresponds to a gauge number which is written just below the hole. The gauge numbers specify the size of a round wire in terms of its diameter and cross-sectional area. The following points are to be noted while using/reading

Fig 5

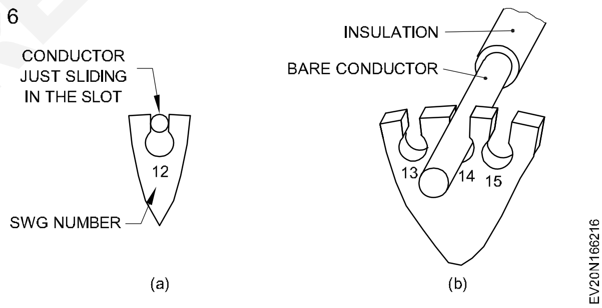


Standard Wire Gauge:

– As the gauge numbers increase from 0 to 36, the diameter and circular area decrease. Higher gauge numbers indicate thinner wire sizes.

– The circular area doubles for every three gauge sizes. For example, No. 10 SWG has approximately twice the area of No. 13 SWG. (Fig 6)

Fig 6



Automobile electrical architecture and power supply systems

Objectives: At the end of this lesson you shall be able to
- **Automobile electrical architecture of power supply systems**
- **State the different types of auto electrical systems**
- **State electrical circuit symbols.**

Introduction to automobile electrical architecture :- The automobile electrical power systems are consisted with multi strand copper conductors and it is covered with good quality of PVC insulation. The electric power supply that carries to various electrical accessories is carried through cables.

The various sizes of cable used in automobile wiring circuits depends on power flow through the cable. Generally in electronic vehicle used the following cable sizes

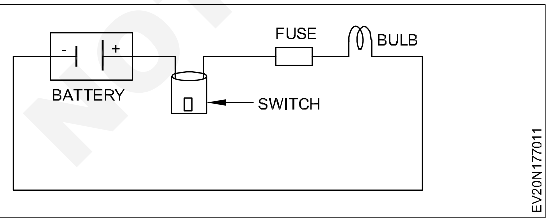
0.5, 0.75, 1.00, 1.5, 2.5, 4, 6mm

The above cables are stand for the temperature up to 40 degrees to 105 degrees C and conductor resistance 52.00 to 03.10 ohms/km at 20 degree C maximum conductor size is 0.35 - 6.00 sq mm and maximum outer diameter of the cable is 1.40 to 4.30 mm power supply through the automotive cable types up to 600 v depend up on the (wire) conductor size.

Automotive cables are used in thin copper wire and it is used to carry current from power switch to electrical component in a wiring circuit. The size of the cable depends upon the current rating of the accessories connected in the wiring circuit .A thin cable carry less current and thick cable carry more current. Electrical cables are used in a wiring circuits depend upon the specification of the electrical components provided in a circuit.

Electrical power supply system :- The automobile battery is used as a power storage unit. The battery power is used to the electrical wiring circuit components through control switches, as shown in the diagram given below. The power supply system of a car is responsible for providing electrical power needed to operate various

Fig 1



electrical components within each electrical circuits.

Nomenclature of auto electrical systems:- There are many types of electrical systems used in an electrical vehicle. They are as follows

- Battery charging system
- Traction motor power supply system
- Lighting system
- Battery power amplifying system
- Audio and Video system
- Power door control system
- Power window glass operating system
- Wiper system
- Horn system
- HVAC system
- ABS brake system
- Clutch system
- Power transmission system
- Electronic control and information system
- Dash board games and warning light system
- Vehicle safety information system
- Power steering control system
- Immobilizer system
- GPS system etc.,

Typical layouts:- In an automobile electrical wire circuits are having separate power control switch and fuse in their wiring circuits.

General vehicle architecture and power supply system:- Automobile electrical architecture and power supply system plays an critical role in its operation and performance. The electrical system is responsible for powering a wide range of components in an electrical wiring circuits. The electrical architecture includes the wiring, connectors, fuses relays and control modules and other systems provided in a modern vehicle.

Basic circuit diagram and symbols:- Automotive circuits are generally shown by wiring diagrams. The parts in those diagrams are represented by symbols. Symbols are codes or signs that have been adopted by various automobile manufacturers as a convention (Fig 2)

Technicians must understand basic circuits to be able to maintain, diagnose, and service these systems. When these circuits are understood, diagnosing becomes much easier and faster. For example

The lighting system (Fig 3) provides illumination on the road to ensure good visibility for the driver and illumination inside the vehicle besides for other purposes. The headlamp(1), fog lamp (15), parking lamps,(2), warning lamps(3), brake lamps(4), panel instrument lamps(5),

Fig 2

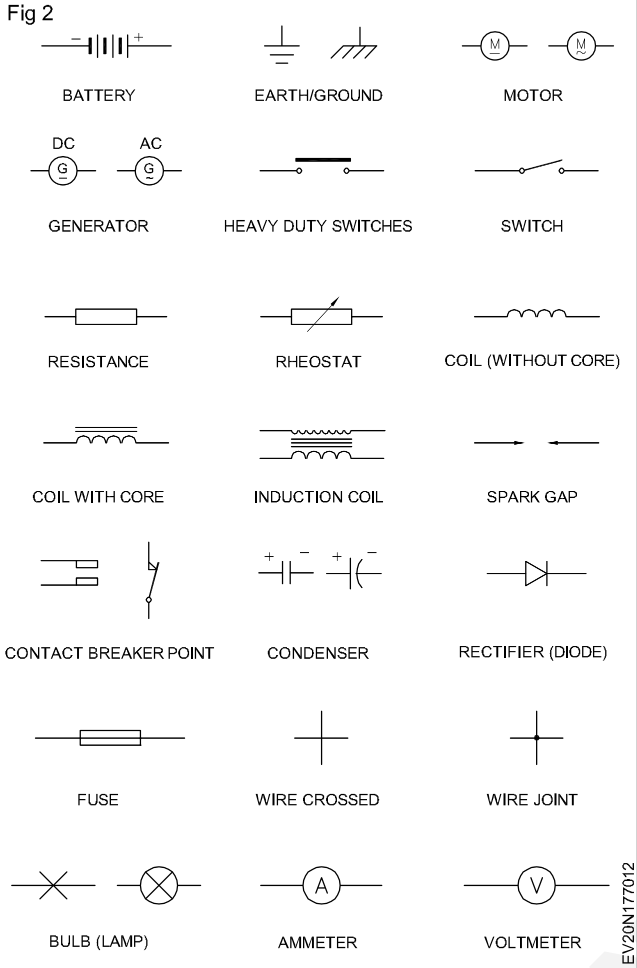
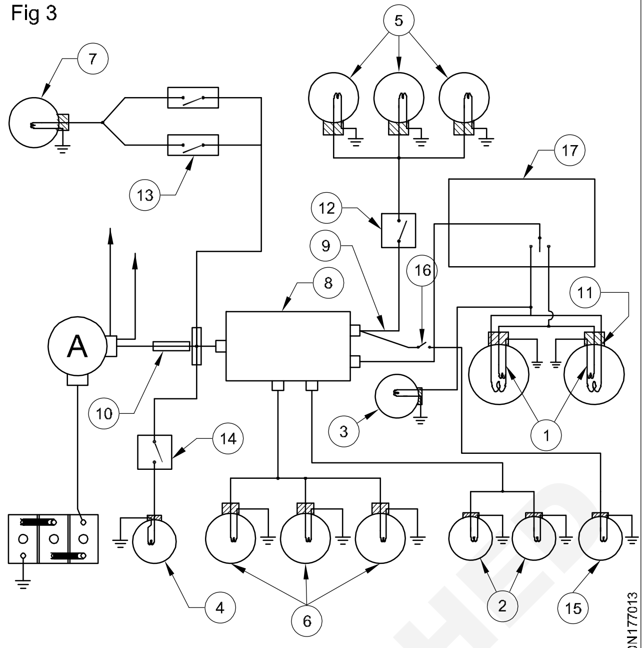


Fig 3



LIGHTING SYSTEM

tail lamp(6), and the interior dome lamps(7), constitute the lighting system.

The lighting system consists of switches (8), lamps, wiring harness(9) and fuse(10)

Instrumental cluster:- There are different type of instruments are used in an electric and general vehicle dash board. They are as analog instrument, digital instrument and hybrid instruments.

The mechanical gauges are is used the needle that moves across a scale to indicate the reading information. The speedometer, tachometer and fuel gauges are known as analog gauges.

The digital instrument cluster uses a digital display to show information to the driver. These instruments display a single screen or multiple screen for a show a wide range of information including vehicle speed RPM and other vehicle signal and warnings.

The hybrid instrument cluster combines analog and digital displays to provide a more customizable and versatile display. The main gauges are displayed by using analog gauges and other informations are displayed on digital screen.

Tell- Tales :- Tell- Tales refer to warning lights or symbols that are displayed on the instrument cluster to alert the vehicle driver. The tell tales information about a potential issue with vehicle operating system. For example low oil pressure, malfunctioning air bag, door open check engine, hand brake engaged, check oil level, battery low power.etc

Electrical distribution system

Objectives: At the end of this lesson you shall be able to
- **State the function of wire, fuse, relay**
- **State the selection process of wire, fuse and relay**
- **State the voltage drop analyses grounding and splicing**
- **State the wiring harness design**
- **State the switches type and their classification**
- **State the fault finding and root cause analysis of vehicle electrical systems.**

Introduction to the vehicle electrical distribution system:- The vehicle electrical distribution system is responsible for distributing the electrical power to various electrical components in a wiring circuits of a vehicle. The electrical circuits are used the wire fuse and relay for the following purposes.

- Wires are used to transmit the electrical power from battery to end component of the circuit .
- Fuses are used in between the circuit to protect electrical components damage by short circuits or overload. Fuses are located in a fuse box in different sizes and rating fuses are used depending upon the specific application.
- Relays are used to control the flow of electrical power in a wiring circuit. Relay work by using a low current signal to activate the magnetic coil, which is turn to

open and closes a switch to allow the current flow in a circuit to operate the electrical component.

Selection process of wire, fuse and relay:- The selection process of wire, fuse and relay should follow the vehicle manufacturers specification. Before replace any component of an electrical circuit refer the manual for suitable one.

Wire selection :- While wire selection follow the standard color coding and proper wire size as per manufacturers specification . Automobile cable sizes are indicated by the number of strands of wire.

Selection of fuse:- Different types of fuses are used in a vehicle while selection of fuse refer the old type fuse and their rating or refer the vehicle service manual for select the new fuse.

Selection of relay:- Relays are used in different types of electrical circuits in a vehicle. Relay selection process involves choosing the appropriate relay size and power rating as per manufacturers specification.

Circuit voltage:- The voltage of electrical circuit determine the wire size connectors and the components in a circuit. Voltage is a critical factor to consider it is decided when designing a wiring harness by vehicle manufacturer. Only we can measure the voltage in a circuit for compare with manufacturers specification data.

Voltage drop analysis:- Voltage drop analysis involves calculating the voltage drop along the length of the wire to ensure sufficient voltage at the end of the wire to power component. When you are selecting wire and connectors consider the color, size, length, strand and resistance of wire to avoid unnecessary voltage drop.

Circuit wire grounding:- Grounding or Earthing is an important role to complete the electrical circuit. As it ensure vehicles wire harness is properly grounded and safe to use the wiring circuit. Whenever ever you repair or replace the circuit wire or harness wiring ensure the negative wire end is properly grounded throughout the electrical circuits.

Splicing strategy of wiring harness design:- Automobile wiring harness involves multiple wires joining together to create a single electrical circuit under control one switch. Wire joints are including crimping, soldering and pluging. Each splicing strategy design made for a specific application of vehicle's requirement.

Designing the wiring harness:- When wiring harness is designing several factors are considered like safety of passenger and other users. The wiring harness design should be accommodate for future upgrades or modification of vehicle electrical system. The wiring harness design should be cost effective and ensuring efficient and reliable operation of the vehicle.

Harness topology:- The vehicle's wiring harness is used the physical layout for connect the various electrical systems and components connected with electrical circuits. There are three types of wiring harness is used in a vehicle. They are as centralized, distributed and hybrid type.

The centralized wiring harness wires from different electrical systems are connected with in a single central location.

The distributed topology wiring is distributed through the vehicle, with each system having its own wiring.

The hybrid topology wiring harness is combination of the centralized and distribute topology, in this type of wiring some systems connected to a centralized other systems are having separate own wiring circuit.

Switch:- Switches are used to ON/OFF the flow of current in a electrical circuits. There are different type of switches are used in a electrical circuits. They are as follows (1) Toggle switch (2) Rocker switch (3) Push button switch (4)Rotary switch (5) Slide switch (6) chip switch (7) Tactile switch (8) Limit switch (9) pressure switch (10) read switch (11) single pole single throw switch (12) single pole double throw switch (13) double pole single throw switch (14) double pole double throw switch

Classification of switches based on their functions

1 ON/OFF Switches

2 Selector switch

3 Momentary switch

4 limit switch

- ON/OFF switch is used to turn ON OFF the electrical power in a electrical circuit.
- Selector switches are used to select different modes or settings
- Momentary switches are used for pressed for ON position and released for its original (OFF) position

Switch is based on their construction

1 Mechanical switch

2 Solid state switch

- Mechanical switches having a physical contacts to control the flow of current.
- Solid state switches are used the semi conductor devices to control the flow of current in a circuit

Diagnostics of electrical circuit:- Modern cars are accommodate with many type of electrical wiring circuits. Electrical wiring and their connection may be fault at any time. Faulty electrical circuit or components may effect the function of vehicle.

To finding the fault look at the wire connectors and wire damage, including the wire insulation, cracked, dried out, short circuit, loose grounding, corrosion, fuse, defective switches etc. steps for finding fault as follows.

- Study the user manual for achieve the knowledge of various electrical circuits used in a vehicle
- Start the vehicle and check all type of electrical systems.
- Find the defective electrical system in a vehicle
- Switch off the vehicle and disconnect the battery power

- Trace the faulty wiring circuit and components in a circuit
- Find the defective part in a circuit and remove it from the circuit.
- Find the root cause for the defect and rectify the defect or if need replace the defective component like wire, connectors, switches, controller, invertor, traction motor, battery pack charger etc.
- Reassemble the defect corrected part in a wiring circuit
- Ensure the wire connections and circuit continuity is property connected.
- Use the testing tools for check electrical circuit continuity

Note:- Use the safety devices while you are repairing electrical wiring circuit in a electric vehicle.

- Connect the battery power and switch on the power
- Start the vehicle for check the function of repaired circuit component
- Ensure there is no any system or components are malfunction warning shown in a dash panel.
- Ensure all the system of a vehicle functioning properly.
- Switch off the vehicle

Note:- The instructor should be explain the method of fault diagnosing and finding a root cause for that particular fault by using video in smart class room

Electrical vehicle wiring and circuit diagram

Objectives: At the end of this lesson you shall be able to
- **State the automobile wiring circuit diagram**
- **State the wire color codes and number codes**
- **State the wiring harness.**

Automotive

Wiring and circuit diagram :- Many types of connections are used in automotive wiring. Circuit wires are complicated to inspect and tracing fault in automotive wiring circuit. Automotive wiring diagrams help to speed up the whole process. The wiring diagrams have many number codes and symbols in order for diagrams. To read the wiring diagrams you should know the electrical symbols and wire color code and numbers used in a car wiring diagrams. It helps to trouble shoot and fix simple electrical system problems in no time. Wire color codes and numbers are easy to identify the wiring circuit to go to quickly find where the connector is located on the vehicle (Fig.1)

Difference between the primary and secondary wiring

Primary wiring system carries low power systems 16 volts or less and secondary wiring carries the higher amperages to be found under hood. For example Gauges lightening & traction motor circuit. (Fig 1)

Comparison between solid and stranded primary wire

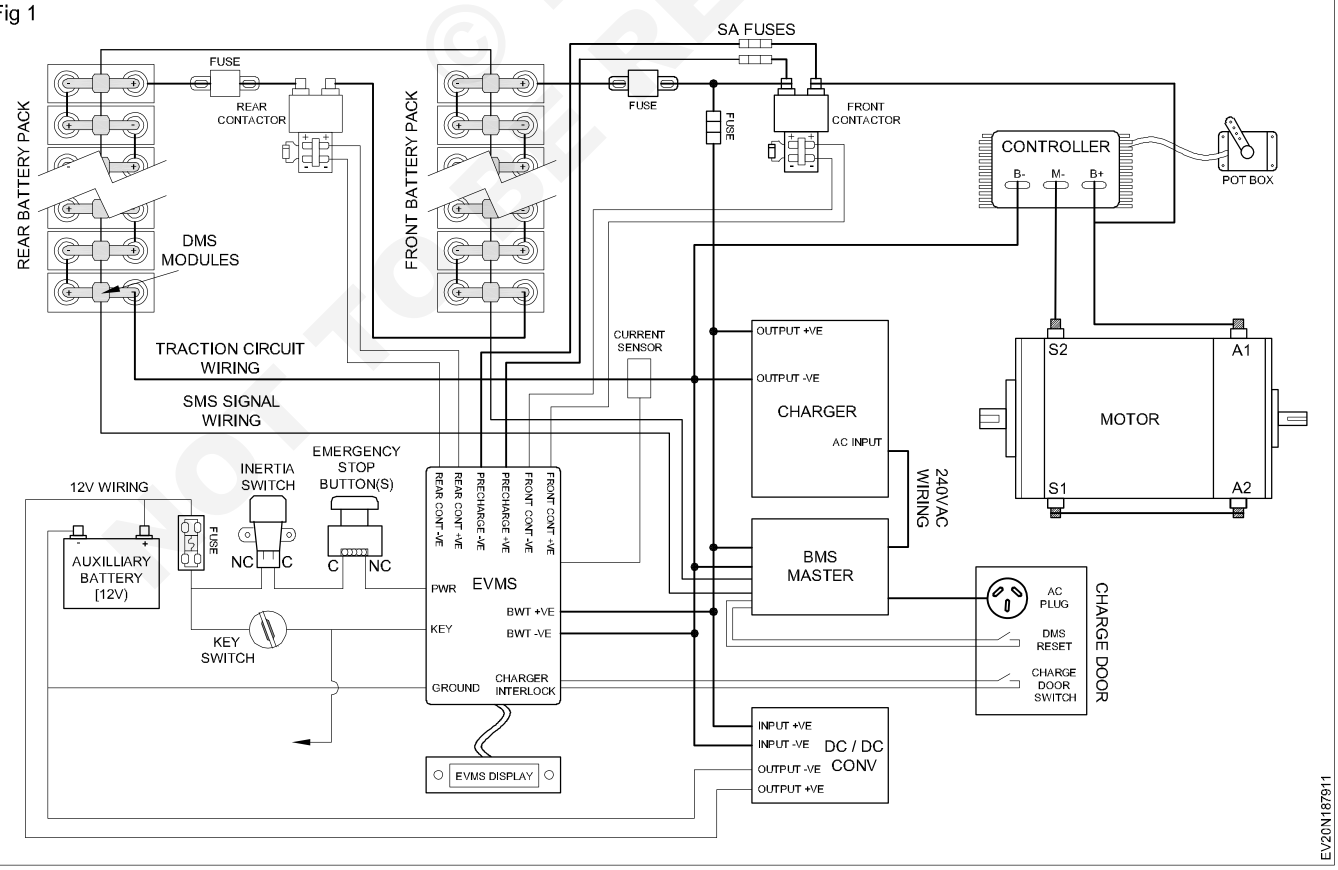
Solid wire conductors are conducted of one single piece of metal. It is tougher than a stranded conductor but rigid and less flexible than a stranded conductor. Stranded conductors aree made up of multiple strands, which group to make up a single conductor. It is more flexible than a solid conductor, but less durable.

Types of stranded constructions

- Bunch stranding
- Unilay stranding
- concentric stranding
- Rope lay stranding

A More Complete Wiring Diagram for DC Electric Vehicles

Fig 1



Cable sizes: Cable sizes are indicated by the number of strands of wire followed by the diameter of each strand measured in thousands of an inch e.g. 14/0.12 i.e. fourteen strands of twelve thou' wire (30 SWG)

On 12 volt systems, as generally used on the vehicles, the current carrying capacity of cables having copper conductors can be reckoned as follows

Cable size	Current carrying capacity (amps)
44/0.012	22
28/0.012	14
14/0.012	7

Wire size		60°C (140°F)		75°C (167°F)	
AWG	(mm2)	Copper	Aluminum	Copper	Aluminum
14	(2.1)	15	-	15	-
12	(3.3)	20	15	20	15
10	(5.3)	30	25	30	25
8	(8.4)	40	30	50	40
6	(13.3)	55	40	65	50
4	(21.2)	70	55	85	65
3	(26.7)	85	65	100	75
2	(33.6)	95	75	115	80
1	(42.4)	110	85	130	120
1/0	(53.5)	-	-	150	120
2/0	(67.4)	-	-	175	135
3/0	(85.0)	-	-	200	155
4/0	(107.2)	-	-	230	180
250 KCMIL	(127)	-	-	255	205
350	(177)	-	-	310	250
500	(253)	-	-	380	310
600	(304)	-	-	420	340

AWG

In the American wire gauge (AWG) system. Wire size diameter can be calculated by applying the formula D(AWG)= 005.92(C36-AWG/39) inch for the00,000,0000 etc gauges you use -1-2-3, which makes more sense mathematically than double naught. This means that in American wire guage every 6 gauge decrease gives a doubling of the wire diameter and every 3 gauge decrease doubles the wire cross sectional area similar to dB in signal and power levels. An approximate but accurate enough D= 460* (57/64)(awg+3) or D = 460* (0.890625)(awg+3)

Metric wire gauges

Metric wire gauge scale, the gauge is 10 times the diameter in millimeters. So a 50 gauge metric wire would be 5mm in diameter. Note that in AWG the diameter goes up as the gauge goes down but for metric gauge, it is the opposite. Probably because of the confusion most of the time metric sized wire is specified in millimeters rather than metric gauges.

Ground strap function

Ground strap or ground wire is the cable that connects the engine block to the chassis or sometimes directly to the negative battery terminal. This strap completes the circuit for electrical accessories grounded to the engine block instead of directly to the chassis. The accessories may include the ignition system, alternator or any other sensors of these, the alternator requires the most power flow because it produces upward of 200 amps to recharge the battery through its positive output wire. The ground strap and grounding system that helps keep your system simple may also prove it is undoing in causing vehicle wide malfunctions resulting from few little brazed wires.

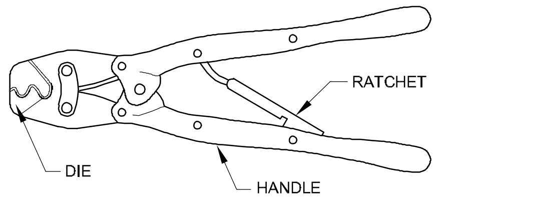
Types of wire terminals

Terminals are defined as a device designed to terminal a conductor that is to be affixed to a post, stud. Wire terminals come in many shapes and sizes. Depending on the sizes of the wire, terminals include ring , spade, hook, quick bullet butt terminals and flagged wire terminals are available in insulated and non insulated, determining the best fit depends on usage. Wire insulation provides a protective cover serving as a non conductor. The insulation spares the wire from water and moisture as well as protects against extreme heat or cold. Wire insulation is typically available in vinyl, nylon and heat shrink non- insulated terminals provide much more economic value with its low cost also commonly used when extra protection is necessary.

Different types of wire termination

Crimp connection: In this type of connection the conductor is inserted into a crimp terminal and then is crimped with a crimping tool (Fig 2)

Fig 2



CRIMPING TOOL

Electrical connectors

While electronic circuit can process signals and produce output they almost always need to be connected to external components power source inputs or outputs. These connectors are done with the use of connectors and they come in many different types, shapes, sizes and ratings. Choosing the wrong connector for your design can cause a range of issues from bulky components product sizes to catching fire so under standing the difference type of connectors is imperative. While there are many connector types available (headers, sockets, DIN and DB)

Types of wire terminals and connectors

Molded connectors

Vehicular molded connectors are in 6 pole, 3 pole, 2 pole configuration molded weather resistant PVC bodies car, trucks, trailers,boats.etc.

Features

- Color coded for easy insulation
- Polarized for proper mating of a circuit
- Terminals are precision aligned for maximum current carrying and disconnecting
- Flat type body

Multiple - wire hard shell connectors: This connector is used in connect CPU, EDC and other electrical circuit boards. Multiple wire is connected with this hard shell connector.

Bulkhead electrical connector

Bulk head connector is a term used to defines mounting style of connectors. These devices are designed to be inserted into a panel. The bulk head connectors are accurately molded of nylon or polypropylene material. These devices are regarded as a kind of coupler.

Weather pack connectors

Many different styles of connector are available including PVC heavy duty and weather proof. This type of connector is suitable type for all weather.

Metripack connectors

Metripack system are designed to compatible with processing techniques such as automated push to seal and pull to seal assembly, dual stage crimping, load cell crimp inspection and automated parts identification and orientation. The metri pack connectors are ideal for sealed and unsealed applications in motors, switches, sensors, junction boxes and other devices.

Heat shrink butt connectors

Heat shrink butt connector are water proof connector, electrical connectors wire terminals are insulated automotive copper connectors.

This type of wire connector increased the current flow and ensure less voltage drop, preventing wiring failures and reducing equipment down time wire never slip out of the connector, dual- walled tubing ensures water proof seal and prevents wire corrosion.

Importance of printed circuit board

The printed circuit board is very important in all electronic gadgets, which are used either for domestic use or for industrial purpose PCB design services are used to design the electronic circuit. A part from electrically connecting it also gives mechanical support to the electrical component.

Printed circuit board is used to connect electronic components using conductive pathways tracks or signal traces etched from copper sheets laminated on to a non conductive substrate.

Wiring harness

The wire harness is an assembly of electrical cable or wires, which transmit signals or electrical power. The cable are bound together by a durable material such as rubber, vinyl, electrical tape, conduit a weave of extruded string or a combination. Wire harness provide several advantages over loose wires and cables by binding the many wire and cables can be better secured against the adverse effects of vibrations, abrasions and moisture. By constructing the wires into a non- flexing bundle usage of space is optimized and risk of a short circuit is decreased and wire installation time also decreased and the process can be easily standardized. Binding the wires into a flame retardant sleeve also lowers the risk of electrical fires.

Wire size and ampere ratings

Ampacity is the maximum current that a conductor can carry continuously under conditions of use without excluding its temperature rating current is measured in amperes.

Color code in cables and wirings

In automobile a number of electric circuits are connected to the battery which is quite complicated.

The large number of cables are braided into a single harness assembly.

The automobile manufactures use cables of different colors and usually follow the lucas color code system. It consists of basic colors (main colors) and combination of colors. to identify individual circuits (Refer. of Fig 1)

The distinction between wires in a group is done by use of a colored bracer on the main color of insulator of each wire.

Color coding

The color coding for electrical system provides easy identification of each circuit in a vehicle conform to the color coding standard when used in conjunction with the wiring diagram. The color coding may vary from model to model. But the color coding adopted for a particular model is clearly given on the makers wiring diagram.

Standard color coding

Standard color coding should be adopted for motor vehicle wiring. Every electrical unit have three wires or conductors are used to enable the circuit to be completed .i.e. feed wire switch wire and return wire. In vehicles, the metal chassis is used for return wire (ground return), in some case the switch is incorporated in the unit. In some units, the switch is placed in the return side of the unit instead of on the feed side. Certain accessory circuits are fed through the ignition switch and certain auxiliary lighting circuits through the side and tail lamp switch.

Main feed color

There are seven main feed colors, each of which is allocated to a particular circuit. Feed colors each of which is allocated to a particular circuit. Feed wires are braided in the main circuit color, switch wires are braided in the main color but carry also a colored tracer woven spirally into the braiding, return or ground leads are black.

1 **Brown -** Battery circuit interior light, horn, control box, ammeter, ignition switch.

2 **Yellow -** Generator circuit- generator terminals to control box terminals and ignition warning light.

3 **White -** Ignition circuit - all units which are wired through the ignition switch and which are essential for the starting and running of the vehicle and which are not fused, i.e electrical control pump, standing motor, solenoid switch, etc

4 **Green -** Fused auxiliary circuits which are fed through the ignition switch, i.e stop lamps, fuse gauge, direction indicators, windshield wiper etc.

5 **Light green -** Flasher unit to flasher indicator waving light.

6 **Blue -** Headlamp circuit fed from the terminal on lighting switch. Included in this circuit are fig lamps, panel lights, door lights, etc. which are only required when the side lamps are switched on.

7 **Black -** All ground wired. If an unit do not internally grounded or is mounted on an insulated portion of the vehicle, a cable must be connected from the body of the unit to a good ground point on the chassis.

Automotive wiring and circuit numbering:

Automotive wiring constructed with standard wire color coding. The color coding design is decided by machine manufacturers. For identify the circuit wires refer the vehicle manual. Almost every vehicle's wiring circuits each wire has a number code to standardize the wiring. These numbers are defined in cable coding number as per Indian Industrial Standard.

Horn

Objectives: At the end of this lesson you shall be able to
- **Explain the horn circuit**
- **State the type of horn**
- **Explain the parts and working of relay type of horn**
- **Explain the working of horn switch**
- **State common troubles and remedies in horn.**

Horn circuits (Fig 1)

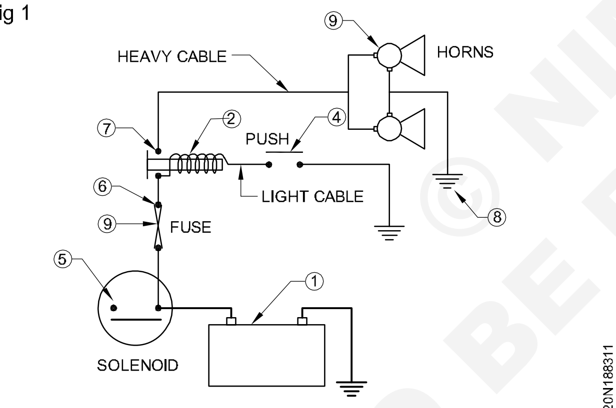
- Battery (1)
- Horn relay (2)
- Fuse (9)
- Horn push-button (4)
- Horn (single or pair) (3)

The circuit is connected in the following ways.

Battery (1) to the solenoid switch input terminal through a cable.

Solenoid switch (5) input terminal to horn fuse (9).

Fig 1



TWIN - HORN CIRCUIT

Ammeter is not connected in the horn circuit.

Horn fuse (9) to the horn relay ‘B’ (6) terminal.

Horn relay ‘S’ (6) terminal to the horn push switch (4)

Horn relay ‘S’ (7) terminal to the horn (3) terminal.

Horn grounded; terminal is earthed (8).

Function of Horn:-

When the horn switch (4) is pressed, the current from the battery (1) flows to the fuse relay (2) and then to the horn (3).

The circuit completes to operate the horn relay (2).

The relay (2) connects the horn (3) direct with the battery to supply more current. The horn (3) produces sound waves.

When the horn button (4) is released the horn circuit is opened.

The relay (2) disconnects the horn from the battery (1) current.

The horn (3) stops producing sound waves.

Need of a horn

The electromagnetic horn is fitted generally in the front end of the vehicle. It produces sound waves due to the vibration set up in the diaphragm to clear or warn the traffic on the road. It is used single or in pairs to produce sound and is operated through the horn switch in the drivers cabin. The horn switch does not operate the horn directly. It operates the horn relay.

Purpose of horn

Horn produce powerful sound waves to indicate and warn the traffic in front of the vehicle.

Types of horn

- Electric horn
  a) Vibrating type
  b) Wind-tone type
- Air horn (Wind horn)
- Bulb horn

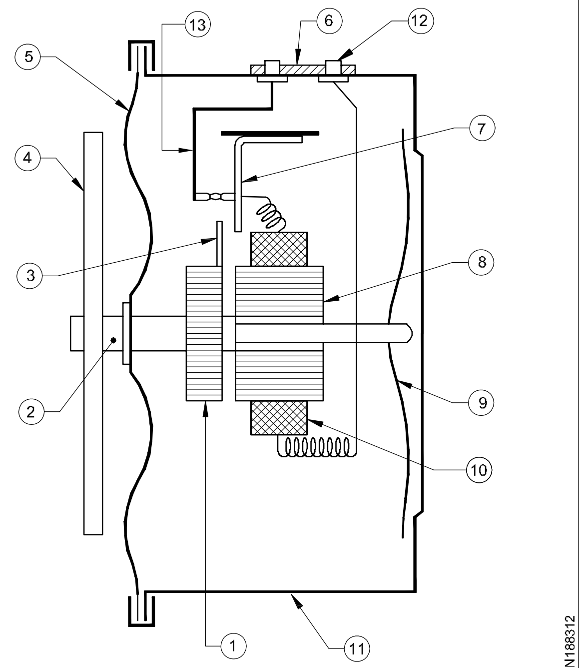
Construction of Electric horn (Fig 2)

The electric horn consists of a shell or body (11) in which a laminated magnet core (8) is fitted. The winding (10) is wound over the core. One end of the winding (10) is attached to the horn terminal (12) and the other end to the movable contact breaker (7). The movable point connects with the fixed point (13) which is earthed. The armature (1) is attached to a central spindle (2). One end of the spindle (2) is supported by a guide spring (9) and the other end by a diaphragm (5). The armature carries a striker plate (3). The tone disc is at the outer front end of the diaphragm (5) and the diaphragm is clamped to the horn shell.

Operation/working

When the horn switch is pressed the current flows through the contact breaker (7) & (13) and the solenoid circuit is completed; the laminated core (8) is magnetized. The magnet attracts the armature (1). The armature (1) moves towards the magnet core (8). Thus spindle (2) and diaphragm (5) also move towards the core (8). Thus the striker plate (3) on the moving armature (1) then returns to its normal position with the diaphragm guide spring (9) in tension. This cycle of operation sets the vibration in the diaphragm (5), about 300 vibrations per second. The tone disc (4) at the end of the horn gives a frequency of about 2000 vibrations per second. This produces the sound of the horn.

Fig 2



ELECTRIC HORN

In the vibrating type, the sound is emitted directly from the diaphragm.

In the wind-tone type, the sound from the diaphragm is made to pass through a wind pipe, which is like a bugle or trumpet.

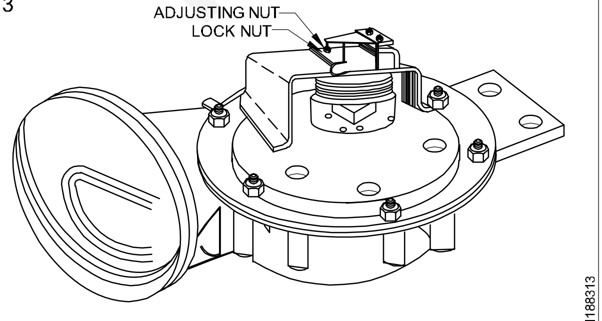
Electric power wind tone horn (Fig 3)

Principle of operation

These horns operate over the same electrical principle as the high frequency types, but a diaphragm is arranged at the inner end of the trumpet.

This diaphragm is vibrated in the centre of the air column by an electromagnet. This vibration produces sound waves which travel down the length of the trumpet, which decides the note produced by air in motion. The diaphragm is so mounted that its centre is attracted by the electromagnet.

Fig 3

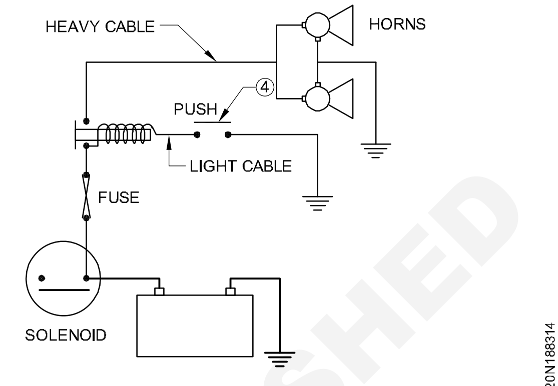


METHOD OF ADJUSTING A WIND TONE HORN

Circuit of horn & current drawn b y them (Fig 4)

This type of horn draw a heavy current intermittently than that of high frequency horns. Two such horns are connected in series with a relay and current from the battery is supplied through this relay and through a fuse of 50 amps. Each horn carries a current of 13 amps in a 12 volt system, but the adjusting amperage for these horns is from 6 amps to 8 amps.

Fig 4



TWIN - HORN CIRCUIT

Special construction

The trumpet is coiled for occupying less space in its mounting. The heavy currents are being carried by heavier and short cables and the relay current (being small) is carried by lighter cables. The relay contacts are protected by a pellet type resistance.

Air horns (Compressed air operated type)

A number of vehicles incorporate an electrically driven air pump or compressor which forces air through two or more plastic trumpets in sequence. The length of trumpets differ and so provide different notes. These are also operated via relays.

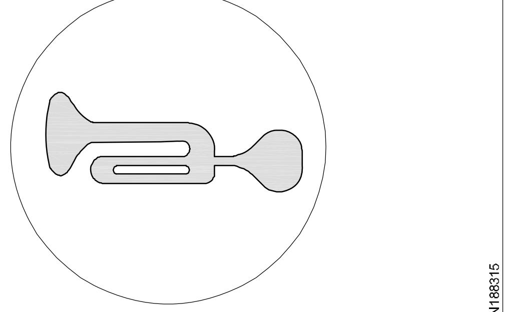
Bulb horn (Fig 5)

Application

These bulb horns are fitted to motor vehicles such as trucks (closed), lorries, auto-rickshaws in addition to electric horns.

These are generally used by drivers when electric horns fail to function due to short circuit or lack of current supply from the battery. These are also compulsory as per M.V.Act and Rules.

Fig 5



BULB HORN

Construction

In the bulb horn a reed (metallic)is fitted on a metal base and the unit mounted on the windpipe near the bigger end of the horn tube. The windpipe is coiled for space consideration. The wind pipe is bigger in diameter at one end (called mouth) and is less in diameter at the small end. A hollow rubber bulb is fitted at the small end. It is simple in construction, can be mounted near driver cabin easily and its maintenance is less. The reed can be replaced when it goes out of order.

Operation

When the rubber bulb is pressed a number of times, the air in the wind pipes pass through the reed, making it to vibrate and produce the sound. This sound is transmitted through the bigger dia. of the horn tube in a high tone to the outside atmosphere.

Horn circuit connection

The horn used in a vehicle must give good quality sound and penetration.

The relay type of horn

When more powerful horns are employed - as in the larger cars - the current needed to operate the horn can be appreciable and would cause severe pitting of the horn's contacts, due to sparking action. To obviate this it is now usual to employ a relay unit. Thus, the horn switch would require a current of 3 or 4A, but when operated would energize a solenoid which in turn would cause a pair of contacts to close so as to switch in the larger current of some 8 to 12A at 12 volts.

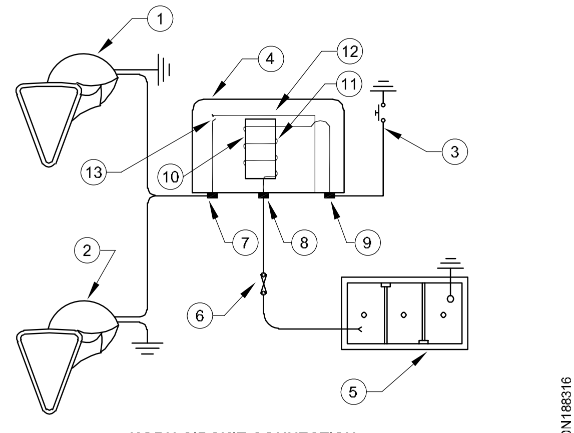
Horn relay and its description (Fig 6)

The horn relay (4) consists of a base with three terminals (7,8 & 9) marked as H,B and S. Inside the horn relay an iron core (10) is wound with a coil (11). One end of the coil (11) is attached to the 'B' terminal (8) and the other end is connected to the armature (12) which carries the contact breaker point (13). The fixed point of the contact breaker point is connected to the 'H' terminal (7). In relay the 'H' terminal (7) is connected to the horns (1 & 2), the 'B' terminal (8) is connected to the battery (5) via the fuse (6) and the 'S' terminal (9) to the horn button (3).

Operation/working

When the horn button switch (3) is pressed, the current from the battery (5) flows through the coil (11) and to the horn switch (3), thus completing the circuit. Now the iron core (10) becomes an electromagnet. The armature (12) is attracted by the iron core (10). The movement of the armature (12) closes the contact breaker points (13) together. Maximum current starts flowing to the horns (1 & 2) via 'H' terminal (7) and the horns starts produce sound waves.

Fig 6



HORN CIRCUIT CONNECTION

When the horn button switch (3) is released, the current to the horn button (1) is cut off and the circuit breaks. The iron core (10) is demagnetised and the armature (12) is pulled back by the spring tension. The point (13) gets opened and the current to horns (1 & 2) is cut off and the horn stops working.

Location of horn switch (Fig 7)

The horn switch is fitted normally at the centre of the steering wheel hub. In some vehicles the horn switch is fitted on the dashboard.

Purpose of Horn Switch

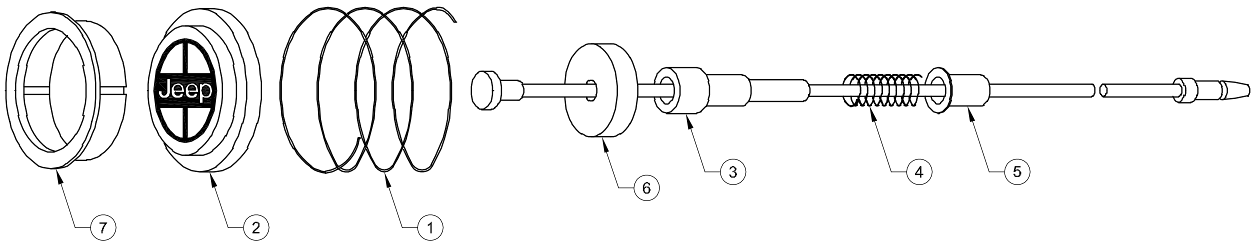
The horn switch is part of the horn circuit and it is used to operate the horn relay.

The horn switch is operated by a button or ring or lever. The horn switch does not connect the horns directly to the battery. It consists of a spring loaded button (2), horn cable (3) with spring (4) and cup (5). The cable runs through the inner steering column and the end is attached to the horn button and the other end to the 'S' terminal of the horn relay. The horn button (2) is kept disengaged from the steering wheel hub's grounded plate (6) by the spring (1). The horn button is retained in the steering wheel hub by the retainer (7).

When the horn button (2) is pressed, the button touches the grounded plate (6) thus completing the electrical circuit. When the circuit is completed, the relay comes into action and supplies maximum current to the horns.

When the horn button is released, the spring (1) pushes the button (2) back to its position. The horn circuit breaks and stops the working of the horn.

Fig 7



Sl.No	Defects/Faults	Causes	Remedies
1	Horn does not produce any sound.	1 Broken circuit wire connections 2 Defective horn points (burnt or broken off) 3 Defective switch 4 Incorrectly adjusted relay 5 Battery charge is low or dead. 6 Fuse blown off 7 Open field coil winding	Rectify. Replace. Rectify or replace. Readjust. Charge the battery. Provide new fuse of correct ampere age. Rectify.
2	Horn sounds continuously (when button switch is in the off position).	1 Short circuit of switch wire 2 Relay points stuck up	Rectify. Rectify.
3	Horn produces low improper sound (unsatisfactory tone).	1 Voltage at horn terminal is too low or too high 2 Voltage drop in the circuit excessive 3 Low battery voltage 4 Loose cover & bracket screws 5 Cracked diaphragm 6 Incorrectly adjusted horn points 7 Tone disc damaged 8 Poor electrical connections	Check & adjust generator output voltage. Rectify fault. Recharge. Tighten. Replace. Readjust. Replace. Rectify.

Wiper circuit and wind screen wiper

Objectives: At the end of this lesson you shall be able to
- **explain the need of wiper unit in vehicle**
- **describe the wiper wiring circuit and operation**
- **state the types of wiper**
- **explain care & maintenance**
- **attend defects, cause and remedies.**

Need of a wiper unit

During the rainy season when the vehicle is driven on the road the rain water falls on the wind shield glass of the vehicle. Due to this it becomes very difficult for the driver to see the road and traffic clearly. The water layer on the wind shield glass is wiped off by an accessory called wind shield wiper.

Description (Wiring circuit) (Fig 1)

The wiper circuit consists of a battery, fuse, wiper switch and a wiper unit.

The circuit consists of the following.

The battery (1) is connected to the wiper switch (2).

The wiper switch (2) to the wiper fuse (3).

The wiper fuse (3) to the wiper electric motor terminal (4).

Motor terminals (4) to the armature brush (5) and field coil (6).

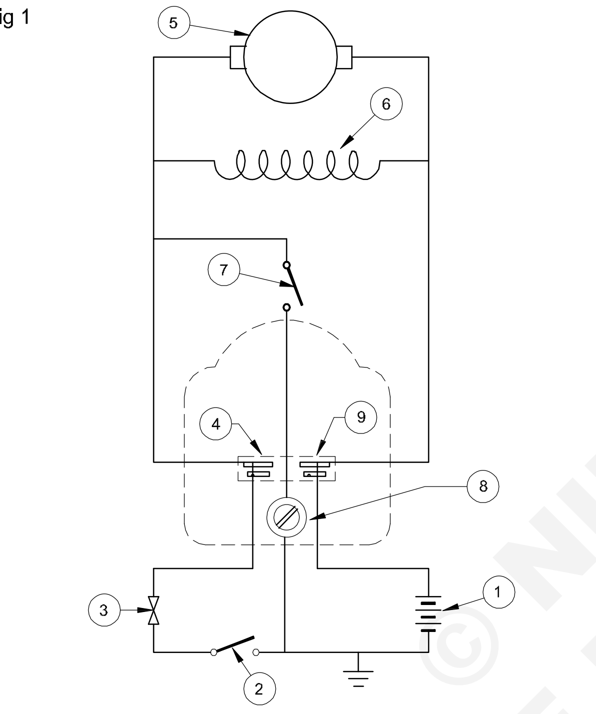
The other terminal of the wiper motor (9) is grounded.

The limit switch's (7) one end is connected to the wire from the terminal (4) and the other end to the earth screw (8).

Operation

When the wiper switch (2) is switched 'ON' the current from the battery (1) flows to the wiper motor terminal (4) via the fuse (3).

Fig 1



WIND SHIELD WIPER MOTOR WIRING DIAGRAM

The current flows to the motor field (6) and armature (5) through the brushes. The motor rotates like a starter motor.

When the wiper switch (2) is switched 'OFF' the current from the battery is cut off; so the motor stops rotation.

Windscreen wiper unit

The wiper unit is fitted at the top or bottom of the wind shield glass frame/pillar.

Types

The following types of wiper units are used in vehicles

- Hand operated
- Vacuum operated
- Compressed air operated
- Hydraulically operated
- Electrically operated.

Short description of the types

(A) Hand-operated wiper unit

These are no longer used in vehicles and have been replaced by electrically operated wiper units.

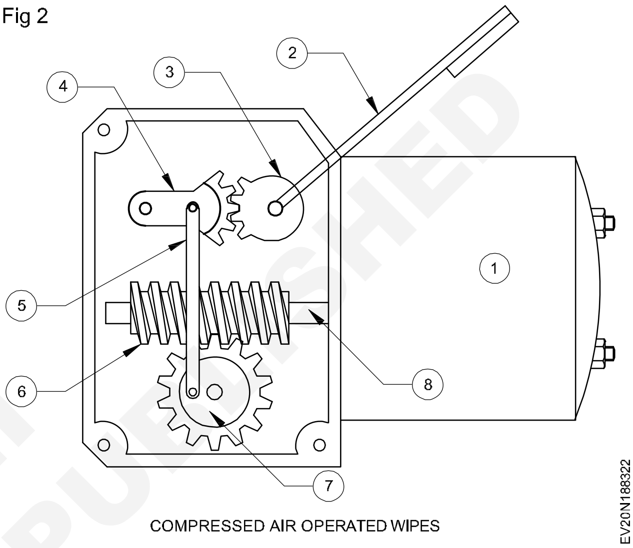
B Vacuum operated wiper

The wiper units work under the engine vacuum for their function. In certain vehicles (old models like jeep, land rover) a double AC pump (petrol) was used for operation of these wipers. The vacuum required for their operation is developed by the AC pump diaphragm having valves in its body.

C Compressed air operated wipers (Fig 2)

The vehicles fitted with air compressors use this kind of wipers. These are used in heavy motor vehicles (diesel trucks & heavy haulage vehicles)

Fig 2



COMPRESSED AIR OPERATED WIPES

D Hydraulically operated wipers

These are not popularly used in vehicles nowadays.

E Electrically operated wipers

These are widely used in all motor vehicles nowadays. Their construction and operation are described briefly in this lesson.

Explanation

The motor is of a self-switching, two-pole design, having a permanent magnet field system provided by high-energy magnets, together with a gearbox housing a two-stage reduction gear. The power from the motor is transmitted by a three-start worm gear provided on the extension of the armature shaft through a low stage reduction gear system. The drive to the blades is transmitted via a shaft and rotary link assembly. It is incorporated with a special limit switch which ensures application of regenerative braking to the armature on completion of the wiper cycle during which the control switch is turned to OFF position. It thus ensures consistent parking of the wiper arms and blades in the correct position.

Electrical connections are made to the motor via a non-reversible in-line plug and socket assembly. This type of connection ensures the maintenance of correct motor polarity during the course of motor connecting to the vehicle wiring. The working of the wiper unit is explained below.

Working

When the wiper switch is operated, the current passes to the electric motor and the motor shaft (8) rotates. A worm (6) is fixed on which the motor shaft drives the gear (7).

The gear wheel operates the cranking link (5).

The cranking link (5) operates the sector (4).

The sector (4) operates the pinion (3) with the arm shaft.

The arm shaft oscillates the arm (2) and moves the blade to and fro on the glass.

When the wiper switch (7) is put off the motor stops working.

The arm (2) returns to the edge of the wind shield glass and stops due to limit switch action.

The blade is provided for 50 to 100 oscillations per minute depending on the speed of the wiper motor and the drive arrangement of the blades.

The wind shield wiper motor consumes a current of 2.7 amps to 3.4 amps at 12 volts under normal operating conditions.

A 5-amps fuse is provided in the motor circuit.

Care and maintenance

Keep the wiper unit secure on its mounting.

Keep the electrical connection tight.

Never operate the wiper on dry glass.

Do not attempt to turn the arms on the spindle.

Fit the arms to the driving drums at the correct angle.

Replace the perished or worn wiper blade immediately.

A drop or two of machine oil should be applied to the outside cranking link and hinge pin joints.

Power window

Objectives: At the end of this lesson you shall be able to
- **explain the purpose of power window**
- **explain the operation of power window**
- **state safety for power window.**

Power windows are usually inoperable when the car is not running. This is primarily a security feature. It would be a simple thing to allow electric power windows to be operable when the ignition is turned off, however it would also make the car much easier to steal. As a compromise, some systems offer the compromise of leaving power applied to the windows until a passenger door is opened at which time the window power is removed.

Electric power windows operation

Comfort and convenience systems

This allows electric opening and closing of the windows and where fitted, sliding sunroof via a rocker switch (pushbutton switch).

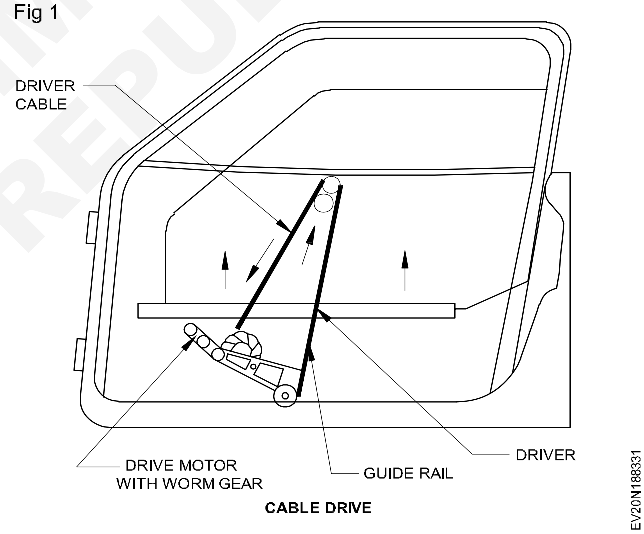
To power the window glass move up and down, a cable drive system is normally used (Fig 1). The drive motor actuates a cable via a worm gear mechanism, which will open or close the window depending on the direction of motor rotation. The self - locking effect of the worm gear mechanism prevents the window from opening in response to application of force.

Electrically - operated windows

In this system a DC permanent magnet motor is normally used to operate each window, and a three position rocker switch changes the polarity of providing up and down motion of the window. Four main window switches one for each window are installed on the drivers panel, and an isolation switch is also added to disconnect the supply to the rear windows. Two relays control the current to each motor and are powered by a common feed.

A gearbox forms the drive between the motor and the window glass and amplifies the torque sufficiently to undertake upward motion of the window, which is more difficult than the downward motion.

Fig 1



CABLE DRIVE

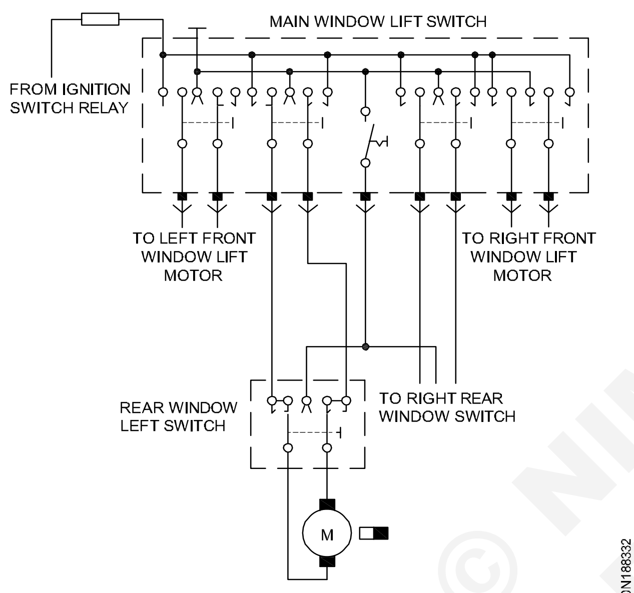
To limit the current during overloading one or more thermal cut out switches are installed in the circuit, sometimes in the motor. The cut out is opened if the operating switch is held closed when the window has reached its limit of movement or in case where free movement of the glass is arrested by vice. A main overload switch, (if used) is generally requiring for resetting after encountering an overload situation.

Fig 2 shows the circuit for electric operation of a rear passenger window, but the balance of the circuit has not been shown for simplicity. The motor in this layout is powered directly through the ignition switch. The ganged switch supplies the current with suitable polarity to rotate in the required direction during the operation of the window.

Safety

Power windows have come under some scrutiny after several fatal accidents in which children's necks have become trapped, leading to suffocation. Some designs place the switch in a location on a hand rest where it can be accidentally triggered by a child climbing to place his or her head out of the window. To prevent this many vehicles feature a driver controlled lockout switch, preventing rear-seat passengers (usually smaller children) from accidentally triggering the switches. This also prevents children from using them as toys and pets riding with their heads out windows from activating the power window switch.

Fig 2



LEFT REAR WINDOW LIFT MOTOR

Central door locking

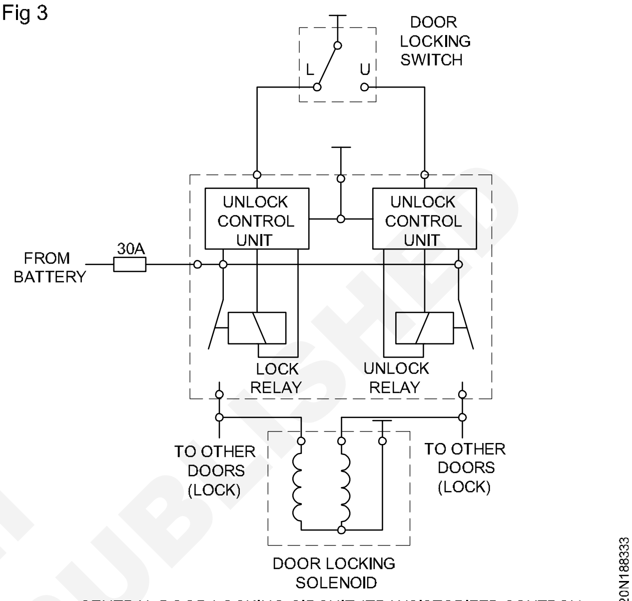
A door locking system normally locks all doors, including the tailgate or boot simultaneously when the driver's door lock is activated. When the key is turned or the driver's door lock button is operated the electrical system actuates all the locking activators installed adjacent to the door locks. Unlocking the door takes place in the similar way except the locking actuators work in the opposite direction. Both for convenience and safety reasons, a mechanical latches system is fitted which unlocks each door manually from inside the car. Various types of control are incorporated to provide the locking / unlocking pulse for operation of the actuators. In some designs two relays are used, one for locking and the other for unlocking the doors. A transistorised switching circuit controls these relays. The circuit timed by the charge - discharge action of capacitor to provide a current pulse length sufficient to actuate the locks. (Fig 3)

Now a day's almost all door actuators use small motors which, via suitable gear reduction, operate a linear rod in either direction to lock or unlock the doors. A simple motor reverse circuit is presented in Fig 4 & 5, where the driver's door switch operates the locks on four doors. More sophisticated systems are now becoming popular for consideration of safety as well as improved comfort.

Key less entry system

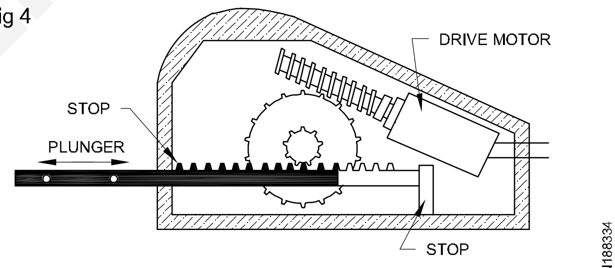
A keyless entry system is an electronic locks that controls access to a building or vehicle without using a traditional mechanical key. The term keyless entry system originally meant a lock controlled by a keypad located at or near the driver's door, which required entering a predetermined numeric code. Such systems now have hidden touch - activated keypad and are still available on certain modern cars.

Fig 3



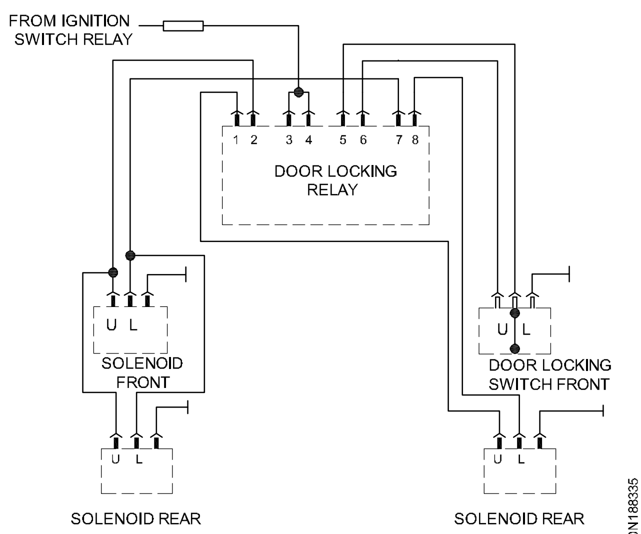
CENTRAL DOOR LOCKING CIRCUIT (TRANSISTORIZED CONTROL)

Fig 4



DOOR LOCKING ACTUATOR (USING REDUCTION GEAR)

Fig 5



EXTERNAL CIRCUIT FOR CENTRAL DOOR LOCKING

Remote control locking refers to a lock that uses an electronic remote control as a key which is activated by a handhold device.

Keyless entry system performs the functions of standard car key without physical contact. When within a few yards of the car, pressing a button on the remote car lock or unlock the doors, and may perform other functions. A remote keyless entry system which unlocks the doors.

Car anti theft system

Though most of the car models are with immobiliser, still the number of cars stolen are on raise. Gear locks considered one of the base defence a car thief would be in a very rare circumstance puts up time to break gear lock in the car.

Ignition cut off

A key operated or hidden manual switch that interrupts the power supply from the battery to the ignition system. This manual switch can be taken out by the driver once the car is locked.

Introduction to hybrid vehicle

What is a hybrid? A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/ battery. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems. Thus to be a True hybrid, the vehicle must have at least two modes of propulsion.

For example, a truck that uses a diesel to drive a generator, which in turn drives several electrical motors for all-wheel drive, is not a hybrid . But if the truck has electrical energy storage to provide a second mode, which is electrical assists, then it is a hybrid Vehicle.

These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly.

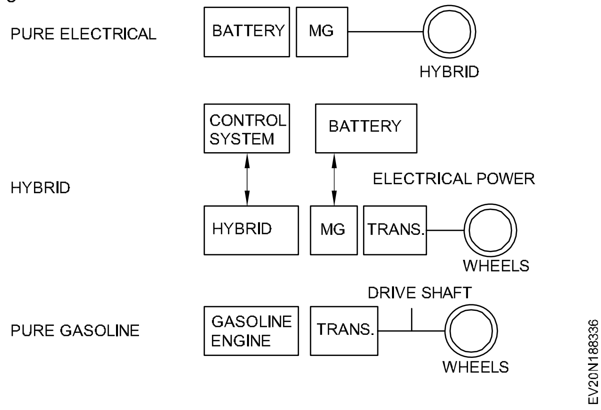
Hybrid electric vehicle (HEV)

Consistent with the definition of hybrid above, the hybrid electric vehicle combines a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor.

Fig 6 shows the components of a hybrid Vehicle that combines a pure gasoline with a pure EV.

As shown in Fig 6, a HEV is formed by merging components from a pure electrical vehicle and a pure gasoline vehicle. The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. In Honda hybrids, the M/G is connected directly to the engine. The transmission appears next in line. This arrangement has two torque producers; the M/G in motor mode, M-mode, and the gasoline engine. The battery and M/G are connected electrically.

Fig 6



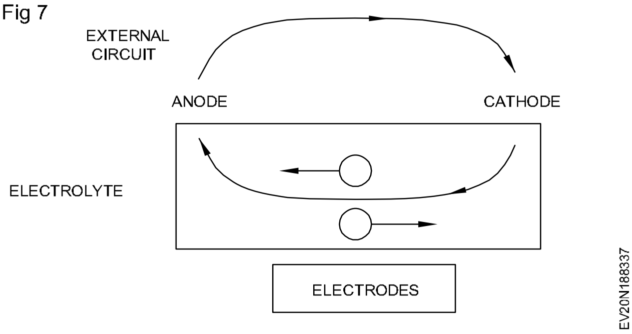
HEVs are a combination of electrical and mechanical components. Three main sources of electricity for hybrids are batteries, FCs, and capacitors. Each device has a low cell voltage, and, hence, requires many cells in series to obtain the voltage demanded by an HEV. Difference in the source of Energy can be explained as:

- The FC provides high energy but low power.
- The battery supplies both modest power and energy.
- The capacitor supplies very large power but low energy.

The components of an electrochemical cell include anode, cathode, and electrolyte (shown in Fig 7). The current flow both internal and external to the cell is used to describe the current loop.

Fig 7 shows An electrode, a circuit for a cell which is converting chemical energy to electrical energy. The motion of negative charges is clockwise and forms a closed loop through external wires and load and the electrolyte in the cell.

Fig 7



A critical issue for both battery life and safety is the precision control of the Charge/Discharge cycle. Overcharging can be traced as a cause of fire and failure.

Applications impose two boundaries or limitations on batteries. The first limit, which is dictated by battery life, is the minimum allowed State of Charge. As a result, not all the installed battery energy can be used. The battery feeds energy to other electrical equipment, which is usually the inverter. This equipment can use a broad range of input voltage, but cannot accept a low voltage. The second limit is the minimum voltage allowed from the battery.

Hydrogen is used in cars two ways: a source of combustible heat or a source of electrons for an electric motor. Hydrogen fuel cells create electricity.

Internal combustion vehicle

Hydrogen internal combustion engine cars are different from hydrogen fuel cell cars. The hydrogen internal combustion car is a slightly modified version of the traditional gasoline internal combustion engine car. These hydrogen engines burn fuel in the same manner that gasoline engines do; the main difference is the exhaust product. Gasoline combustion results in carbon dioxide and water vapour, while the only exhaust product of hydrogen combustion is water vapour.

A hydrogen vehicle is a vehicle that uses hydrogen as its onboard fuel for motive power. Hydrogen vehicles include hydrogen-fuelled space rockets, as well as automobiles and other transportation vehicles. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or, more commonly, by reacting hydrogen with oxygen in a fuel cell to run electric motors. Widespread use of hydrogen for fuelling transportation is a key element of a proposed hydrogen economy.

As of 2016, there are three models of hydrogen cars publicly available in select markets: the Toyota Mirai, the Hyundai Nexo, and the Honda Clarity. Several other companies are working to develop hydrogen cars. As of 2014, 95% of hydrogen is made from natural gas. It can be produced by thermo chemical or pyrolytic means using renewable feed stocks, but that is an expensive process. Renewable electricity can however be used to power the conversion of water into hydrogen: Integrated wind-to-hydrogen (power-to-gas) plants, using electrolysis of water, are exploring technologies to deliver costs low enough, and quantities great enough, to compete with hydrogen production using natural gas. The drawbacks of hydrogen use are high carbon emissions intensity when produced from natural gas, capital cost burden, low energy content per unit volume at ambient conditions, production and compression of hydrogen, and the investment required in filling stations to dispense hydrogen.

Hydrogen

Hydrogen does not exist in convenient reservoirs or deposits as do fossil fuels or helium and is produced from feed stocks such as natural gas and biomass or electrolyzed from water. A suggested benefit of large-scale deployment of hydrogen vehicles is that it could lead to decreased emissions of greenhouse gasses and ozone precursors. However, as of 2014, 95% of hydrogen is made from methane. It can be produced by thermo chemical or pyrolytic means using renewable feed stocks, but that is an expensive process. Renewable electricity can however be used to power the conversion of water into hydrogen: Integrated wind-to-hydrogen (power to gas) plants, using electrolysis of water, are exploring technologies to deliver costs low enough, and quantities great enough, to compete with traditional energy sources.

Hydrogen fuel-cell vehicles would generate only three-fifths the carbon dioxide as a comparable vehicle running on gasoline blended to 10 percent ethanol. While methods of hydrogen production that do not use fossil fuel would be more sustainable, currently renewable energy represents only a small percentage of energy generated, and power produced from renewable sources can be used in electric vehicles and for non-vehicle applications.

The challenges facing the use of hydrogen in vehicles include chiefly its storage on board the vehicle. While the well-to-wheel efficiency for hydrogen from the least efficient manner of producing it (electrolysis) is less than 25 percent, it still exceeds that of vehicles based on internal combustion engines.

Electrical and electronic architecture

Instead of simply being modes of conveyance as in the past, today cars are also expected to entertain and inform passengers in a safe and protected environment. Further, they are supposed to ease the complexity of driving by providing different forms of assistance to the driver. To support these increasing demands, automotive - specific buses and gateways. Moreover, emerging functionally like car - to - car and car to infrastructure communication, as well as infotainment and driver assistance systems have increased the number of vehicle components with communication interfaces to the outside world. Such complex E/E and connected automotive architectures are increasingly vulnerable to malicious attacks and recent this topic considering security side - by - side with safety is crucial for the overall reliability of an automotive E/E architecture, since s vulnerable electronic component might undermine the passenger's safety to the extent as a faulty one. However, in the highly competitive automotive domain, the cost of security features often pose an obstacle to their adoption.

Immobilizer system

Objectives: At the end of this lesson you shall be able to
- **description of immobilizer system**
- **state immobilizer circuit.**

Engine immobilizer

The engine immobilizer is a theft protection system that prevents someone from starting the engine with an incorrectly coded key.

> **Do not shield the car keys with metal objects. This may prevent the receiver from recognizing that key as a valid one.**

Engine immobilizer system description

The engine immobilizer system is designed to prevent reduces motor vehicle theft.

This system uses a transponder key ECI that stores the key codes of authorized ignition keys. If an attempt is made to start the engine using an unauthorized key, the ECU sends a signal to the ECM to prohibit fuel delivery and ignition, effectively disabling the engine.

When the ECU detects that the unlock warning switch is ON, the ECU provides current to the transponder key coil and produces a faint electric wave. A transponder chip in the key grip receives the faint electric wave. Upon receiving the faint electric wave, the transponder chip outputs a key ID code signal. The transponder key amplifier amplifies it, and then the signal is transmitted to ECU. The ECU matches the key's ID code with the vehicle's this signal, the transponder key amplifier amplifies it, and then the signal is transmitted to the ECU. The ECU matches the key's ID code with the vehicle's ID code, which was previously registered in the ECU and then communicates the results to the ECM using the SFI communication.

After the identification results show that the key's ID code matches the vehicle's ID code and the ECU has confirmed their match:1) the immobilizer system is cancelled and the engine starting controls (fuel injection control and ignition control) enter standby mode; and 2) the ECU transmits a security indicator signal that communicates "indicator OFF" to the multiplex network body EXU. Then, the multiplex network body ECU turns OFF the security indicator lamp.

Immobilizer circuit (Fig 1)

Car alarms

There are several alarm systems that will serve to deter or discourage vehicle thefts and alert others of forced entry into the car. You need sure that these noise speakers should be installed in such a way as not to be easily accessible on glance, else will be forts disabled by them.

Steering lock

A long metal bar with a lock that fits on the steering wheel and is designed to prevent the steering wheel from turning, steering wheel locks are effective.

ICAT

ICAT means Intelligent Computerised Anti - Theft system under this system the car starts only when car starts only when the sensor in the vehicle accepts the chip in the key. Even sensors creates alarms buzz, when someone tries to insert the fake key in a car.

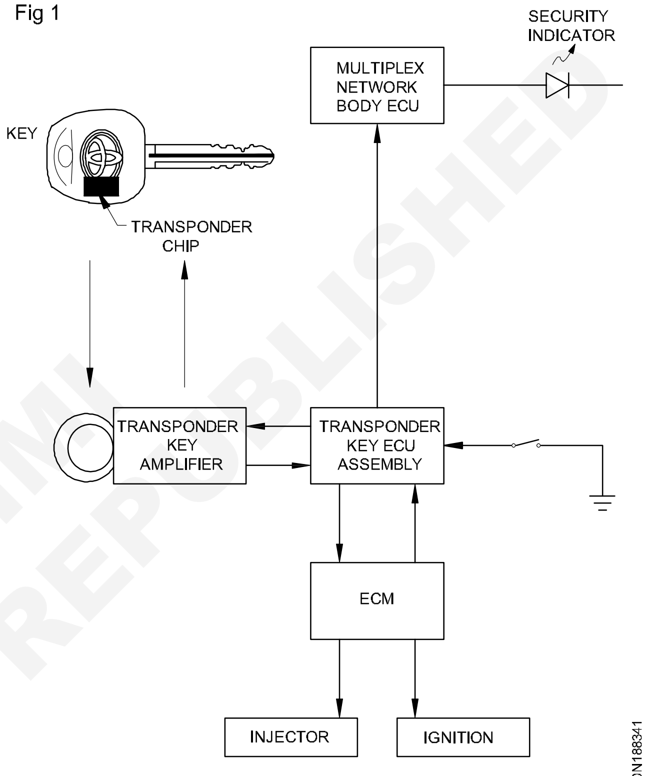
GPS tracker

A GPS facility, which can help tracking a stolen car. In fact, it can also alert a misuse of your car by any service station.

Tyre lock

Tyre lock device is very difficult to lock and unlock the car wheel, but its cost is very lower than other anti theft system device.

Fig 1



ENGINE IMMOBOLIZIER-SYSTEM DIAGRAM

Audio and Video system

Objectives: At the end of this lesson you shall be able to
- **describe head unit**
- **describe the amplifier**
- **describe the speaker**
- **state the car video system**
- **state the Navigation system.**

Head unit (Fig 1)

A car audio system uses separate electronic components - a radio tuner, DVD player, preamp, amplifier - connected by various cables. The head unit performs two main functions are controlling the overall system volume and the various audio and video sources in a vehicle.

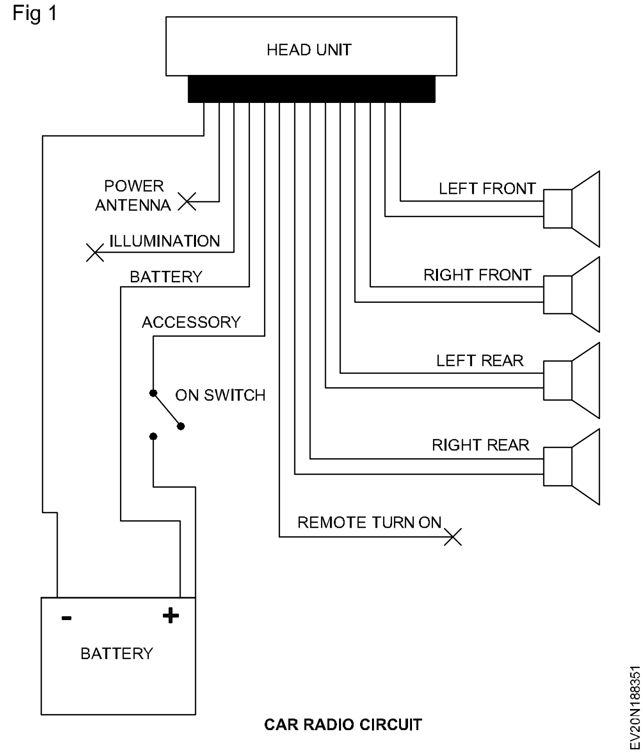
Head units can also be used to control media players like the iPod or navigate the content of a USB flash drive that's connected to the stereo system. Head units with Blue tooth audio can also play music that's streamed wirelessly from a compatible mobile phone.

In addition to controlling the system's volume, head units usually include basic tone controls such as bass and treble to tailor the sound to the listener's taste. Many audio systems also include signal processing that automatically adjusts the volume, depending on the ambient noise in a moving vehicle. Some audio systems also have a separate subwoofer and subwoofer level controls.

The amplifier (Fig 2)

A car stereo system has to have an amplifier to increase the power of an audio signal so its strong enough to move the speakers and create sound. Amplification is a two stage processes handled by a preamp and a power amplifier. The preamp is usually housed inside the head unit and

Fig 1



CAR RADIO CIRCUIT

takes data from a radio, CD player or other audio source and prepares it for the power amplifier. This process includes slightly boosting the audio signal, which makes it compatible with the input of the power amplifier and ensures that its resistant to noise that can radiate from other electronics in a vehicle. The power amplifier then takes the preamp's low -level single and significantly boosts it so it can move the speakers and create sound. Many head units have a small, built - in low power amplifier that can "drive" smaller speakers. This allows the audio system to be reduced to just a head unit and a few speakers. But better sound requires more power. So higher - end systems have separate power amplifiers that are mounted away from the head unit due to their size and the heat they generate.

The speakers (Fig 2)

Speakers take an amplified electrical signal and convert it into mechanical energy that moves the speaker cone back and forth to create sound. Sound is essentially vibrations in the air that we hear, and a speaker cone creates these vibrations. The human ear hears these vibrations in a frequency range from about 20 hertz (very low bass) to 20,000 Hz (very high notes).

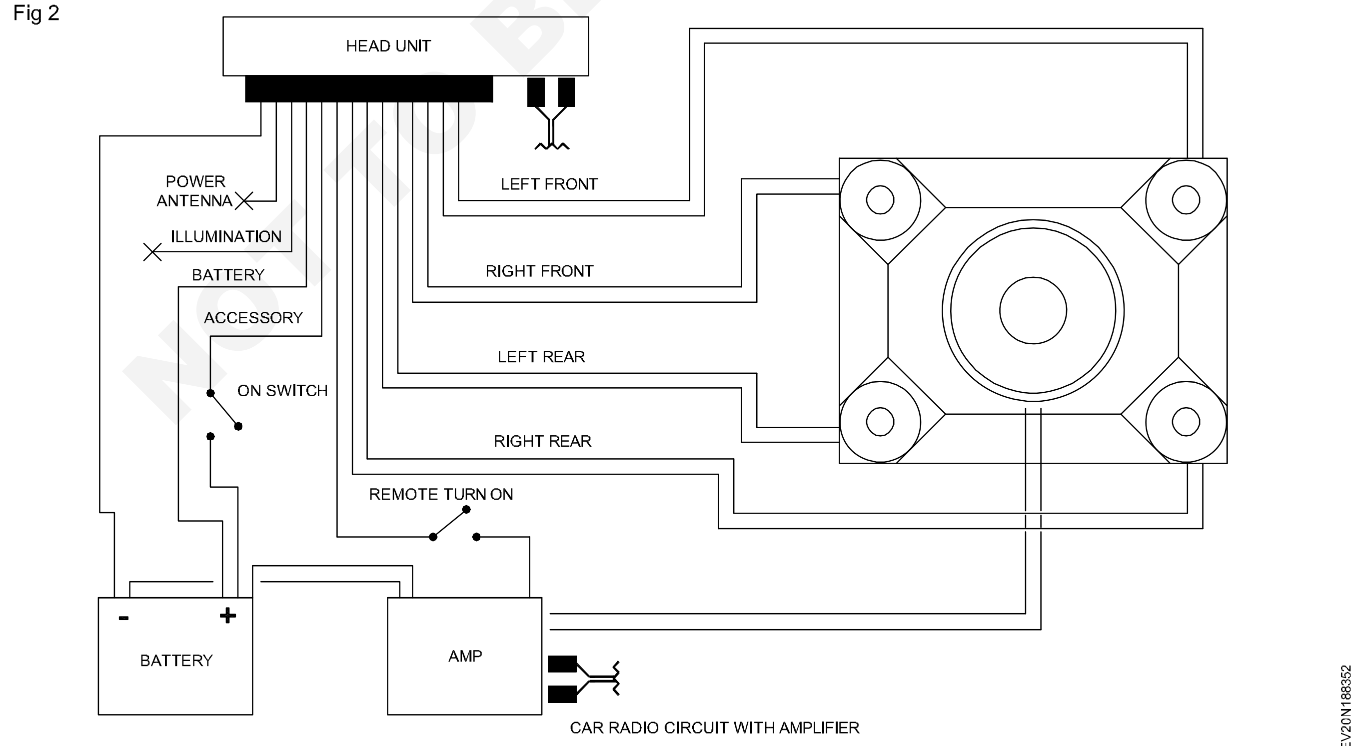
The most basic automotive speakers are designed to be "full range" to cover the entire frequency range. But by trying to cover the entire frequency spectrum, bass response is generally nonexistent and higher frequencies are dull. You can get more accurate sound reproduction by using an assortment of speakers dedicated to reproducing a smaller range of sound.

Woofers and subwoofers are large speakers designed to reproduce only low frequency bass sounds. The aptly named midrange drivers handle the middle range frequencies. Some systems take it one step further and use a specialized Midas driver to handle the troublesome frequencies between low bass and midrange. Tweeters are the smallest of the specialized drivers and reproduce the upper treble frequencies.

Car videos

A car video system uses separate electronic components. The LCD monitor is connected with DVD players, speakers and rear view camera. In many cars sound system for used two speakers of different sizes are combined on one frame to create two way speaker.

Fig 2



CAR RADIO CIRCUIT WITH AMPLIFIER

For example a coaxial speaker mounts a small tweeter directly above and on the same axis as a small woofer. That create a full range speaker from two speaker drives.

Car Navigation system:- Vehicle Navigation system is used for find the vehicle position on a road. Satellite Navigation system used for constellation of satellites that provide worldwide navigation location and timing services.

The satellite navigation system is a system based on a world wide network of artificial satellites. The satellites send reference information from navigation. The satellite navigation system is autonomous. The vehicle navigation equipment fitted in vehicle dash board, which is visible to the driver.

Air bag and seat belt

Objectives: At the end of this lesson you shall be able to
- **State the need of air bag and seat belt**
- **State the functions of seat belt**
- **State the types of seat belt restraints**
- **Describe the passive seat belt restraints**
- **State safety points for drivers and passengers**
- **Describe the air bag system - Describe the air bag system warning light**
- **Describe the multi stage air deployment**
- **Describe the seat belt pre - tension.**

Need of air bag and seat belt

Vehicle safety is one of the most important considerations of the average vehicle buyer today. In simple terms, safety sells vehicles. Therefore, vehicle manufacturers have spent a large amount of money in engineering improved safety systems. Passive restraints at the present time include the driver's air bag, side - impact air bags, air bag curtains, and seat belt tension. The seat belt and air bag systems are intended to work together to protect the driver and passengers.

Functions of seat belts

An air bag equipped vehicle, conventional seat belts perform these functions.

1 Hold the occupants in proper position when air bags inflate.

2 Reduce the risk of injury in a less severe collision severe collision in which the air bags do not deploy.

3 Reduce the risk of occupant ejection from the vehicle and thus reduce the possibility of injury.

State types of seat restraints

All vehicle manufacturer sold their vehicles with passive restraints

Passive restraints may be air bags or automatic seat belts. Most vehicles with air bags also have active restraints

These are

1 Passive restraints

2 Active restraints

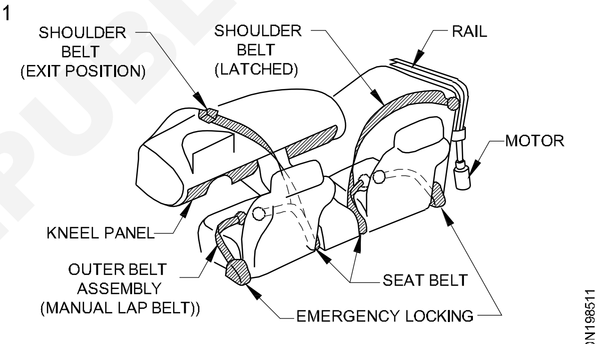
Passive restraints

Operate automatically with no action required by the driver. Active restraints require action by the driver or passengers before the restraints provide any protection

Passive seat belt restraints

A passive seat belt system uses electric motors to automatically move the shoulder belts across the driver and front seat passenger. The upper ends of the belts are attached to a carrier mounted in a track just above the top of the door frame. The other end of each shoulder belt is secured by an inertia lock retractor that is mounted in the centre console. When a front door is opened. The outer end of the shoulder belts move forward in the door tracks to allow easy entry and exit from the vehicle (Fig 1). When the door is closed and the ignition switch turned on, the shoulder belts move rearwards in the door tracks to secure the front seat occupants. The active lap belt must be buckled by the driver or passenger and must be worn with the shoulder belt

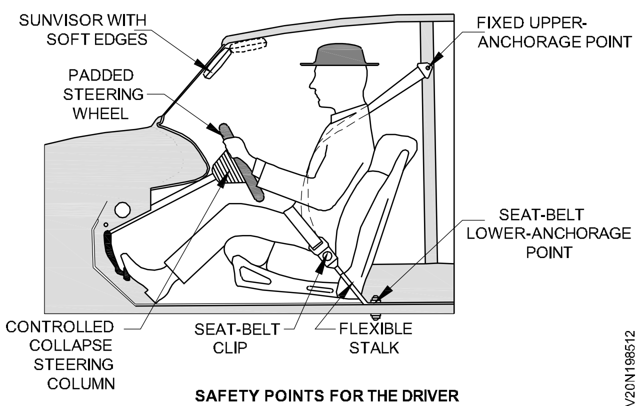
Fig 1



A PASSIVE SEAT BELT RESTRAINT SYSTEM

Safety points for driver and passenger (Fig 2)

Fig 2



SAFETY POINTS FOR THE DRIVER

Some of the better modern front seats embody an adjustable lumber support in the backrest. Where the seat must hinge forward to give access to the rear compartment, a catch is usually fitted on recent models to secure it in a collision. Fascias and parcel shelves are now well padded to minimize injury, and some inside mirrors are designed to break from their mountings on impact, instead of shattering.

Comfort

The seat belt anchorage, which incorporates the retaining clip, should be so located that the belt can be put on and taken off quickly, using only one hand. The belt must fit comfortably and must not slip off or cut into the wearer. A settled, restful position reduces strain and fatigue a considerable safety factor.

Air bag system components

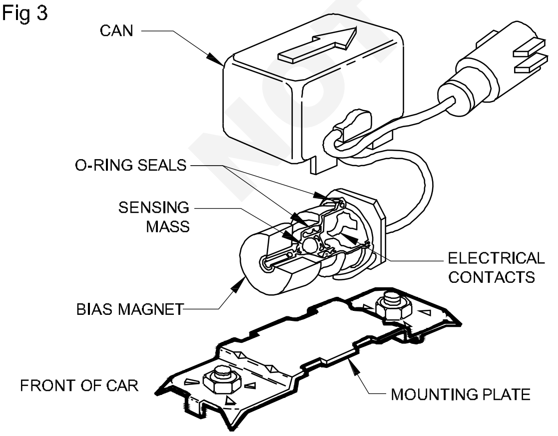
Understanding air bag system components is essential to comprehend the complete system operation. A knowledge of air bag system operation is absolutely necessary to maintain, diagnose and service air bag systems quickly and accurately.

Sensors

Some air bag system sensors contain a set of normally open, gold plated contacts and a gold plated ball that acts as a sensing mass (Fig 2). This ball is mounted in a stainless steel - lined cylinder. A magnet holds the ball about 1/8 in away from the contacts. When the vehicle is involved in a collision of sufficient force, the ball moves away from the magnet and closes the switch contacts. These contacts remain closed for 3 milliseconds before the magnet pulls the ball away from the contacts. The sensor is completely sealed in epoxy to prevent contaminants and moisture from entering the sensor. Sensors must be mounted with the forward marking on the sensor facing toward the front of the vehicle. To operate properly, sensors must be mounted in their original mounting position and sensor brackets must not be distorted.

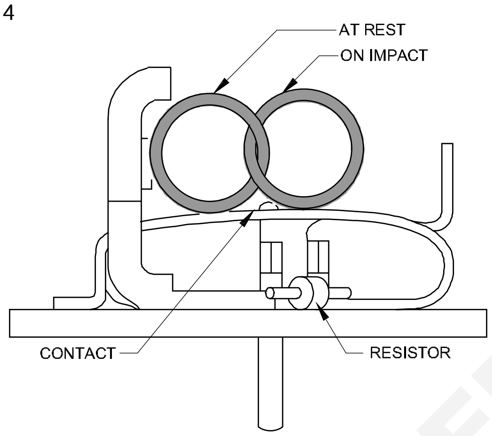
Some air bag sensors contain a roller on a ramp. This roller is held against a stop by small, retractable springs on each side of the roller. If the vehicle is involved in a collision of sufficient force, the roller moves up the ramp and strikes a spring contact completing the electrical circuit between the contact and the ramp. (Fig 3)

Fig 3



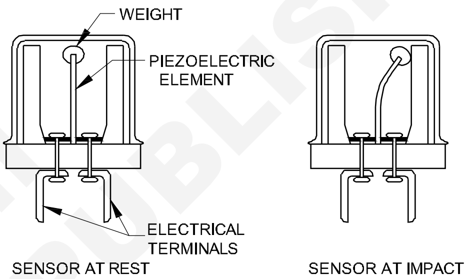
Some air bag sensors contain an accelerometer that contains a piezoelectric element (Figs 4 & 5). If the vehicle is involved in a collision, this element is distorted. The voltage signal from the sensor to the air bag system module depends on the force of the collision and the amount of element distortion.

Fig 4



A MASS-TYPE AIR BAG SYSTEM SENSOR

Fig 5

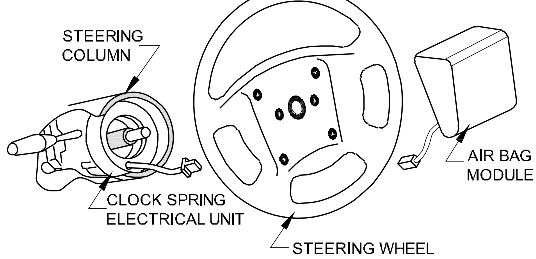


AN ACCELEROMETER-TYPE AIR BAG SYSTEM SENSOR

Inflator module

The inflator module contains the air bag, air bag container and base plate, inflator, and trim cover. The retainer and base plate are made from stainless steel and are riveted to the inflator module. The air bag is made from porous nylon and some air bags have a neoprene coating. The purpose of the inflator module is to inflate the air bag in a few milliseconds when the vehicle is involved in a collision. A typical driver's side air bag has a volume of 2.3 cubic feet. The driver's side air bag inflator module is usually retained with four bolts in the top of the steering wheel. (Fig 6)

Fig 6



A DRIVER'S SIDE AIR BAG INFLATOR MODULE

Air bag system warning light

The air bag system warning light is mounted in the instrument panel. The air bag system warning light should come on when the ignition switch is turned on. If the ignition switch is left in the on position without starting the engine or when the engine is started, the air bag system warning light should flash a few times and then go out. This light action indicates the air bag system is satisfactory. If the air bag system warning light is on with the engine running, there is an electrical defect in the air bag system and the air bag system may not be operational in a collision.

Side impact air bags (Fig 7)

Some vehicles are now equipped with side impact air bags that protect the driver or passengers during a side collision. The side impact air bag systems are separate from the driver's side and passengers side air bag systems. Side impact air bag systems have their own sensors and ASDM. (Adaptive Security Device Manager). Separate ASDMs are usually installed for each side impact air bag. The ASDMs for the side impact air bags may be under the front seats or behind the B-pillar panels.

Left and right side ASDMs for side impact air bags are not interchangeable.

Some vehicles have a side impact air bag that deploys out of the door panelling. In other systems, the side air bags are mounted in the side of the seat back near the top. Some vehicles have a side air bag curtain that deploys out of the headliner just above the doors. This type of air bag protects the front and rear seat occupants from head injury.

Smart air bag systems

Some air bag systems have a switch in the passenger's side of the front seat. This switch informs the ASDM if anyone is sitting in the front passenger seat or not. If no one is sitting in this seat, the passenger's side air bag does not deploy if the vehicle is involved in a collision. Some smart air bag systems can detect from the passengers weight. If a child below a certain weight is occupying this seat, the air bag does not deploy. In some air bag systems, the weight of the person in the passenger's side air bag deploys.

On some smart air bag systems, if a rearward facing child's seat is place in the front passenger's seat, the passenger's side air bag does not deploy.

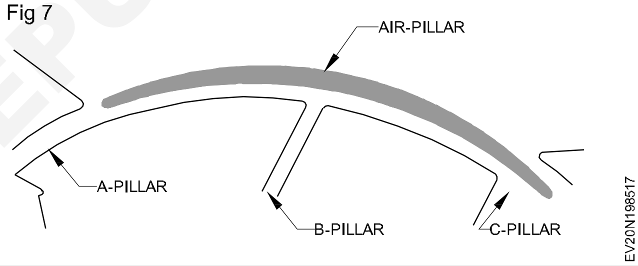
If a child in a rearward facing child's seat is placed in the front passengers seat and the air bag deploys, the deployed air bag may force the seat and the child against the vertical part of the front seat causing the child to suffocate.

Some vehicles have a small knee air bag that deploys out of the dash in front of the drivers knees. This air bag protects the driver from knee injury and also keeps the driver from sliding under the seat belt during an accident. This action maintains the driver in a better position to be protected by the driver's side air bag.

Seat belt pre tensioners

Some vehicles have seat belt pre tensioners on the seat belts. The pre tensioners contain materials similar to a single stage air bag inflator module. The pre tensioners may be mounted on the buckle side of the seat belt (Fig 7). If the front air bags are deployed, the ASDM also fires the pre tensioners. A thin cable sis connected between the buckle and a small piston in the pre tensioner. When a pre tensioner is fired, the piston moves up the cylinder and the cable pulls the buckle tight. This action holds the occupant tightly against the seat and helps to prevent injury.

Fig 7



Global positioning satellites (GPS)

Objectives: At the end of this lesson you shall be able to
- **state the uses of global positioning satellites (GPS)**
- **describe working of GPS**
- **describe the uses of crash sensors**
- **describe on integrated communications system**
- **describe the uses of proximity sensor**
- **describe the uses of reflective displays**
- **describe triangulation / trilateration**
- **describe telematics**
- **describe networking & multiplexing.**

Global positioning satellites (GPS)

A system known as a Global Positioning System, or GPS can be used to determine the exact location of a vehicle on the earth's surface.

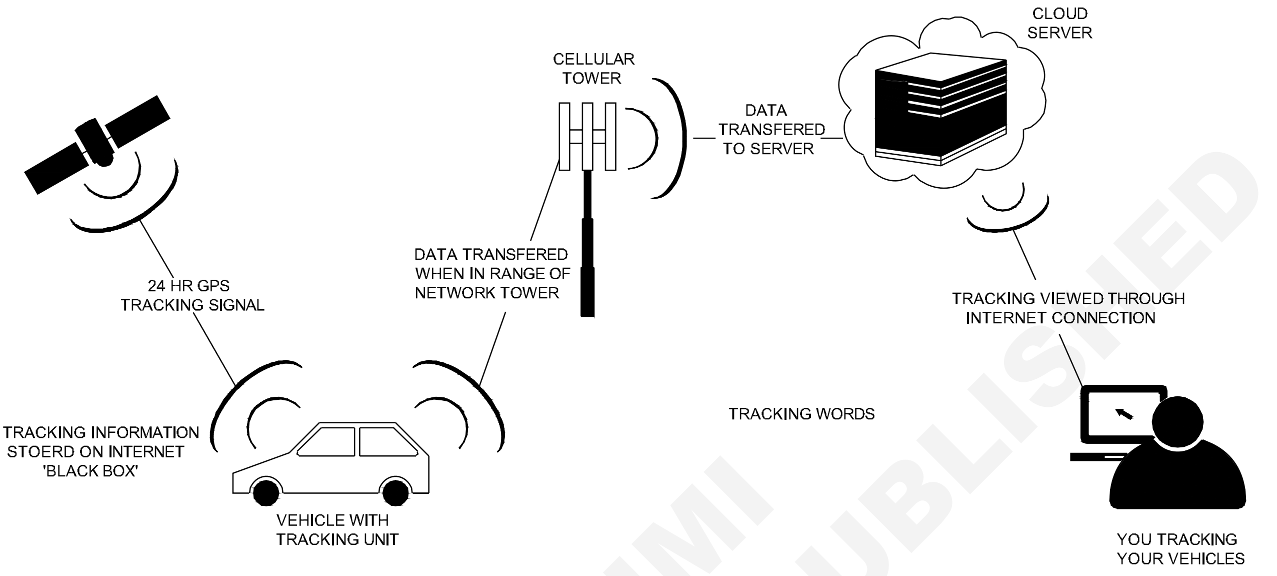
Thousands of satellites, service a variety of purposes, are continually in orbit high above the earth. The use of satellite technology in vehicle systems provides an ever increasing array of options for vehicle manufacturers. It is an area of automotive technology that increases the flexibility and power of many onboard systems.

Satellite technology is used in: Navigation, vehicle tracking, vehicle theft recovery, communication and internet access.

Mountains, tunnels, large buildings and other objects can interfere with satellite communication and make it unreliable. Most vehicle tracking systems can work very accurately without satellites once their initial position has been determined. On board sensors can be used to keep track of the exact vehicle location.

Working of global positioning system (Fig 1): The basis of the GPS is a constellation of satellites that are continuously orbiting the earth. These satellites, which are equipped with atomic clocks, transmit radio signals that contain their exact location, time and other information. The radio signals for the satellites, which are monitored and corrected by control stations, are picked up by the GPS receiver. A GPS receiver needs only three satellites to plot a rough, 2D position, which will not be very accurate. Ideally, four or more satellites are needed to plot a 3D position, which is much more accurate.

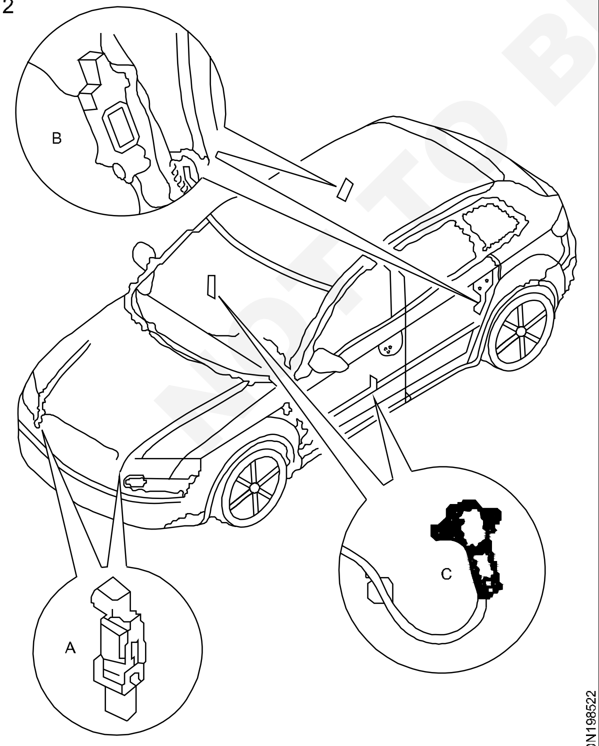
Fig 1



WORKING OF GLOBAL POSITIONING SYSTEM

Crash sensor (Fig 2): Sensors are located behind the front bumper, headlights, dash and doorsill or 'B' pillar. Some manufacturers also place sensors with the electronic control unit.

Fig 2



LOCATION OF CRASH SENSORS

Crash sensors can be fitted in various positions throughout the vehicle. Their location depends upon the direction of deceleration they are designed to detect.

Some manufacturers place the sensors within the electronic control unit. Others are located behind the front pumper, headlights and dash.

Side impact sensors are located in the doorsills or "B" pillar. They will inform the SRS control unit of side impact and whether to deploy the left or right side air bags.

When the sensors indicate that a predetermined deceleration rate has been exceeded and it is from the appropriate direction, the SRS control unit deploys the relevant air bags.

If the collision is from the front, the driver and passenger air bags will deploy.

If the collision is from the side, the sensor determines whether the seat mounted air bag, or curtain air bags for one side of the vehicle will deploy.

With more refined designs, the passenger air bag deploys only if there is an occupant in the seat. Deployment can also depend on the weight of the occupant and whether the passenger air bag switch, if fitted, is turned on.

To prevent incorrect and unnecessary deployment, systems include a safing sensor mounted within the SRS control unit. The SRS control unit will only pass current through the squib if both the safing sensor and a crash sensor indicate simultaneously that a predetermined deceleration rate has been exceeded.

The SRS warning light is illuminated, and stays on, if a fault is detected in the system.

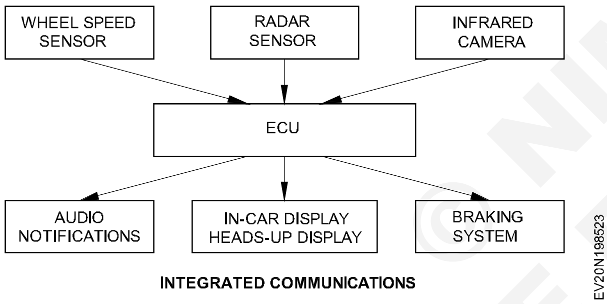
Capacitors within the SRS (Supplemental Restraint System) control unit are used to store electricity and act as a backup power supply. If a vehicle has its battery destroyed or disconnected in an accident, the capacitors supply the electricity required to keep the SRS system operational.

Some seat mounted side impact air bags also operate without electricity. When the side of a vehicle is crushed inwards, a detonator mounted on the lower outside edge of the seat is detonated. Pyrotechnic tubes connect the detonator to the air bags, which in turn ignite the squib. Many vehicles use two stage side impact bags. This provides protection to the upper chest over a more extended time.

Integrated communications (Fig 3): Modern vehicles integrate audio, video and communication systems into a network.

Modern vehicles integrate audio, video and communication systems into a network. This allows for a high quality, compact and ergonomic system, which combines entertainment features with simple operation.

Fig 3



INTEGRATED COMMUNICATIONS

Controls are centralized with hardware, such as CD stackers, and DVD players located remotely.

Communication between components uses a combination of hard wiring and data buses.

With data being used, audio messages can be broadcast over the audio system that relate to other vehicle systems. For example, a voice message can say "the park brake is on" or "left rear tire is under inflated".

The system allows for features such as the interruption or replacement of audio entertainment when there is an incoming phone call, or simply muting the audio to allows for safer driving.

The music played on a system usually comes from one of several sources. Magnetically on a cassette tape, optically on a CD or DVD, by radio frequency from radio stations or satellites, or from other portable devices.

The information is decoded or processed by the control unit and outputted to drive speakers located throughout the vehicle.

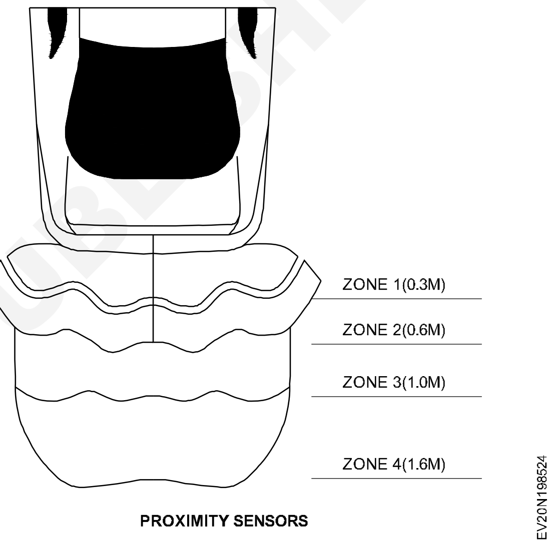
Another function provided by the body control unit is that of speed dependant volume. The control unit has an input from the vehicle speed sensor, which allows it to gradually increase audio system volume proportionally with road speed. As speed and therefore engine and road noise increases, the audio volume will increase. As speed decreases the audio volume will decrease.

Viewing screens for onboard TV, DVD and games can be located in the dash, however, if the screen is viewable by the driver it must disable when the vehicle is in motion. Other mounting points are from the roof or integrated into the rear of seat headrests.

Control units can be hard wired, or wireless using an infrared remote control.

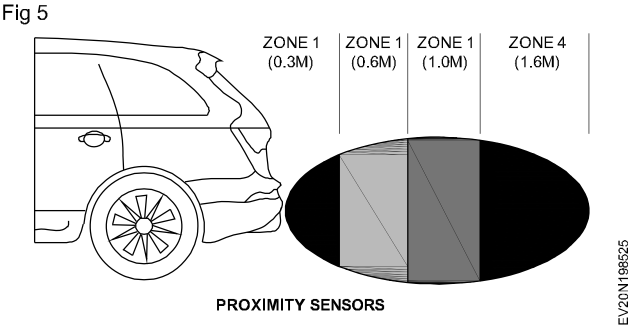
Proximity sensors (Figs 4 & 5): Proximity sensors are mounted in the front or rear bumpers. The control unit determines the distance between the sensor and an obstacle by measuring the time taken for sound waves to leave and return to the sensor.

Fig 4



PROXIMITY SENSORS

Fig 5



PROXIMITY SENSORS

To allow for safer parking, proximity sensors can be mounted in the front or rear bumpers.

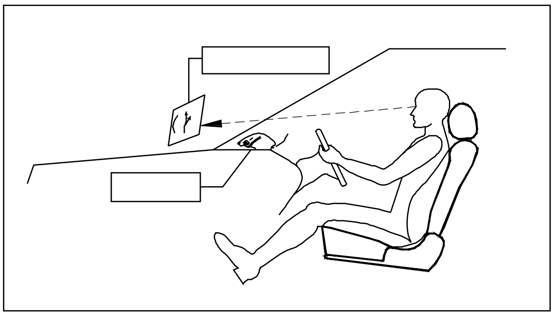
These colour matched sensors emit ultrasonic sound waves that the human ear cannot detect.

These piezo sensors are used to transmit and receive coded sound waves. The control unit determines the distance between the sensor and an obstacle by measuring the time taken for the sound wave to leave and return to the sensor. Normally 4 sensors are used to allow for full coverage across the width of the vehicle.

Proximity to obstacles can be indicated by separate audible and visual alarms, or by integrating warning sounds with the vehicles audio system. If a trailer is attached to a coupling, the rear sensors are disabled automatically when the harness plug is inserted. Front sensors can be disabled manually in start or stop and go traffic.

Reflective displays (Fig 6): Reflective displays use a mirror embedded in the dash so the instruments appear further away than they are actually. This way the drivers focal point changes less when looking from the road to the instruments and back.

Fig 6



REFLECTIVE DISPLAYS

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Conventional instrument panels require the driver to change the line of sight and their visual focal length to read information on the instrument cluster. This means the driver is looking away from the road for a significant distance when travelling at speed.

Reflective displays are mounted within the dash panel. They use a mirror embedded in the dash, forward of the driver, to reflect an image of the instrument cluster. The actual instruments are hidden in the dash and it is a reflected view of them that the driver sees.

This has the effect of the instruments appearing to be located further away than they actually are. The benefit of this system is that the drivers focal point changes less when looking from the road to the instruments and back.

Triangulation / trilateration

Trilateration or triangulation is the system whereby a vehicles location is determined by forming a triangle with a group of four or more satellites.

The Global Positioning System or GPS uses a group of at least 24 satellites orbiting approximately 12 600 miles or 20 200 kilometers above the earth. The vehicle is equipped with a receiving antenna and computer system. The GPS receiver on the vehicle has to locate four or more of these satellites, determine the distance to each, and use this information to establish its own location. This operation is based on a mathematical principle called "trilateration".

"Trilateration" in three dimensional space is quite complex. For ease of understanding, the term that is generally used in the automotive industry to describe how the GPS positioning system operates, is "Triangulation". "Triangulation" is the process of finding the position of an unknown point based on forming a triangle with two known points.

For simplicity, the dimensions used to determine these points are commonly known as latitude, longitude and elevation.

If a group of three satellites are taken to form a triangle, 12 600 miles or 20 200 kilometers above the earth, the shape and size of this triangle will never change.

Equally any fixed point on the surface of the earth will triangulate with the satellites. The numbers of fixed points are infinite.

What the GPS does to work, is form many triangles with triangulate with the satellites. The numbers of fixed points are infinite.

What the GPS does to work, is form many triangles with different pairs of satellites.

Each satellite has an atomic clock onboard and regularly transmits a unique radio frequency signal simultaneously with all other global positioning satellites. The RF signals travel out across space in all directions.

The speed at which RF signal travels in space is approximately 186,000 miles or 300,000 kilometers per second, the speed of light in a vacuum.

Each of these transmitted signals will reach the GPS antenna of the vehicle. The time taken for the RF signal to travel from each satellite and arrive at the vehicle is dependent on the distance each satellite is from the vehicle. The greater the distance the longer the time taken.

The vehicle's onboard GPs system needs to know three things to determine the location of the vehicle.

The time it takes for the signal to travel from the satellites to the vehicle.

The location of each satellite.

And accurate time.

Given these facts, enough information is available to form a three dimensional figure of a pyramid with a triangle base.

The base of the pyramid is formed by the location of the satellites and the apex of the pyramid is the location of the vehicle on the earth, a point derived from triangulation of the known points of the base.

The GPS equipment knows that all of the apexes (the position of the GPS) of each triangle must be in the same literal position.

Telematics

Automotive telematics is a satellite based system that combines two way communication and information technology within the vehicle.

Using this system allows for: vehicle tracking, monitoring of onboard systems, messaging, travel information, entertainment, security, safety and fleet management systems which monitoring of onboard systems, messaging, travel information, entertainment, security, safety and fleet management systems which monitor information such as location, distance travelled, speed, stops and fuel usage.

A vehicle manufacturer may offer telematics as a service to its customers. The benefits of this can include: the location & immobilization of a stolen or lost vehicle, notification to emergency services after SRS deployment, engine shut down and door unlocking in the event of a severe accident, roadside assistance and remote diagnosis.

Car becomes a connected mode on the network

Network & multiplexing

A multiplex network reduces the number of wires in the wiring harness and greater vehicle content flexibility.

Even the most basic vehicles include many electronically controlled systems. If each electronic system had its own ECU, harness and sensors, the weight of the added components would negate any efficiency it provided. A vehicles multiple electronic systems could require over 1 mile or 1.6 kilometers of insulated wiring, consisting of around 1000 individual wires and many terminals.

One solution to the problem is the use of a system that integrates sensors into a common wiring harness by combining all the individual systems, where possible, into a multiplexed serial communications network, so they can share the information.

An added advantage of such a system is that if there is less wire and connections there is less chance of dirty connections causing faults.

This system is referred to as a controlled Area Network BUS or BUS and it uses two thin wires to connect, or multiplex, all the control units and their sensors to each other. The output devices are referred to as nodes.

The advantage of a multiplex network is that it enables a decreased number of dedicated wires for each function, and therefore a reduction the number of wires in the wiring harness, reduced system cost and weight, improved reliability, serviceability and installation.

In addition, common sensor data such as vehicle speed engine temperature etc. are available on the network, so data can be shared, thus reducing the number of sensors.

Also, networking allows greater vehicle content flexibility because functions can be added or modified through software changes.

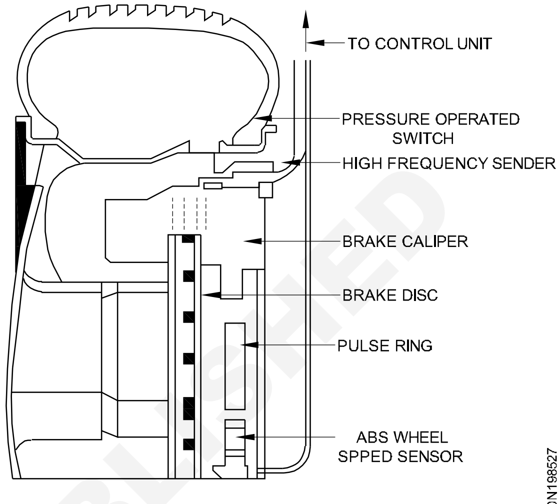
Other control units can be added to the system by simply connecting them to the network.

A diagnostic tool can be connected to the CANBUS to extract operation information to assist in diagnosis and fault.

Tyre pressure warning

Poorly inflated tyre causes loss if control and increase fuel consumption. Fig 7 shows the layout and circuit of the tyre pressure warning system. The main idea is to give the driver warning of reduced pressure. There are three basic components used in the system. A pressure operated switch is mounted in the wheel rim, the contacts of which close when pressure falls. This is recognized by a high frequency pulse transmits an appropriate pulse to the electronic evaluator. When the pressure drops below the set valve, the switch contacts close. This causes the high frequency pulse to interrupt its stream of pulses to the evaluation circuit so that the warning lamp lights up. The system measures the tyre pressure with an accuracy of ± 5kPa. The design of the switch is such that changes in the temperature of the air in the tyre do not cause false readings. If a tyre pressure warning system is used in conjunction with wheels fitted with limp home tyres.

Fig 7



HIGH FREQUENCY SENDER

Controller area network (CAN bus): CAN bus is a robust vehicle bus standard designed to allow micro controllers and devices to communicate with each other's applications without a host computer. It is a message based protocol, designed originally for multiplex electrical weiring with in automobiles to save on copper, but can also be used in many other contexts for each device the data in a frame is transmitted sequentially but in such a way that more than one device transmits at the same time the highest priority device is able to continue while the other back off. Frames are received by all devices, including by the transmitting device.

(Local interconnect network): LIN is a serial network protocol used for communication between components in vehicles the need for a cheap serial network arose as the technologies and the facilities implemented in the car grew, while the CAN bus was too expensive to implement for every component in the car LIN may be used also over the vehicle battery power line with a special LIN over DC power line (DC. LIN) transceiver.

CAN in automation has been appointed by the ISO technical management board as the registration authority for the LIN supplier ID standardized in ISO 17987 series

LIN advantages

- Easy to use
- Components available
- Cheaper than CAN and other communication buses
- Harness reduction
- More reliable vehicles

- Extension easy to network implements
- No protocol license fee required.
- It is used within subsystems that are not erotised to vehicle performance or safety.

MOST Network (Media oriented systems transport): it is a high speed multimedia network technology optimized by the automotive industry. It can be used for applications inside or outside the car.

Most is a serial communication system for transmitting audio, video and control data via fibre-optic cables this multi functional high performance multimedia network technology based on synchronous data communication requires professional software tools and hardware interfaces.

Flex ray: Flex ray is an automotive network communication protocol developed by the flex ray consortium to govern on-band automotive computing it is designed to be faster and more reliable than CAN and TTP but it is also more expensive flex ray is used is particular for data communication technology in very safety-critical use areas in the automobile.

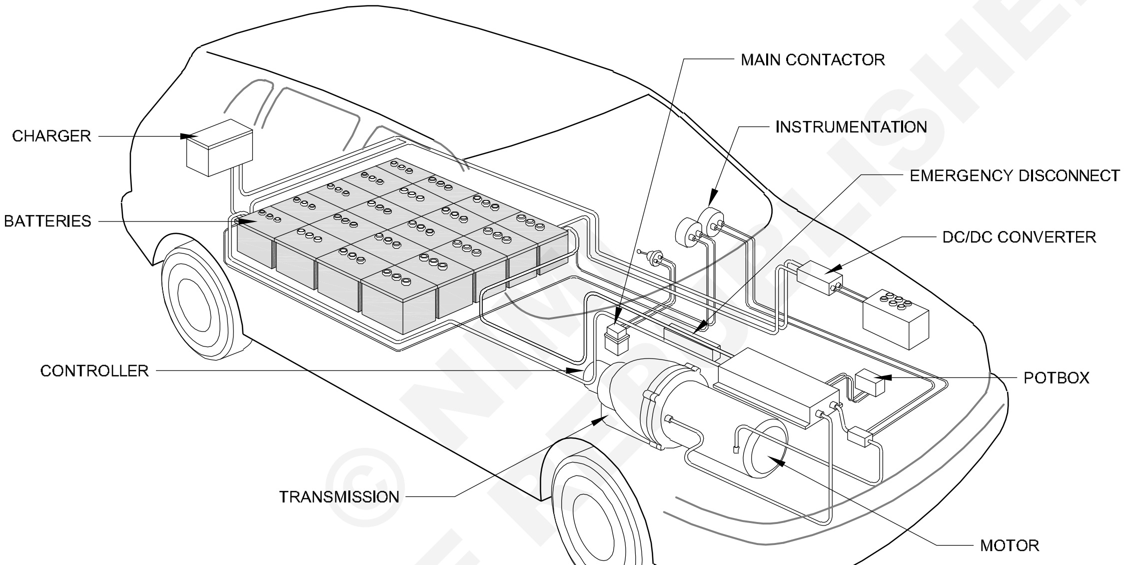
Impotence of electrical and electronic vehicle architecture: It helps to improve vehicle performance, safety and reliability and at the same time reduces vehicle weight thus resulting in lower system costs, it also helps to develop an automotive system architecture requires a series of steps, all influencing each other. Continental can offer the realization of every steps with complete traceability while fulfilling automotive standards.

Electrical and electronic Architecture

Objectives: At the end of this lesson you shall be able to
- **State the electric vehicle electrical and electronic architecture**
- **State the high voltage elements**
- **State the high voltage cabling**
- **Describe the scan tool and reading vehicle diagnostics.**

Importance of electrical and electronic architecture: The adoption of electric vehicle is steady growing across the world including India. It is not just limited to automobile but includes two wheelers commercial vehicles such as van, truck, bus and other public transports. They are a number of different approaches to electric vehicles too with BEV, HEV, PHEV and FCEV

Fig 1



MAJOR COMPONENT OF ELECTRIC VEHICLE

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The electric vehicles have an electric motor and battery instead of internal combustion engine and a fuel tank. The electric vehicle architecture becomes simple and controllable for the compartment level. When designing the architecture the electric vehicle it is mandatory to use modeling and simulation tools with specific consideration of electric power train including battery, power electronics, electronics motors, sensors and others control systems.

The electric vehicle architecture consists of a motor which is self started and can easily control by the input current. They produce uniform power and speed at the output power, because of this reason motor is lighter than internal combustion engine. The electric vehicle architecture is the back bone of the EV's. Electric vehicle is categorized in different types as we studied in previous lesson.

Modern electric vehicles have different adoption seen with their architecture because of a drastic reduction in the components. Electric vehicle architecture needs to be reliable efficient, fault tolerant and vehicle's safety.

Electric vehicle architecture power train: EV consists of 5 major important components and through this components the electric power train is completed such as the electric, battery pack and inverter, charger, DC-DC converter etc.

Electric motor

Electric motor provides torque to the vehicle by utilizing electromagnetic fields energy supplied by the battery and the motor torque controlled by varying the current flow.

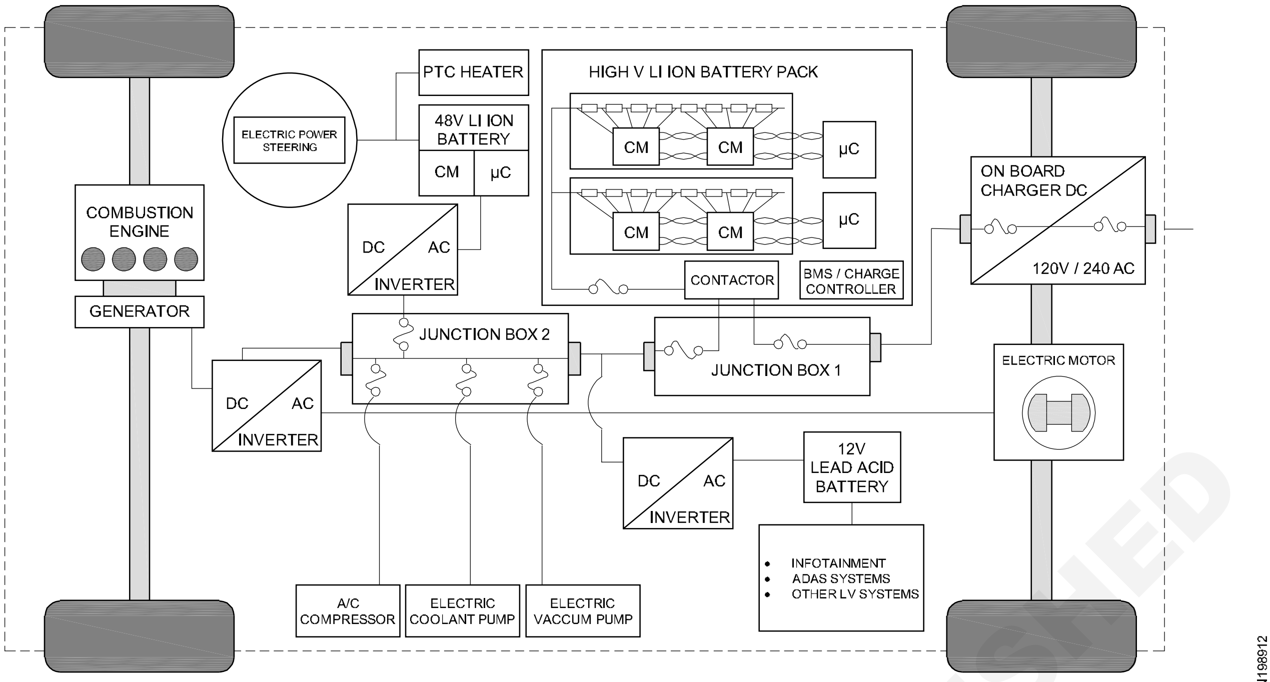
Battery pack

The battery pack is the energy storing device battery packs provide direct current at their device battery packs, provide direct current at their output terminals , electric machines are controlled by varying an alternating current wave form.

Inverter

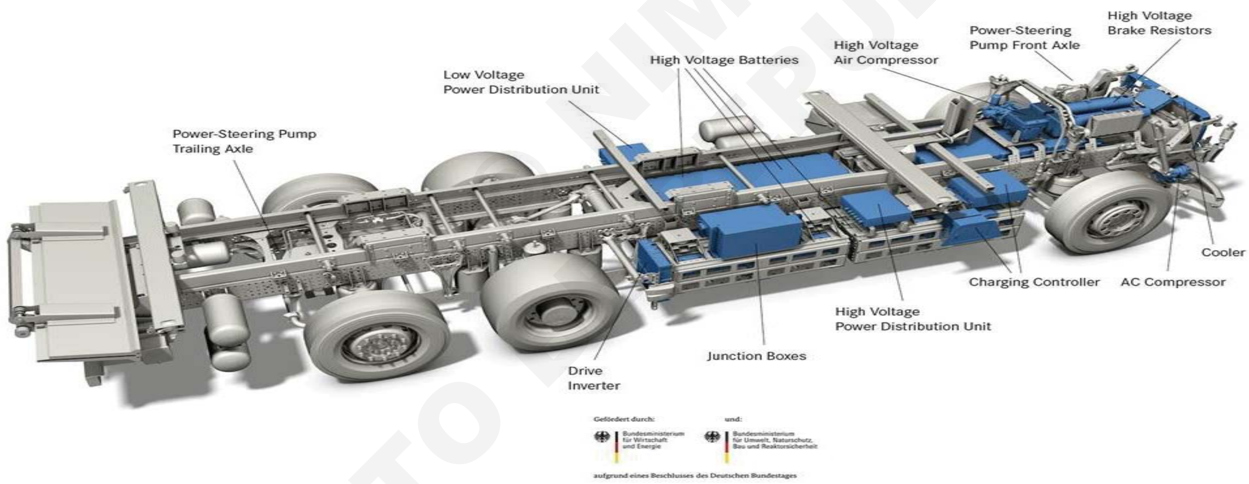
The motor inverter provides this conversion between DC and AC and the torque control functionality.

Fig 2



HV/PHEV ARCHITECTURE BUILDING BLOCKS

Fig 3



DC-DC

The DC/DC converter is used to convert power from battery pack voltage down to 12 volts for operate the electrical accessories in an electrical circuit like wiper motor head light, gauges light, interior lights and other systems.

ON- board charger

- It converts AC voltage from the grid to Dc voltage.
- It controls the current flowing into the battery pack by controlling the DC output voltage.
- It communicates with vehicle, off vehicle equipment

Battery management system components: BMS is used to monitor the state of the battery and is responsible to take the necessary measurements. Apart from these important components there are multiple hardware and software used in electric vehicle power train architecture. They are ECU placed for specific function and communication is done by CAN protocol systems.

The electric vehicle components are selective and the arrangements of such components defines the architecture plus there is the possibility to arrange more components in the architecture. While modifying the Electric vehicle architecture requires special attention for designing and needs to test and validate in various safety measures.

Electric Vehicle's high voltage elements: There are many electric vehicle high voltage components are used in electric vehicle.

They are as follows

- Traction battery
- Traction motor
- Motor control unit
- Power distribution unit
- PTC heater
- Electric AC compressor
- on board charger
- DC- DC converter
- Manual power disconnect unit
- High voltage wiring harness
- Charge port

Power distribution unit:

Power distribution unit is assembly of various part of electric vehicle. It distributes power from the battery pack to the electric motor and other components used in EV. Such as climate control system , it is large box with many wires and high voltage connectors, that must be able to handle high voltage DC power.

Electric power switching devices:

There are different types of switching devices used in electric vehicle. The switches are used to connect and disconnect the power flow in a circuit. Switching devices are electronic components that can switch a signal or power flow between two or more circuits. Commonly mechanical digital or analog circuit switches devices are used to control the flow of current or Electrical components are used in digital circuits as well as power switching applications. Relay also used as switch in control units. Diodes are also used as a switch where current flow need only one direction

Solid state switches are used for control power or control signals without any moving parts.

High voltage diagnostics:

- Fault diagnostic process involves, fault finding, Isolating and repairing faults in a circuit as follows
- Visually inspect the wiring circuit for cable insulation damages, broken cables, loose connections, fuses, wiring short circuits etc.
- Use the specialized test equipments for check the cables continuity and power flow through the components.
- Visually check the circuit breakers for their proper function diagnose and rectify the fault if found any fault during your fault diagnostic method rectify the fault during your fault or replace the defective components.

High Voltage Cabling :

High voltage cables are used to transmit the power from the power pack to invertor and inverter to traction motor. High voltage cables are designed to handle high voltage levels from 12 v to 800,1000,1200 volts HV cables are design in different sizes. The high voltage cables are constructed with specialized materials and insulation to with stand high electrical stresses and prevent cable conductor break down.

High Voltage Cable Repairing:

High voltage cable repair may be requred due to damage caused by external factor such as weather or technical interference or internal faults such as conductor or insulation damage due to bad workership or by vehicle met with an accident.

use the special testing equipment to find the cable damage type and cable damage location in a circuit, Before repair the cable, take safety equipments and the in start repair works, if need replace cable, before repair or replacing cable switch off the battery power for avoid electrical accident.

Safety Certification:

Safety certification training programs typically include training on electrical hazard, personal protective eauipment usage, safe work practice, self preperation, work preperation selection of tools and materials for repair works.

High voltage interlock loop

HVIL is a safety device used in high voltage systems, including the electrical safety of Battery pack, wire harness connectors, DC - DC converter , motor controller, power distribution box and protective cover it is basically a circuit that monitor has state of the high voltage connecters in electric vehicles and it is automatically disconnect the connector, when excess voltage or any other abnormal condition in the function of the electric vehicle components.

HVIL connectors operating temperature range from - 40°C to +140°C. The maximum operating voltage of HVIL connectors is up to 1000V. The HVIL design ensures the safety of the electric vehicles connectors in use HVIL connectors are divided into male and female connectors based on different positions, different high voltage components are connected with each other by EV wire harness through screws or bolts to ensure electrical contact between them.

The function of high voltage interlock connectors is used to prevent accidental contact between high voltage conductors. It also prevents arcing or sparking across disconnecting devices, when power is removed from a circuit.

Electric vehicle isolation: Isolation is an important fundamental technology that is embedded with electric vehicle. Electrical vehicle electrification systems constructed with high -voltage power electronic become critical components to the new electronic drive train and battery management systems. These high voltage electronics need to be communicated with and controlled by low voltage digital controllers. These are require electrical isolation of low voltage side from the high voltage power system.

Electric vehicle battery management systems include four major circuit assemblies each with specific isolation needs. They are battery management systems, DC/DC converter, on board charger, traction inverter. Electrical isolation connects or disconnects a section of circuit using mechanical and electronic switch to protect the components in a circuit from high voltage damages.

Testing power electronics inverter:

EV monitoring and protection are necessary due to the full electrifications of vehicles safety requirements. The vehicle manufacturers provided many type of safety systems to protect the components with electrical circuits. The traction inverter is vital to the drive systems to protect the components with electrical circuit and prevent system level failure modes such as over and under torque or motor shut down etc.

Before the inverter, you should know the traction motors specification like motor drive type, rated voltage, rated torque, rated power peak torque, peak power, peak speed, working system, protection class and gear speed ratio, breaking + DCAC + steering DCAC + PDU. Follow the traditional testing methods using a multimeter test the continuity of motor stator and rotor, grounding check the insulation resistance to ground meters, check the rotor and stator, check the casting voids of motor, check the centric rotor, check the unequal air gaps between stator and rotor check the cracked rotor bars. Check the stator winding, check the motor's winding resistance, inductance, impudence, phase angle, current frequency response, check the motor's dynamic task. Follow the method for testing the inverters . The inverter provide power supply to the traction motor.

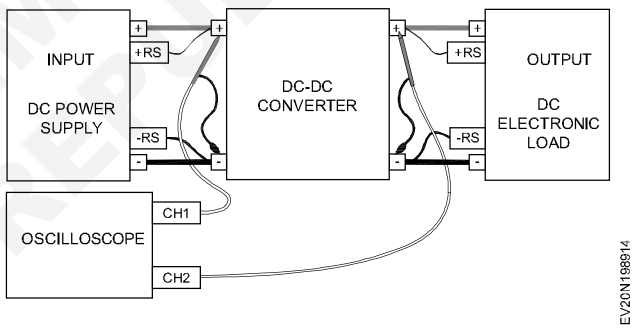
- Select the power testing or measure tools.
- Study the Electric vehicle manual for technical specification
- Take PPE before measuring the voltage.
- Use the multimeter to check continuity, voltage current input and output range and compare it with original specification.
- Check the wire connectors.
- Check the inverter's in power ON/OFF mode.
- Use the simulator test bench to test the function of traction motor.
- Ensure IGBT, MOSFET functions are satisfied if provided between the circuit.
- Check and test the switches provided with in a power circuit if found defective replace it.

Testing voltage converter:

Electric vehicle DC-DC converter receives high voltage from battery pack and converts it into a lower voltage power on board devices such as instrumental panel, sensors, LED lighting, audio and video systems and any other on board devices requiring low voltage DC power .To test the converter's input and output voltage , use the simulator test bench powered from the DC/DC converter

Another method is osciloscope used to test the converter as shown in the figure . In this method you can test the nominal or maximum input voltage, output voltage, output ripple or noise voltage, output over current protection, output over voltage protection custom load wave form simulation and converter's efficiency teat etc.(Fig 4)

Fig 4



Scan tool data

Objectives: At the end of this lesson you shall be able to
- **use a scan tool data.**

Obtaining and interpreting scan tool data

OBD I & II stands for on board diagnostics second generation super standing that of OBD I, OBD II is a system that was mandated by the federal EPA and was developed by the society of automotive electronic diagnostics, technicians can use the scan tool to test all makes and model of automobiles with special adoptors or factory seamers. When the EPA mandated OBD II computer systems, they also mandated that all manufacturers would also mandated that anybody. Scanner could have access to the computer system with the proper software and adoptors. The information would have the same code terminology data parameters, freeze frame data and system monitors updated scanner software will usually have OBD II generic mode and allow you to retrieve codes, data, monitor information and freeze frame data without having to buy specific software for that manufacturer.

Standardisation of OBD computer system

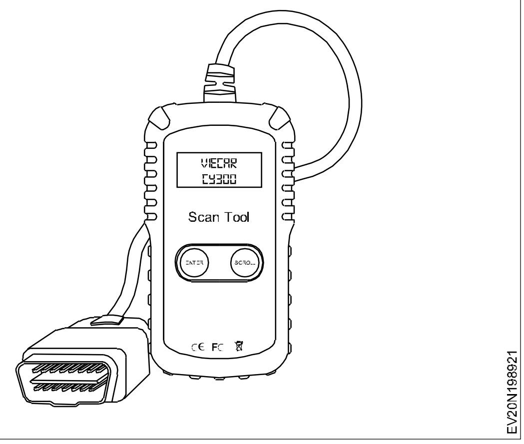
- Universal diagnostic test connector or data link connector (OBD - II)
- Standard location for the DLC (dash board)
- Standardised list of generic diagnostic trouble code (DTC)
- The ability to clear all hard and pending codes with a scan tool
- The ability of the computer system to record a frame of data as a fault occurs within the computer system known as freeze, frame data

Obtain an OBD II scan tool (Fig 1)

- Locate the diagnositic link connector in your vehicle.
- Insert the scan tool connecter or code reactor into the DLC

- Enter your vehicle information
- Find the menu

Fig 1



Malfunction Indicator lamp (MIL)

The MIL is that terrible little light in the dash that indicates a problem with the car. There are a few variations, but they all indicate an error found by the OBD -II protocol.

Scan tool letter codes

First unit identifies the type of error code

- Pxxxx for power train
- Bxxxx for body
- Cxxxx for chassis
- Uxxxx for class 2 network

Second digit shows whether the code is manufacturer unique or not

- x0xxx for government - required code
- x1xxx for manufacturer - specific code

Third digit shows us what system the trouble code references

- xx1xx/xx2xx show air and fuel measurements
- xx3xx shows ignition systems
- xx4xx shows emissions systems
- xx5xx references speed / idle control
- xx6xx deals with computer systems
- xx7xx/xx8xx involve the transmission
- xx9xx notates input/ output signals and controls

Digits four and five show the specific failure code

- xxx00 to xxx99 - these are based on the systems defined in the third digit.

Learn the letter with code number

For example

P 0XXX - Models

P1XXX - Manufacturer

P07XX - Transmission

Read engine fault code - P0301 - Misfire on No.1 cylinder.

Terminology

Before we get too much farther, let's make sure we understand all the keywords used in these protocols.

Engine/Electronic Control Unit (ECU)

The ECU can refer to a single module or a collection of modules. These are the brains of the vehicle. They monitor and control many functions of the car. These can be standard from the manufacturer, reprogrammable, or have the capability of being daisy-chained for multiple features. Tuning features on the ECU can allow the user to make the engine function at various performance levels and various economy levels. On new cars, these are all typically microcontrollers.

Some of the more common ECU types include:

- Engine Control Module (ECM) - This controls the actuators of the engine, affecting things like ignition timing, air to fuel ratios, and idle speeds.
- Vehicle Control Module (VCM) - Another module name that controls the engine and vehicle performance.
- Transmission Control Module (TCM) - This handles the transmission, including items like transmission fluid temperature, throttle position, and wheel speed.
- Power train Control Module (PCM) - Typically, a combination of an ECM and a TCM. This controls your powertrain.
- Electronic Brake Control Module (EBCM) - This controls and reads data from the anti-lock braking system (ABS).
- Body Control Module (BCM) - The module that controls vehicle body features, such as power windows, power seats, etc.

Diagnostic Trouble Code (DTC)

These codes are used to describe where an issue is occurring on the vehicle and are defined by SAE . These codes, can either be generic or unique to the vehicle manufacturer.

Using a Diagnostic Car Code Reader

Diagnose car problems with an auto code reader. Simply plug it into the car's computer system, then interpret the trouble code readout.

Plug your car code reader into the diagnostic link connector under the dash (engine off). Then start the vehicle and follow the auto code reading procedure in the instruction manual.

An engine code reader/scanner can help you make the drive/no drive decision and even help you fix the problem. It works by plugging into the car's computer system and displaying a "trouble code."

An engine code reader/scanner is worth buying if you're a fairly competent amateur mechanic who understands how an engine works. But it's not a silver bullet that will always tell you exactly what's wrong. An auto code reader give you a head start, but you'll still have to do some detective work before you start pulling and replacing parts (more on this later).

The least expensive auto code reader units are simple car code readers that burp up an alphanumeric trouble code but no information about what it means. You'll have to look up the code in a reference book or search the Internet. Mid priced units actually display the problem on the screen, like "P0115 Engine Coolant Temperature Circuit Malfunction." One model even accesses the Internet, so you can upload the trouble code to a Web site that has information on the most likely cause of the problem.

Here are three ways to get to the root of a problem without replacing good parts.

1 Go to the car code reader/scan tool manufacturer's Web site to see if it has information on your trouble code.

2 Take advantage of Internet forums. Just search for your car's model and add "forum" to the search term. Register for the site (usually free) and post your question, including your vehicle's year, mileage, code number and what you've done so far. You'll be surprised by the number and quality of responses you get.

3 Subscribe to an online shop manual. It will have not only all the carmaker's technical service bulletins listed but also the complete diagnostic procedure for your particular code. It will walk you through the testing procedure, telling you which wires to check and what voltages you should see. The services also include component locators to help you find the part in your vehicle, and wiring diagrams showing the connector position for each wire.

Required Tools for this Project

You'll need a code reader or scanner, along with a computer with internet access for interpreting the trouble codes.

Interpreting generic scan data

Generic scan data provides an excellent foundation for OBD II diagnostics./ Recent enhancements have increased the value of this information when servicing newer vehicles.

One of the best places to start is with a factory scan tool.

Example

The Mass Airflow (MAF) Sensor, if the system includes one, measures the amount of air flowing into the engine. The PCM uses this information to calculate the amount of fuel that should be delivered, to achieve the desired air/fuel mixture. The MAF sensor should be checked for accuracy in various rpm ranges, including wide-open throttle (WOT), and compared with the manufacturer's recommendations, volumetric efficiency and help with MAF diagnostics.

When checking MAF sensor readings, be sure to identify the unit of measurement. The scan tool may report the information in grams per second (gm/S) or pounds per minute (lb/min). For example, if the MAF sensor specification is 4 to 6 gm/S and your scan tool is reporting .6 lb/min, change from English units to metric units to obtain accurate readings. Some technicians replace the sensor, only to realize later that the scan tool was not set correctly. The scan tool manufacturer might display the parameter in both gm/S and lb/min to help avoid this confusion.

Oxygen Sensor Output Voltage B1S1, B2S1, B1S2, etc., are used by the PCM to control fuel mixture. Another use for the oxygen sensors is to detect catalytic converter degradation. The scan tool can be used to check basic sensor operation. Another way to test oxygen sensors is with a graphing scan tool, but you can still use the data grid if graphing is not available on your scanner. Most scan tools on the market now have some form of graphing capability.

The process for testing the sensors is simple: The sensor needs to exceed .8 volt and drop below .2 volt, and the transition from low to high and high to low should be quick. In most cases, a good snap throttle test will verify the sensor's ability to achieve the .8 and .2 voltage limits. If this method does not work, use a bottle of propane to manually rich the fuel mixture to check the oxygen sensor's maximum output. To check the low oxygen sensor range, simply create a lean condition and check the voltage. Checking oxygen sensor speed is where a graphing scan tool helps.

The sensor should be tested with a lab scope to verify the diagnosis before you replace it.

Advantage of scan tool

- It provides trouble shooting information or tips.
- Record and play back live data.
- It provide graphic data.
- Manufacturer trouble code provided for each fault finding.
- It reads out the fault from various sensors.

Dismantling and assembling the Electrical vehicle parts

Objectives: At the end of this lesson you shall be able to
- **Study the electric vehicle parts**
- **Study the electric vehicle manual**
- **Dismantling and assembly an EV's parts by using screwing tools.**

Study the electric vehicle components:

Many types of electric vehicle play on the road. Some electric vehicles run safely on battery power, other known as hybrids, combine an electric motor with an internal combustion engine in various ways. Every vehicle manufacturer provide vehicle service manual for understand the internal parts of each vehicle systems like complete working diagram of DC electric to vehicle, and other systems like steering, brake, suspension, panel board vehicle interior and exterior components etc.

Vehicle service manual: Vehicle service manual provides instruction on how to keep a vehicle working properly at different condition in its life. Service manual is a resource provided by manufacturer explaining how to use the manual. How to maintain the vehicle, trouble shoot and repair a product.

Technician must have some background knowledge to understand for refer the vehicle service manual sequence. The service manual contain detailed descriptions and instructions about every part of the vehicle. You can get benefit from service manuals. Everyone don't know everything about every system components of vehicle if you know how to use manual you can easily dismantle and assembly any components of vehicle.

Vehicle manual can used to diagnose or fix a major issues like election vehicle battery pack, converter, inverter, controller and traction motor malfunctions.

Advantage vehicle service manual:

- It provides information about work safety precaution.
- It proves vehicle specification like vehicle model name, product measurement, features and other classification.
- It provides system parts description, including circuit, wiring, parts and other system parts sequence.
- It provides parts disassembling and assembling to repir a product and put it back together safely.
- It provides flow chart to map out trouble shooting options.
- It provides a exploded view diagrams for how all the parts fit into each other in sequence.
- It will help you determine how severe the problem is.
- Vehicle service manual gives detail about the sequence repair operation of the vehicle system party along with their part number and it also provide dismantling and assembling procedures in details to understand it easily by skilled / unskilled technicians to improve their technical knowledge.

Now a day vehicle service manual is available in online . You can access video tutorials and explore the regulations that the product is beholden to as original. Chilton has a largest vehicle data library.

Disassembling and assembling process from service manual:

For dismantling and assembling the vehicle parts, following the steps

Dismantling of controller of electric vehicle:

- Select the vehicles for repair
- Diagnose the fault by using scan tools data.
- Study the vehicle service manual for achieve knowledge of sequence of parts fitted in a faulty circuit.
- Identify the location of faulty component in a circuit for example DC- DC electric vehicle power pack to traction motor.
- Suppose imagine controller is defective component in a circuit.
- Refer the service manual for trace the wiring circuit and their connection.
- Switch off the battery power.
- Select the suitable screwing tools as recommended by the manufacturer.
- Use the safety PPE during repair work as instructions given by the vehicle manufacturer.
- Disconnect the wires connected with controller by using insulated tools

Note: Before removing the wire connection of controller ensure no power is in a circuit

- Remove controller's mounting screw and remove it from its mounting place.
- Clean the controller's outer surface and check the terminal for damage.
- Use the special instrument for check the serviceability of controller ensure the function of controller.
- If found controller is un serviceable, replace it with new one

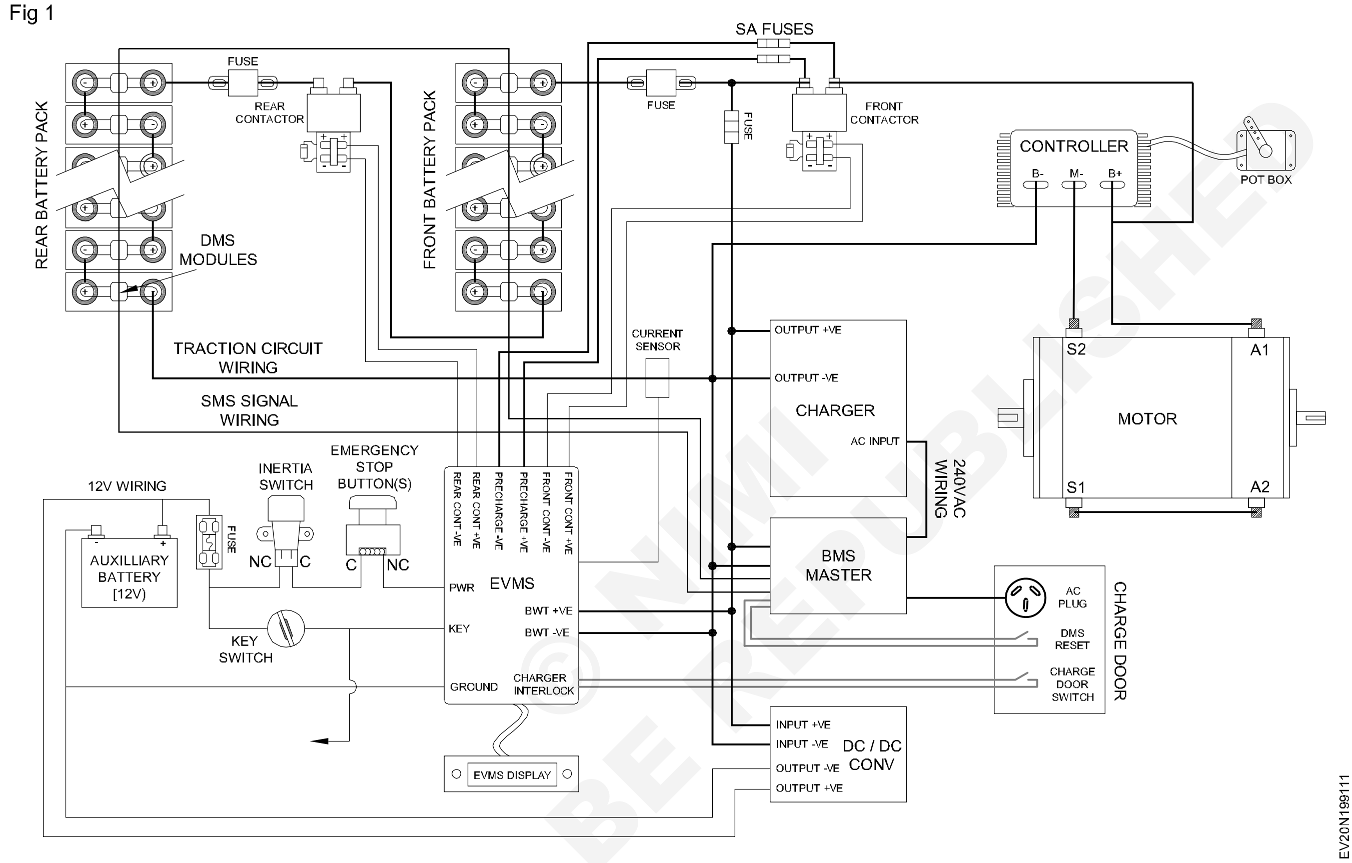
Refitting the controller of electric vehicle:

- Check the controller before fix it in a vehicle like model, power input, output, terminal connection, size etc.
- Fix the controller in that's location and fix the mounting screws with screwing tools.
- Ensure controller is properly mounted in its location.
- Connect the wire's as shown in Figure1.
- Connect the battery power and switch ON the power to traction motor.
- Start the traction motor and move the vehicle for check the performance of power transmission.

Note: Ensure your disassembling and assembling procedure is carried out as per vehicle service manual instructions.

- You can disassemble and assemble the other system components with reference of vehicle service manual as following the above step.(Fig.1)

Fig 1



Thread categorization:

Classes of thread fit are used for fastener application. Thread fit is a measure of looseness or tightness of matting thread. For three classes foe external thread 1A, 2A, 3Aand three for internal threads 1B,2B, 3B. Threads are used for assemble without interference.

Common types of threads :

Threads and connections are divided into six main type

1)UN/UNF 2) NPT/NPTF 3) BSPP(BSP, parallel) 4) BSPT (BSP, tapered) 5) metric parallel 6) metric tapered

Pitch gauge and caliper is used to measure the distance between the crest of threads. and diameter of the thread. For male threads caliper used to measure outside diameter and inside caliper is used to measure inside threads.

Types of parallel threads

- UN/UNF
- BSPP
- Metric parallel

Tapered threads include:-

- NPT/ NPTT
- BSPT
- Metric tapered.

Thread pitch gauge is used to determine the size of thread. Thread pitch gauge helps to measure accurately and calculate the number of threads with in a given distance

Thread type	Pitch size
UN/UNF (SAAE)	- 12, 14, 16, 18, 20, 24
NPT/NPTF (American pipe)	- 11 1/2,14,18,27
BSPP (British pipe)	- 11,14,19,28
BSPT(do)	- 11,14,19,28
metric parallel	- 10, 15, 20
metric tapered	- 10, 15, 20

Pipe thread Acronyms

Abrivation	System Name
BSP	- British standard pipe thread
BSPP	- British standard pipe parallel thread
BSPT	- British standard pipe taper thread
NPT	- National pipe thread
NPTF	- National pipe thread fuel line.

General applications of thread:- The general applications of various objects having threads are using for fastening, joining clamping the various parts of the vehicle.

Type of screwed joints: Different types of screws are used for fastening the parts together. They are as (1) Threaded fasterness (Nut bolts and screws) (2) Self tapping screws are used for wood, plastic where a pre-drilled hole is not available (3) Machine screws are used in applications where a low profile screw is needed (4) Lag screws are used to secure heavy objects to wood or other materials (5) set screws are used for hold a component in place (6) Shoulder screws are used for provide a precise of engagement in a screwed joints (7) Captive screws are used in application where frequent maintenance is required

Types of nuts:- Nuts are classified according their to head construction shape Nuts are classified as following type.

(1) Hexagonal nut (2) Square Nuts ,(3) Self locking nut (4) 'T' nuts (5) Slotted nuts,(6) round nut, (7) speed nut,(8) chuck nut, (9) wing nut,(10) thumb nut, (11) cap nut,(12) hexagonal nut with collar,(13) hexagonal weld nuts,(14) Flange nut

Locking devices: Locking devices are used to lock the threaded fasteners to prevent them from loosening from their position. Common locking devices are used in automobile are as folloWs,(1) Wires,(2) Washers,(3) Circles, (4) keys, (5) split pin,(6) nylon insert, locknuts,(7) thread locking adhesives etc.

Screwing tools: There are different type of screwing tools are used for tighten and loosen the nut & bolts and screws. They are used as hand tools and power tools like double end spanner, ring spanner box spanner, wrench spanner, impact wrench, torque wrench, screw driver, Allen key, offset spanner, screw extractor , adjustable wrench, T-handle wrench, socket wrench, tubular spanner, electric screw driver, ratchet spanner, ratcheting screw driver, torx screw driver, Phillips screw driver etc.

Note: For more details refer the related theory for exercise 54 to 58.

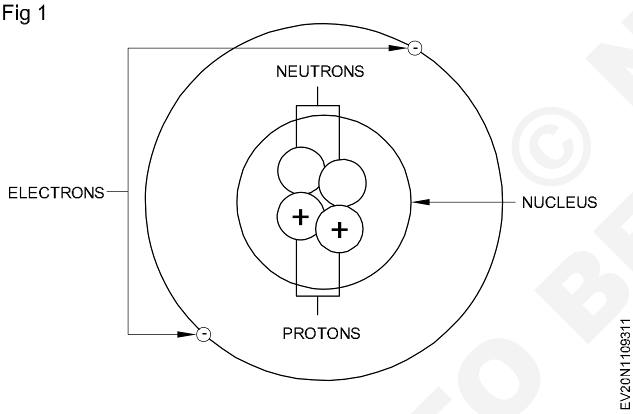
Principle of electrical engineering

Objectives: At the end of this lesson you shall be able to
- **describe the structure of atoms**
- **describe the voltage, current, fuses, conductors**
- **state the type of current and voltage drop**
- **describe the resistor and their types.**

Structure of atoms

Atoms are made up of particles called protons neutrons and electrons, which are responsible for the mass and charge of atoms. Atoms combine to form molecules. Protons and neutrons have approximately the same mass. Electrons are much smaller in mass than protons. Electron contribute greatly to the atoms charge as each electrons has negative charge equal to the positive Charge of a proton. The number of electrons orbiting the nucleus is equal to the number of protons inside the nucleus. In these atoms, the positive and negative charges cancel each other out leading to an atom with no net charge (Fig 1) Every matter has made up of atoms and that atoms are indivisible. Each atom has its own constant mass. (Fig. 1)

Fig 1



Voltage

Voltage is defined as the amount of potential energy between two point on a circuit one point has more charge than another. The difference in charge between two points is called voltage (measuring unit is volt).

Current

The motion of charged particles in any medium is called current. The net transfer of charge per unit time is called current. Current is measured in ampere when one volt is applied across a resistance of one ohm, the amount of current passes through the resistance is said to be one ampere. To measure the current in a circuit, ammeter should be connected in series with the load.

Fuses

Fuses are used for protect the circuit components from damage by over load. There are different type of fuses are used in automobile electrical circuit. They are as follows

- Glass tube type
- Blade type
- Bosch type
- Lucas fuses
- Heavy duty blade fuses
- Regular blade fuses
- Mini blade fuses
- Micro blade fuses
- Limiter type

Conductors

Which type of material contain many free electrons and they are capable of carrying an electric current one end to another end material is known as conductor like silver, copper, aluminium and most other metals are good conductors.

Semiconductor

Semiconductor is a material that has the characteristics of both function of conductor and an insulator. Semiconductor has valence shells containing four electron. Semiconductor components like diodes, transistors and integrated circuit chips.

Type of current

There are two types of current flows used in electric vehicle operating systems. They are as follows

1 Direct current (DC) (Electrons flow steadily in a single direction)

2 Alternating current (AC) (Electron flow forward and the backward direction in a circuit)

Voltage drop

In a electrical circuit voltage drop is the decrease of electric potential along the path of current in a circuit voltage drop in the internal resistance of the source across the contact and contractors are undesirable, because some of the energy is dissipated while passing through the resistor. The current loss is known as voltage drop. Voltage formula is V = I Z

I = Current in ampere

Z = Impedance in Ω (ohm)

V = Voltage

Example:

A current of 10 ampere flows through a circuit that carries a resistance of 10 ohms. Determine the voltage drop across the circuit.

Current – 10 A

Resistance – 10 Ω

V = 1 x R

V = 10 x 10 = 100 V

Thermistor

Thermistor is a combination of two terms like thermal & resistor. Thermistor are available in two type NTC (Negative temperature Coefficient) and PTC (positive temperature coefficient). These are working depend on temperature in that circuit once temperature.

PTC Thermistor

When temperature increases resistance also increase once temperature reduce than resistance will be decrease. So in this type of Thermistor both the resistance and temperature are directly proportional. This type of Thermistor being used on any circuit diagram. Most PTC thermistors are designed with doped polycrystalline ceramic that includes $B_aT_1O_3$ (Barium Titanate) & other compounds. These material have the property that is at a particular critical temperature

NTC Thermistor

NTC (Thermistor is a negative temperature coefficient) thermistors resistance value decreases as the temperature increases its function is opposite to PTC thermistor.

Resistors

Resistor is a electronic component and it is used to reduce or limit or resist the flow of current in any electrical or electronic circuit. The value of resistance is measured in the unit of ohm denoted by the symbol Ω

Classification of resistors

Resistors can be classified under two main categories as fixed value and variable value. Fixed value resistor can be classified as 1) Carbon composition resistors 2) Wire wound resistors 3) Film resistor printed registor can be classified as 1) carbon film resistors 2) metal film resistors 3) metal oxide film prited film resistors, further it can be classified as (i) carbon film resistors (ii) film resistor (iii) metal oxide film resistor 4) Contact film resistors 5) Integrated resistor

graphical coding of resistors

In the typographical coding scheme is indicating resistance values, the ohmic value of the resistor is printed on the body of the resistor using a alpha-numeric coding scheme

Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.

Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

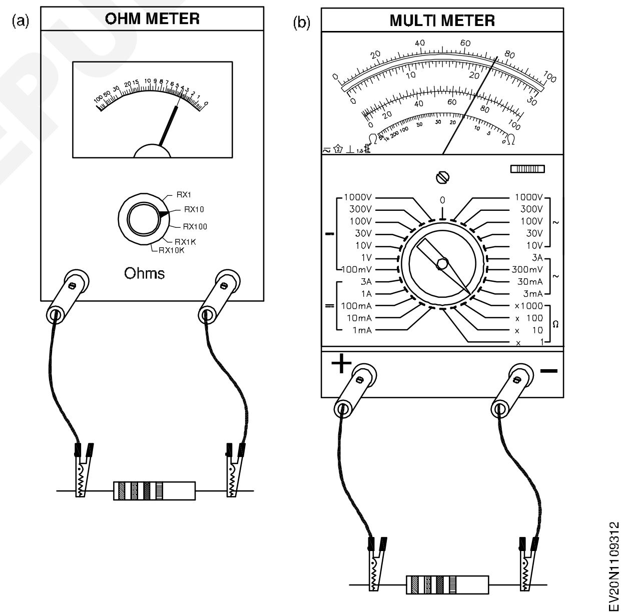
Measuring ohmic value of resistors

It is not possible to read the exact ohmlc value of a registor fro colour/other coding schemesdue to manufacturing tolerance bulit into the registors. to find the exact ohmic value of registors ohmm eters are used. when a resistor is placed between the test prods of an ohmmeter as shown in Fig 2a, the meter shows nearest to the exact resistance of the resistor directly on the graduated meter scale. Multimeters are also used to measure the value of resistors as shown in Fig 2b.

When a multimeter is used for resistance measurement, the resistance range switch on the meter should be put to the most suitable resistance range, depending upon the value of resistance being measured.

The Pocket table book suggest the meter ranges for measuring different resistor values accurately.

Fig 2



Wire-wound Resistors

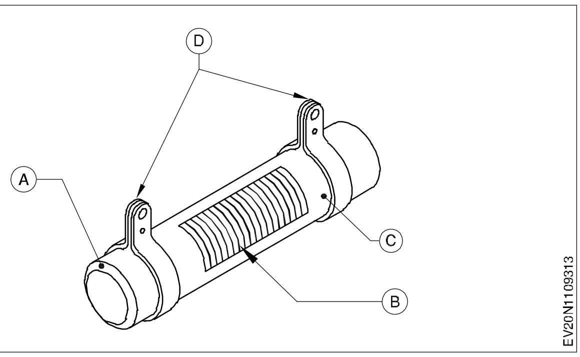
Resistors, in addition to having a required ohmic value, should also be capable of dissipating the heat produced. Carbon by its nature has a limitation in the maximum heat it can dissipate. Carbon resistors become too hot when high current flows through them. This increased heat in carbon resistors changes the ohmic value of the resistors. Sometimes the resistors may even burn open due to excessive heat. Hence carbon resistors are suited only in low power circuits safely up to 2 watts.

This limitation in carbon resistors can be overcome by using wires of resistive materials like Nichrome, Manganin etc., instead of carbon. Resistors made using wires of resistive materials are known as *wire-wound* resistors. These resistors can withstand high temperature, and still maintain the exact ohmic values. In addition, wire-wound resistors can also be made to have fractional ohmic values which is not possible in carbon composition resistors.

Construction

Typical construction of a fixed value wire-wound resistor is shown in Fig 3 . Over a porcelain former (A), resistive wire (B) such as Nichrome, Manganin or Eureka is wound. The number of turns wound depends on the resistance value required. The wire ends are attached to terminals(D).

Fig 3



The entire construction, except the terminals are coated using an insulating binder(C) such as shellac/ceramic paste to protect the wire-wound resistor from corrosion etc. In very high voltage/current application, the resistive wires are coated with vitreous enamel instead of shellac. The vitreous enamel coating protects the wire-wound resistor from extreme heat and inter-winding firing/discharge.

Resistor values

Wire-wound resistors are available from a fraction of an ohm to 100's of Kilo ohms, with a power ratings of 1 watt to several 100s of watts. The higher the power rating, the thicker the resistive wire used, and bigger will be the physical size of the wire-wound resistor.

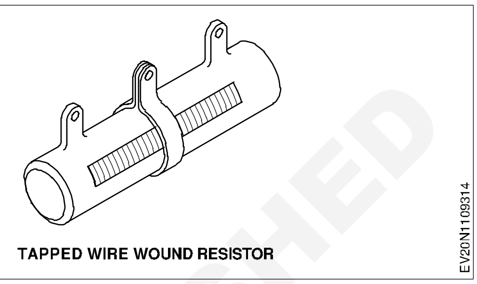
Applications

Wire-wound resistors are commonly used in electronic circuits where small values, precision values, high wattage ratings are required. A few applications are : regulated power supplies, amplifiers, motor controls, servo control circuits, TV receivers etc.

Special types of fixed value wire wound resistors

In applications where more than one fixed value wire-wound resistor is required to be used, a tapped wire wound resistor with more than one value, made in a single unit as in Fig 4 can be used.

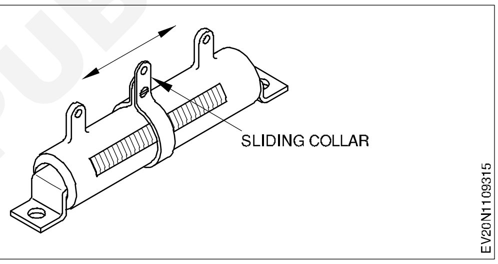
Fig 4



TAPPED WIRE WOUND RESISTOR

Tapped resistors, whose tapings can be adjusted by adjusting the position of the sliding collar are also available as shown in Fig 5. This gives the flexibility of varying the resistance value between the tapings.

Fig 5



Comparison of fixed value carbon and wire-wound resistors		
Characteristics	**Carbon resistors**	**Wire-wound resistors**
Size	Small	Comparatively large
Values available	From 1 ohm to several 10's of Mega Ohms	Fraction of an ohm to several 10's kilo ohms
Tolerance	Generally 5% to 20%	As low as 1% available
Wattage	Generally up to 2 watts	As high as 100 watts
Suitability in circuit	Suitable for high frequency circuits	Unsuitable for high frequency circuits (Suitable up to 200 KHz)
Noise generated	Less noisy	Very noisy operation
Voltage	Low voltage rating	Wide voltage rating

Other types of resistors

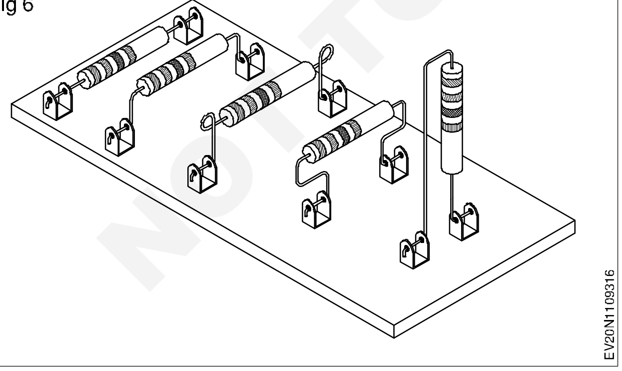
Brief constructional details of some types of resistors is given in Chart - 1 & 2 at the end of this lesson.

Resistors lead bending

The most delicate portion of a resistor is the joint between the leads and the resistor body. The leads give electrical connection to a resistor with the external circuit. While connecting a resistor in a circuit, the leads may come across vibration, shock, rough handling etc. In spite of these,the leads must maintain perfect electrical contact with the resistor. If the lead joint is loose with the body, it may lead to intermittent electrical contact resulting in the malfunctioning of the circuit.

Resistors are the most common components in any electric and electronic circuits. The circuits may be wired on, lug boards or on printed circuit boards. When resistors are to be soldered on boards, it becomes necessary to bend the leads of the resistors to different shapes as shown in Fig 6.

Fig 6

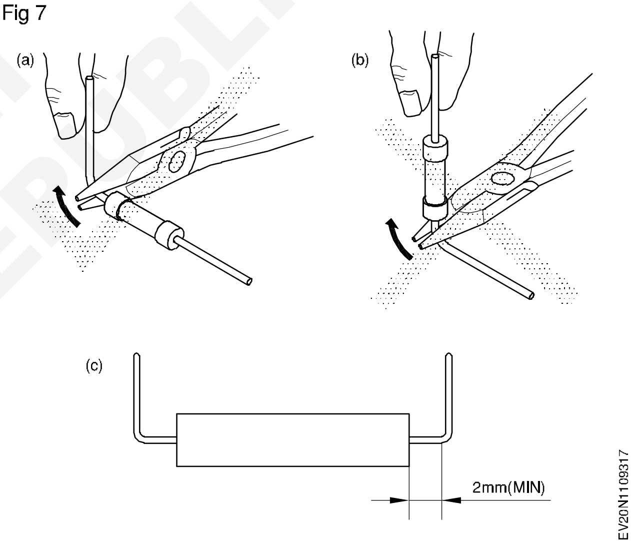


While bending the resistor leads, the following two vital points should always be kept in mind. Otherwise, the strain on the lead may make the resistor's body-to-lead connection weak.

1 Never bend the component as shown in Fig 7. Bend the lead as shown in Fig 7.

2 Bend the lead at least 2mm away from the resistor as shown in Fig 7.

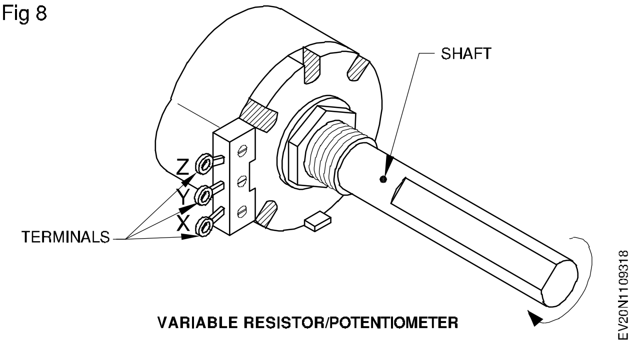
Fig 7

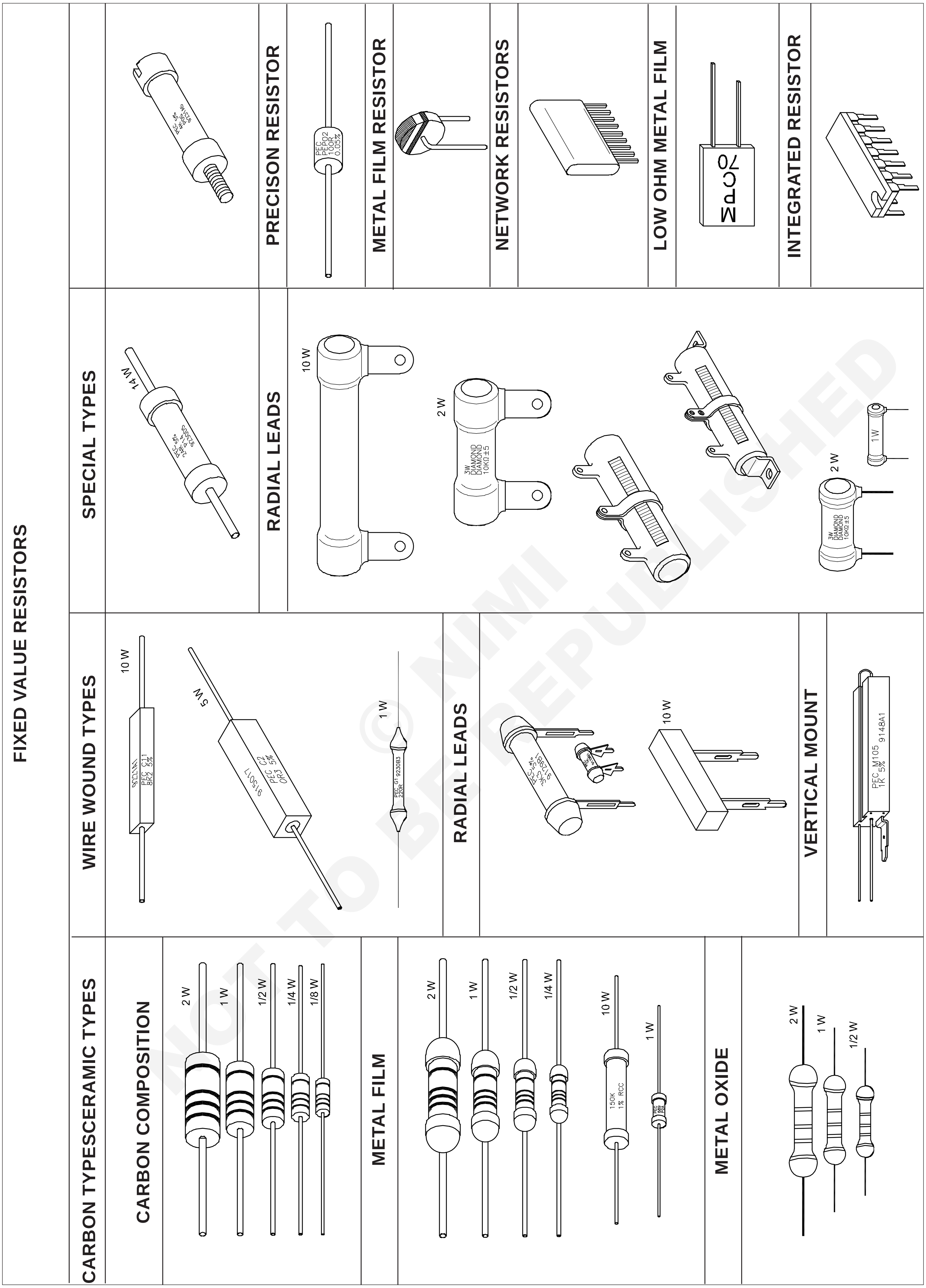


Variable Resistors

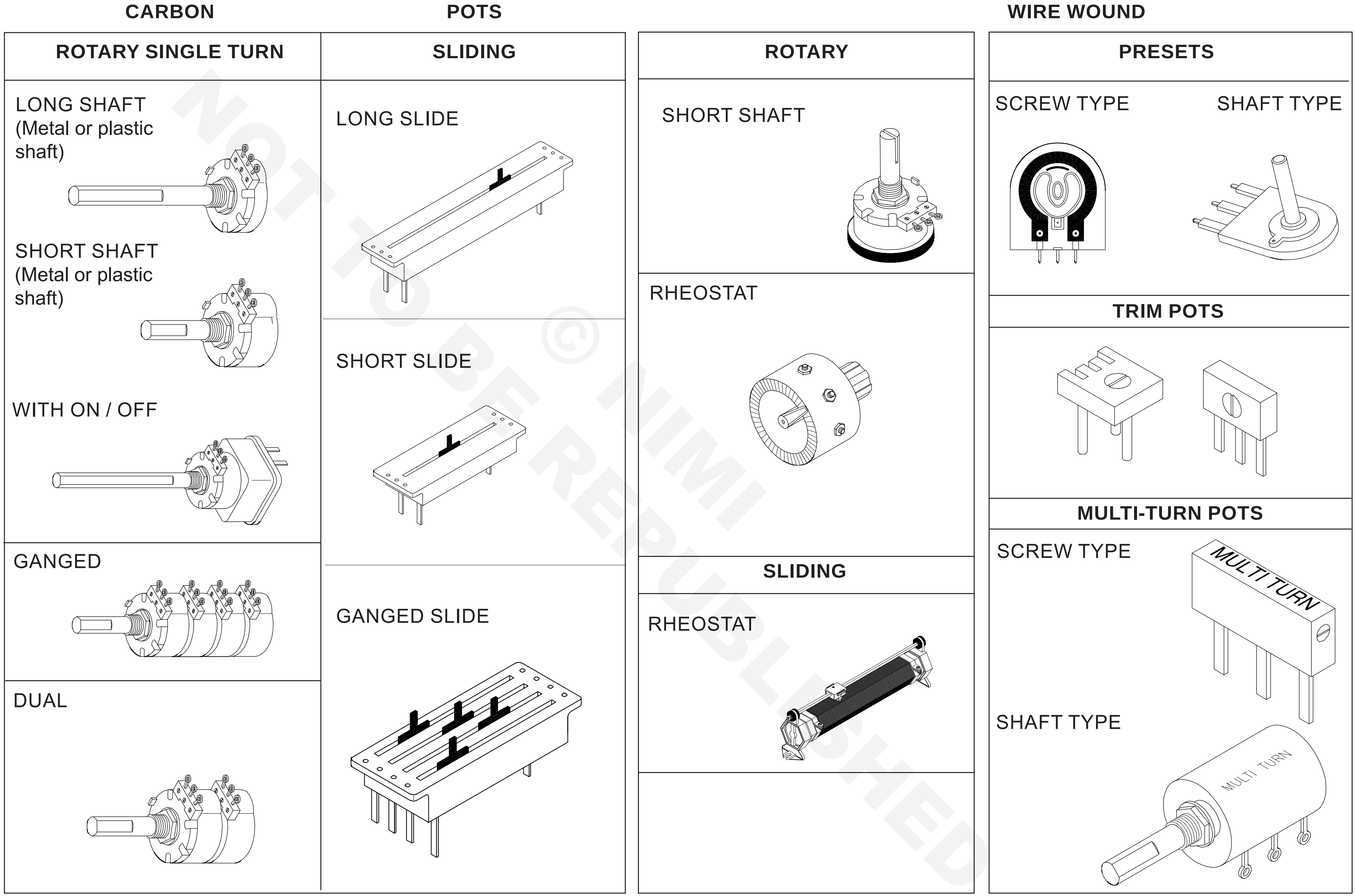
In fixed value resistors the value of resistance is fixed, at the time of manufacture, whereas, variable resistors are manufactured such that its resistance value can be changed by the user. A typical variable resistor, commonly known as *potentiometer* is shown in Fig 8.

Fig 8



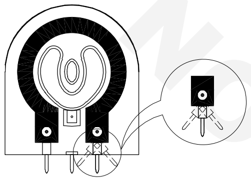

FIXED VALUE RESISTORS
CARBON TYPESCERAMIC TYPES
CARBON COMPOSITION
2 W
1 W
1/2 W
1/4 W
1/8 W
METAL FILM
2 W
1 W
1/2 W
1/4 W
10 W
1 W
150K 1% RCC
METAL OXIDE
2 W
1 W
1/2 W
WIRE WOUND TYPES
10 W
PEC C11 8K2 5%
5 W
PEC C2 0R3 5%
1 W
RADIAL LEADS
10 W
VERTICAL MOUNT
PEC M105 1K 5% 9148A1
SPECIAL TYPES
14 W
RADIAL LEADS
10 W
2 W
3W DIAMOND 10KΩ ±5
2 W
1 W
PRECISON RESISTOR
PEC PEP02 10.0R 0.05%
METAL FILM RESISTOR
NETWORK RESISTORS
LOW OHM METAL FILM
INTEGRATED RESISTOR

Types of Variable Resistors



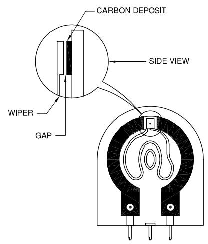
Defect code 1

TERMINAL TAG LOOSE



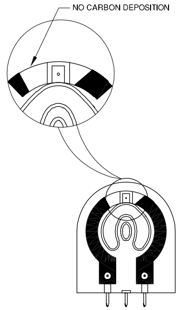
Defect code 2

WIPER NOT MAKING CONTACT AT SOME PLACES.



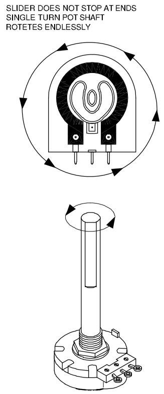
Defect code 3

CARBON TRACK PEELED OFF OR EXCESSIVELY WORN OUT



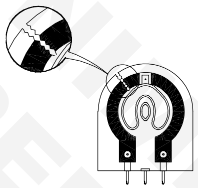
Defect code 4

SLIDER DOES NOT STOP
AT ENDS.
POT.SHAFTROTATES ENDLESSLY.



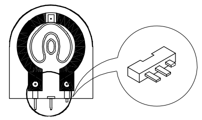
Defect code 5

CRACKED BODY / BASE BOARD



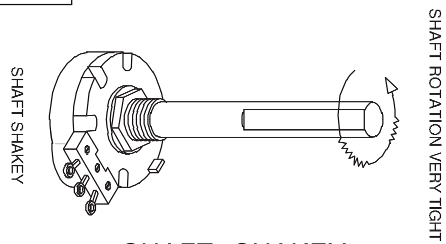
Defect code 6

TERMINALS BROKEN OR TOO SMALL TO SOLDER WIRES



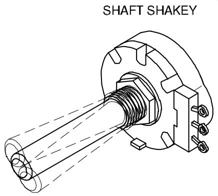
Defect code 7

SHAFT ROTATION VERY TIGHT



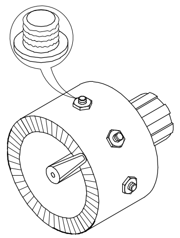
SHAFT SHAKEY

Defect code 8



Defect code 9

WORN OUT TERMINAL / NUT THREADS

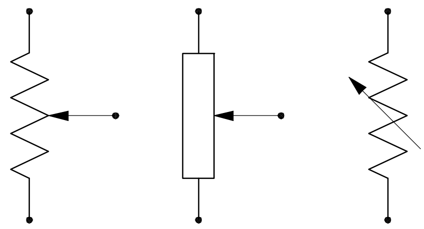


For example, in a variable resistor of 10 KW, it is possible to set the resistance of the variable resistor, to any value between 0 W to 10 KW.

Any variable resistor will have a minimum of three terminals. Referring to Fig 14, the maximum resistance exists across the end terminals X & Z. The resistance across terminals X & Y or across Z & Y can be varied by rotating the shaft.

Different symbols used to represent variable resistors are shown in Fig 9.

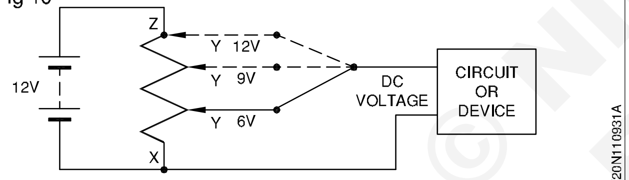
Fig 9



SYMBOLS OF VARIABLE RESISTORS

Variable resistors are also known as *Potentiometers or Pots*. The term *potentiometer* is used for variable resistors because, a variable resistor can be used to adjust the potential difference (voltage) applied to a device or a circuit as shown in Fig 10.

Fig 10



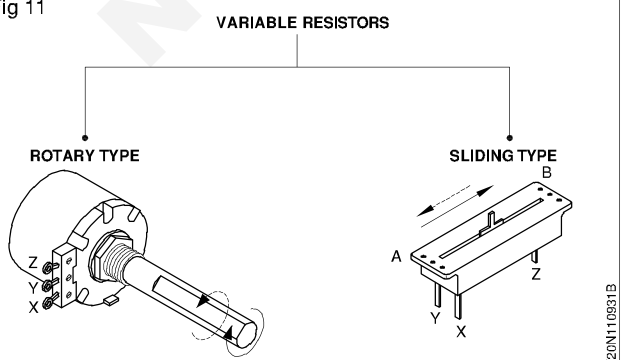
Resistance values of potentiometers are printed on their body either directly in ohms or in a coded form. The value printed always refers to the maximum value that potentiometer can have. Hence the minimum value to which it can be set is always 0 W.

Types of variable resistors

Variable resistors of different types are available in the market. These types can be categorized as follows:

1 Based on the type of control as shown in Fig 11.

Fig 11



In rotary type of variable resistors, the resistance across the terminals X-Y increases as the shaft is rotated clockwise whereas in sliding type, resistance across X-Y increases as the slider is moved from A to B.

2 Based on the resistive material used as shown in Fig 12.

Fig 12

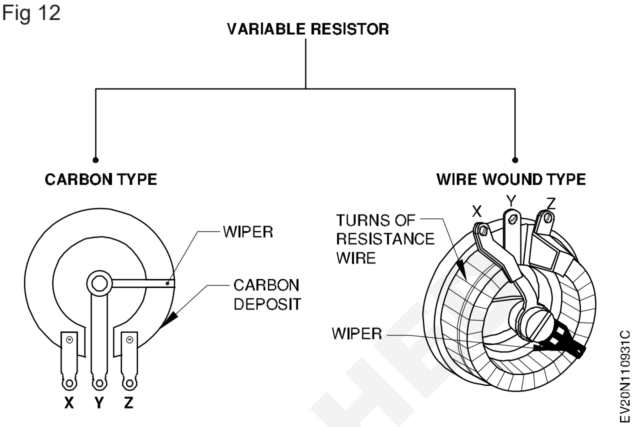


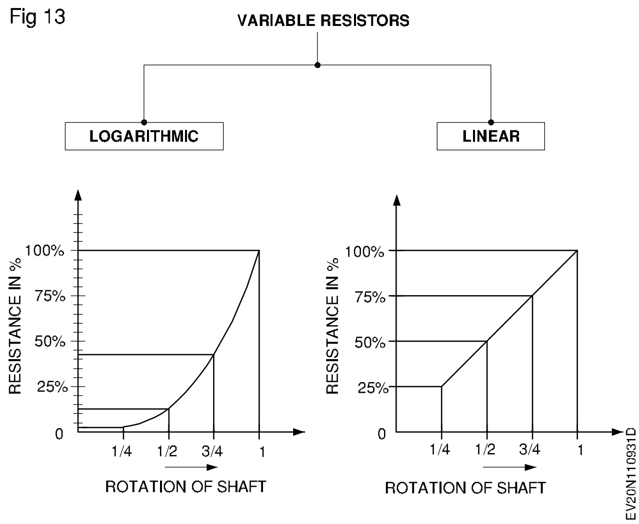
Fig 12 illustrates the brief constructional detail of carbon type and wire wound type variable resistors. In carbon type, the resistive material used is *carbon* or *graphite*. Wire wound type variable resistors uses several turns of resistive wire such as *tungsten* or *manganin*.

3 Based on variation of resistance with reference to shaft position (no. of turns) as shown in graph at Fig 13.

In linear variable resistors, the resistance across the resistor terminals increases or decreases linearly with respect to the shaft position as shown in the graph at Fig 13.

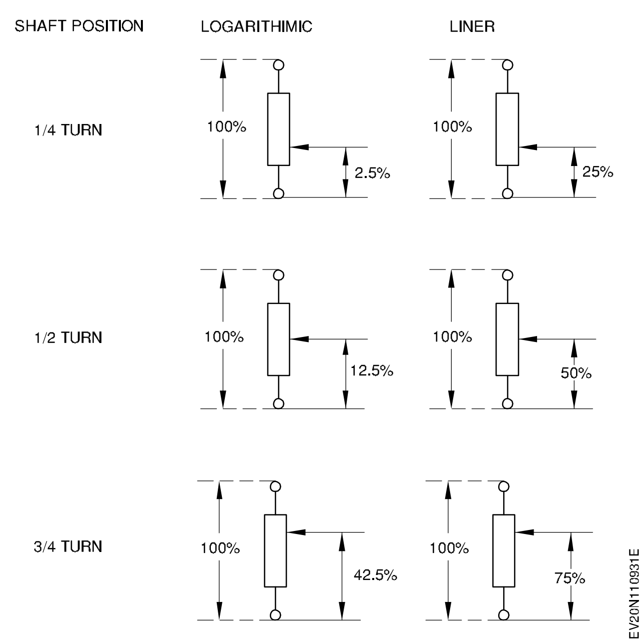
In logarithmic variable resistors, the resistance across the terminals increases or decreases logarithmically (as shown in graph at Fig 13) with respect to the shaft position.

Fig 13



Percentage variation of resistance at different shaft positions of the linear and logarithmic resistors is given in Fig 14 below;

Fig 14

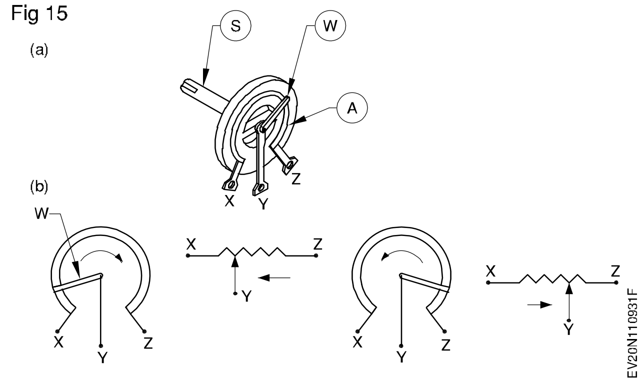


Constructional details of variable resistors

Brief construction of a typical carbon type rotary shaft, variable resistor is shown in Fig 15.

The resistive material carbon or graphite with a suitable synthetic resin is deposited over an arc (A). The ends of the deposit are terminated to lugs (X and Z). The rotatable slider or wiper (W) made of a good conductor, makes contact with the deposited graphite. The other

Fig 15



end of the wiper is terminated to the middle lug (Y). The wiper is mechanically coupled to a shaft (S). As the shaft is rotated, the wiper makes contact at different points on the carbon deposit and the resistance value across X & Y or Z and Y terminals increases or decreases.

In the case of wire-wound type variable resistors, instead of carbon/graphite deposit, suitable number of turns of resistive wire will be wound on an insulating former as shown in Fig 12.

Variable resistors are commonly used in electronic circuits. For ease of mounting and controlling, variable resistors are available in different shapes, sizes. Depending on their type and use they are called by different names such as, Potentiometer or POTs, Presets, Rheostats and so.. on. Refer to Chart 1 given at the end of this lesson for the most commonly used types of variable resistors.

Ohm's Law

Objectives: At the end of this lesson you shall be able to
- **state Ohm's law**
- **calculate the total resistance of series resistance circuits**
- **calculate the total resistance of parallel resistance circuits**
- **power dissipation in parallel resistive circuits.**

OHM'S LAW

The quantity of current flowing through a resistor depends on two factors:

1 The ohmic value of the resistor.

2 The voltage applied across the resistor.

If the voltage applied across a resistor is kept constant, higher the resistance of the resistor, lower will be the current flowing through it. In other words current (I) through a resistor is inversely proportional to resistance(R) value of the resistor.

On the otherhand, if the applied voltage (V) across a fixed value resistor is increased, the current flowing through the resistor also increases. In other words current (I) through a resistor is directly proportional to the applied voltage(V) across the resistor.

Combining the above two relationships between resistance(R), current (I) and applied voltage(V), it can be written as,

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

This relationship of I = V/R was found by the scientist *George Simon Ohm* and hence this is referred to as *ohm's law.*

The relationship of I = V/R can be expressed mathematically in different forms as

$$I = \frac{V}{R} \text{ or } V = I \times R \text{ or } R = \frac{V}{I}$$

These formulas are used invariably while designing or testing electrical/electronic circuits.

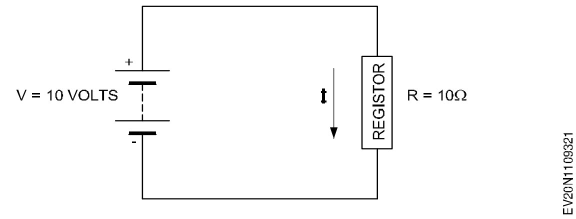
Generalising, ohm's law can be stated as follows:

Under a given constant temperature, the current flowing through a resistor is directly proportional to the voltage across the resistor and inversely proportional to the value of resistance.

This statement holds good not only for a resistor, but in common to all resistive circuits.

Example 1 : Using ohms law, find the current flowing through the resistor in Fig 1.

Fig 1



Solution :

Applied voltage across the resistor is : 10 volts

Resistance value of the resistor is given as 10 ohms.

Therefore current(I) through the resistor by Ohm's law is;

$$I = \frac{V}{R} \text{ Amps.} = \frac{10 \text{ volts}}{10 \text{ ohms}} = 1 \text{ amp.}$$

Current through the resistor is 1 ampere.

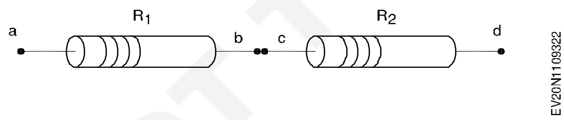
- **Resistors in series**

When resistors are connected end to end as shown in Fig 3, the resistors are said to be in series with each other.

Total resistance of resistors in series

When resistors are connected in series, the total resistance of the series connection will be equal to, the sum of individual resistance values. In Fig 2, total resistance across points a-d will be equal to $R_1 + R_2$.

Fig 2



Example : In Fig 2, if R_1 is 1 K ohms and R_2 is 2.2K ohms. The total or effective resistance between the terminals a and d will be,

(R_1 and R_2 are connected in series).

$= R_1 + R_2$

$= 1.0\ k\Omega + 2.2\ k\Omega = 3.2\ k\Omega.$

Current through a series circuit

When resistors are connected in series as shown in Fig 2, the current that flows through R_1 can only flow through R_2 . This is because

– there is no other path for any other extra current to flow through R_2

– there is no other path for the current through R_1 to escape from flowing through R_2.

Therefore *in a series circuit, the quantity of current will be the same at all the points (a,b,c,d) of the circuit*.

The quantity of current flowing through the series path is decided by both the resistors put together or the effective resistance of the circuit.

Example : Find the total circuit current(I_t) in the circuit at Fig 3.

Solution :

Resistors R_1 & R_2 are in series. Therefore, the effective resistance of the circuit = $R_1 + R_2$

$= 3.3k\Omega + 330\Omega.$

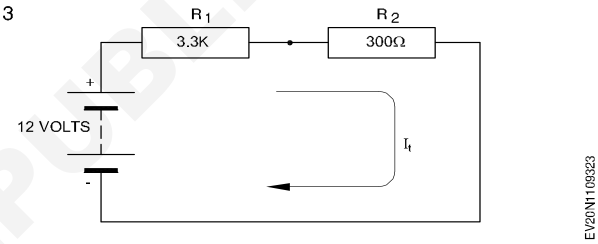
$= 3300 + 330 = 3630$ ohms.

Circuit current I_t

$$= \frac{V}{R} = \frac{12\ V}{3630\ \Omega} = 0.0033 \text{ amps} = 3.3 \text{ mA.}$$

Example : Calculate the voltage drops across R_1 and R_2 for the circuit at Fig 3.

Fig 3



Solution :

In the circuit (Fig 3), R_1 and R_2 are in series. Hence the current through both the resistors is the same. This current is 3.3 mA as calculated in the previous example.

From Ohm's Law

Therefore the voltage drop across R_1

$= I \times R_1$ volts

$= 3.3\ mA \times 3.3\ k\Omega$

$= (3.3 \times 10^{-3}) \times (3.3 \times 10^{3})$

$= 3.3 \times 3.3 = 10.89$ volts.

Similarly the voltage drop across R_2

$= (3.3 \times 10^{-3}) \times 330$ ohms

= 1089 milli-volts

= 1.089 volts.

Verification of solution

Since R_1 and R_2 are in series, the sum of the voltage drops across R_1 and R_2 must be equal to the applied battery voltage of 12V. i.e, 10.89 + 1.089 = 11.979 » 12 volts = applied battery voltage.

Power dissipation in resistors

When current flows through a resistor heat is generated. This is because, the voltage driving the current through the resistor is doing some amount of work in overcoming the opposition to the flow of electrons. It is found through experiments and analysis that, the amount of work done by the voltage is directly proportional to the ohmic value(R) of the resistor and square of the current(I^2) flowing through the resistor. This work done is dissipated in the form of heat generated by the resistor. This heat dissipating capacity is known as the power or wattage of a resistor. The unit of power is *Watt*.

Power dissipated by a resistor = I^2 x R Watts.

Where,

I is the current through the resistor

and R is the resistance of the resistor.

Example : If 10 mA flow through a resistor of 10 K ohms, what is the power dissipated by the resistor ?

Power dissipated by the resistor = I^2 x R = (Ix I) x R

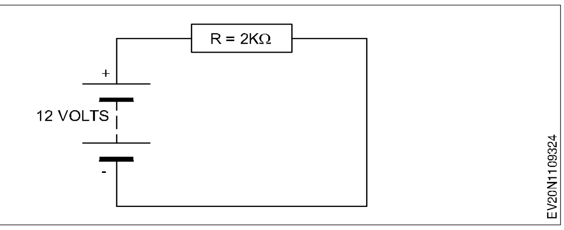
= $(10 \times 10^{-3}) \times (10 \times 10^{-3}) \times (10 \times 10^{3})$

= 1000×10^{-3} = 1000 milli-watts = 1 watt.

The power dissipated by the resistor is 1 watt.

Example : What is the total power dissipated by the circuit given at Fig 4.

Fig 4



Solution :

Current through the circuit is I_t = V/R

= 12V/ 2 kΩ = 6 mA

Power dissipated by the circuit is

= (circuit current)^2 x circuit resistance

= $(36 \times 10^{-6}) \times (2 \times 10^{3})$

= 72×10^{-3} watts

= 72 milli-watts = 0.072 watts.

Magnetism, Relays

Objectives: At the end of this lesson you shall be able to

- **State the magnets and megnetism**
- **explain the properties of magnets**
- **state flux and flux density**
- **state the magnetic field around a current carrying conductor**
- **explain relay types, construction and specification.**
- **state the type of Multimeter and their functions**
- **state the semiconductors**

Magnets and magnetism

Magnets are those which have the power to attract iron or alloys of iron (ferrous materials). Magnets available in nature are called natural magnets or lodestones.

The property of a material to attract pieces of ferrous materials is called magnetism.

Natural magnets are of very little practical use these days because it is possible to produce much better magnets by artificial means.

Magnetic and non-magnetic materials

All materials cannot be made magnets artificially. Materials which are attracted by magnets are called *magnetic materials* and only such magnetic materials can be made as artificial magnets. All other materials are called *non-magnetic materials*. A list of a few magnetic and non-magnetic materials is given below:

Magnetic materials	Non-magnetic materials
IRON	ALUMINIUM
STEEL	COPPER
COBALT	BRASS
NICKEL	LEAD

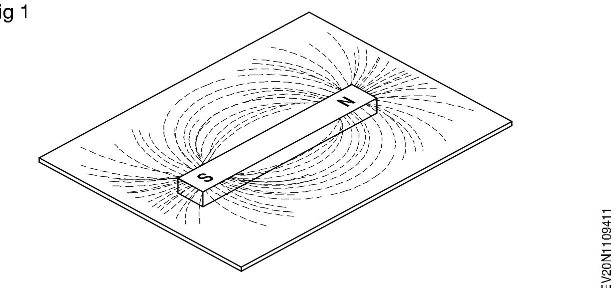
Poles of a magnet

The magnetic strength of a magnet is concentrated at two points on the magnet. These points are called the *poles* of a magnet.

MAGNETIC FIELD AND MAGNETIC FLUX (Ø)

The property of magnetism in any magnet is because of an invisible field of force between the two poles at the opposite ends of the magnet as shown in Fig 1. It can be seen that the magnetic field is strongest at the poles. Magnetic field exists in all directions, but decreases in strength, as you go away from the poles(decreases inversely as the square of the distance from the poles). The magnetic lines can be considered to flow outward from the north pole and enter the magnet at the south pole. The entire group of magnetic lines, which can be considered to flow outward from the north pole of a magnet, is called the magnetic flux. The magnetic flux is symbolically represented by the Greek letter ø (phi). The more the magnetic flux ø, the stronger is the magnetic field, and hence, the magnet.

Fig 1



PROPERTIES OF MAGNETS

- **Unlike poles attract each other.**

When the north pole of a freely movable permanent magnet is brought near the south pole of a second permanent magnet, an invisible force causes the two poles to be attracted to each other. The two unlike poles actually stick to one another. The force of attraction between unlike poles increases as the distance between the poles decreases. Actually, the force of attraction varies inversely as the square of the distance between poles.

- **Like poles repel each other.**

When the north pole of a freely movable permanent magnet is brought near the north pole of a second permanent magnet, an invisible force causes the two poles to repel each other. The two unlike poles actually move away with a jerk. This force of repulsion increases as the distance between the poles decreases. Actually, the force of repulsion varies inversely as the square of the distance between poles.

- **Induces magnetic properties to magnetic materials.**

A permanent magnet can induce magnetism to an unmagnefied iron bar such that the iron bar become a magnet. To induce magnetism, it is enough if the permanent magnet comes close to the iron bar as shown in Fig 2.

What is happening in Fig 2 is that, the magnetic lines of force generated by the permanent magnet, make the internal molecular magnets in the iron bar line up in the same direction as shown in Fig 3b. An unmagnified

Fig 2

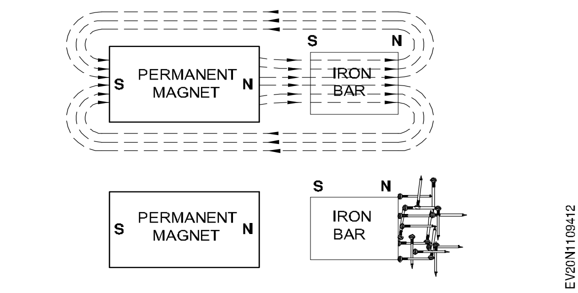
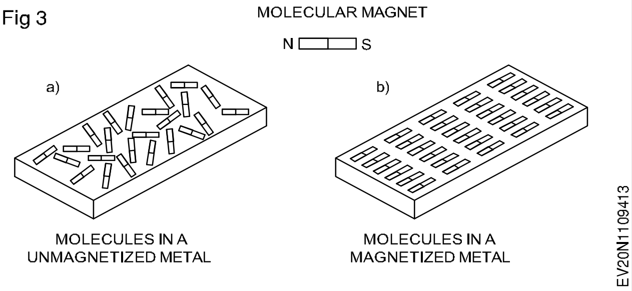


Fig 3



iron as shown Fig 3a, the molecules will be in random directions. Note from Fig 2 that, the induced poles in the iron bar have opposite polarity from that of the poles of the permanent magnet.

It should be noted that inducing magnetism was possible only because the unmagnified material was a magnetic material. In Fig 3 instead of iron, a copper bar is used, the permanent magnet will not induce magnetism in copper as copper is a non-magnetic material. The magnetic field lines will be unaffected by the non-magnetic materials when placed in the magnetic field of a magnet.

TYPES OF MAGNETS

Magnets are available naturally, and can also be made artificially. When magnets are made artificially, depending on the type of material magnetism is retained for different durations. For example, if a piece of soft iron and a piece of steel are magnetized. The magnetism in steel remains for a much longer duration than in soft iron. This ability of a material to retain its magnetism is called retentivity of the material. Depending upon the retentivity of the material, artificial magnets can be classified as temporary magnets and permanent magnets. Temporary magnets lose their magnetic power or magnetism once the magnetizing force is removed.

The magnetism that remains in a magnetic material, once the magnetizing force is removed, is called residual magnetism. This term is usually only applicable to temporary magnets.

Permanent magnets retain magnetism for a long period of time.

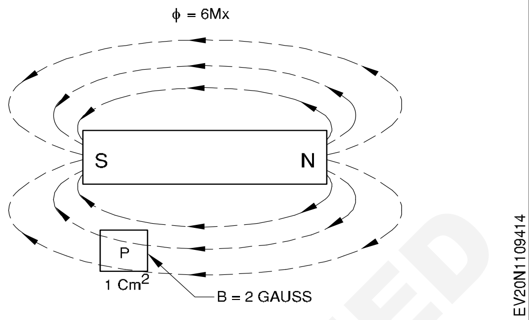
Classification of magnets, popularly used types of magnets and their applications are given in Chart 1 at the end of this lesson.

Units of magnetic flux ø

Maxwell

One Maxwell (Mx) unit equals one magnetic field line. In Fig 4, for example, the flux illustrated is 6 Mx because, there are six field lines flowing in or out of each pole. A one pound magnet can provide a magnetic flux ø of about 5000 Mx.

Fig 4



Maxwell is a unit of magnetic field in CGS system of units.

This is a larger unit of magnetic flux. One weber (Wb) equals 1×10^8 lines or maxwells. Since weber is a large unit for typical fields, microweber (µWb) unit can be used.

$1\mu Wb = 10^{-6} Wb$.

For a one lb magnet producing the magnetic flux of 5000 Mx, corresponds to 50 µWb.

Weber is a unit of magnetic field in SI system of units.

FLUX DENSITY (B)

The flux density is the number of magnetic field lines per unit area of a section perpendicular to the direction of flux as shown in Fig 4.

As a formula,

$$B = \frac{ø}{A} = \frac{\text{flux}}{\text{Area}}$$

In magnets, the flux density will be higher close to the poles because flux lines are more crowded near the poles.

Units of flux density

Gauss: One Gauss is equal to one flux line per square centimeter, or 1 Mx/cm^2.

Gauss is a unit of flux density in CGS system of units.

Since gauss is a small unit, flux density if often measured in kilogauss

1 kilogauss = 10^3 Gauss.

In SI units of measurement, the unit of flux density B, is webers per square metre (Wb/m^2). One weber per square metre is called a tesla, abbreviated as T.

Tesla is a unit of flux density in SI system of units.

CLASSIFICATION OF MAGNETIC MATERIALS

Based on the strong magnetic property of iron, other materials are classified as either magnetic or non-magnetic materials. However, a more detailed classification is given below;

1 Ferromagnetic materials

2 Paramagnetic materials

3 Diamagnetic materials

These are materials which become strongly magnetized. These materials gets magnetised in the same direction as the magnetizing field. These materials have high values of permeability in the range of 50 to 5000. Examples of ferromagnetic materials are iron, steel, nickel, cobalt, and commercial alloys such as alnico and permalloy. Permalloy has a μr of 100,000 but gets saturated at relatively low values of flux density.

Paramagnetic materials

These are materials which become weakly magnetized. These materials gets magnetised in the same direction as the magnetizing field. The permeability of paramagnetic materials is slightly more than 1. Examples of paramagnetic materials are aluminum, platinum, manganese, and chromium.

Diamagnetic materials

These are materials which become weakly magnetized. These materials gets magnetised in the opposite direction of the magnetizing field. The permeability of diamagnetic materials is less than 1. Examples of diamagnetic materials are bismuth, antimony, copper, zinc, mercury, gold and silver.

The basis of the above three classifications is the motion of orbital electrons in atoms.

There are two kinds of electron motion in the atom;

1 The electron revolving in its orbit: This motion provides a diamagnetic effect. However, this magnetic effect is weak because of the thermal agitation at normal room temperature. This results in random directions of motion that neutralizes the magnetic effect of each other.

2 The magnetic effect from the motion of each electron spinning on its own axis: The spinning electrons works as a tiny permanent magnets. Opposite spins provide opposite polarities. Two electrons spinning in opposite directions form a pair, neutralizing the magnetic fields. In the atoms of ferromagnetic materials, however, there are many unpaired electrons with spins in the same direction, resulting in a strong magnetic effect.

Iron, cobalt and nickel are said to be very good magnetic materials. Alloys of these three metals make up almost the entire range of magnetic materials used by the electrical, electronic and communication industries.

Temporary and permanent magnets

Another classification of magnetic materials based on their application are:

1 Temporary magnets

2 Permanent magnets

Soft and hard magnetic materials

Magnetic materials can be classified as:

1 Hard magnetic materials

2 Soft magnetic materials

Hard magnetic is a term is used to cover the range of materials used for making permanent magnets.

Some of the hard magnetic materials commonly used and a brief of their magnetic properties are given below;

Carbon steel

This was the only material used for permanent magnets in olden days. It has poor magnetic materials and not in much use today.

Carbon steel is now used only for applications where low cost is more important than magnetic performance.

Carbon steel is used in making compass needles, thin sheet magnets and magnets for toys.

Tungsten and chromium steels

The addition of tungsten and chromium to carbon steel gives a group of alloys having better magnetic properties than carbon steel. These materials can be rolled or forged to different shape and are machinable.

Large quantities of instrument magnets are produced from steel containing approximately 6% tungsten.

Chromium steel is cheaper to produce but slightly less effective than tungsten steel as a permanent magnet. Instrument magnets are made by punching out the shape required from steel strips containing 3% chromium.

Cobalt steel

The addition of cobalt to chromium steel considerably increases the magnetic strength of the material.

To meet all reasonable industrial requirements, a range of five cobalt steel alloys, each having a different cobalt composition are produced. These alloys can be rolled or cast and machined before hardening.

Cobalt steel alloys are used for making rotating magnets, telephone receivers, speedometer magnets, multi-pole rotors used in electric clocks and hysteresis motors.

Iron-aluminium-nickel

In 1931 an alloy of iron, aluminum and nickel was discovered. This alloy gives a better magnetic performance as a permanent magnet when compared to all the other commercially produced permanent magnetic materials.

Most permanent magnets produced today are made from Alnico and Alcomax group of alloys. These have iron-nickel and aluminium with additions of cobalt and copper.

Magnets made from these alloys can only be produced by the processes of casting and sintering. They are very brittle and cannot be machined except by grinding.

Soft magnetic is a term which covers the range of materials which are easy to magnetize and demagnetize. They are used for the cores of electromagnets or temporary magnets.

Soft magnetic materials used for making electromagnets are easy to magnetize and demagnetize. They have low hysteresis loss, higher saturation value (B), higher permeability and low coercivity values when compared with hard magnetic materials.

Soft magnetic materials are generally used for making laminated, transformer cores, motor & generator armatures and other electrical equipments which are subject to continual reversal of magnetization.

Some of the soft magnetic materials commonly used and their magnetic properties are given below;

Mild steel

It is an inexpensive material to produce, and, therefore, an ideal material to use where cost is important and the magnetic properties required not so stringent. As the carbon content in mild steel is increased, the effect is to lower the magnetic properties.

Iron-silicon alloys

A range of iron-silicon alloys, containing silicon between 0.3% to 4% is produced as sheets or strips and used for making laminations. Iron with a small amount of silicon has better magnetic properties than pure iron.

These alloys have low hysteresis loss, high saturation and are used for the magnetic circuits of electrical equipment operated at power frequencies of 50 Hz such as power transformers, alternators and electric motors of all sizes.

Due to the brittleness of the higher silicon alloys, it is not possible to make it into very thin sheets or strips.

Magnetic field around a current-carrying conductor

When current is passed through a conductor, a magnetic field is produced around it. It is important to note the following two factors about the magnetic lines of force around a current carrying conductor.

1 The magnetic lines are circular and the field is symmetrical with respect to the current carrying wire in the centre.

2 The magnetic field with circular lines of forces is in a plane perpendicular to the current in the wire.

The direction of the magnetic lines around the conductor can be determined by the right hand screw rule. The direction of magnetic lines reverses, if the direction of current through the conductor is reversed. This magnetic field around a single conductor is too weak to make the wire behave as a useful magnet.

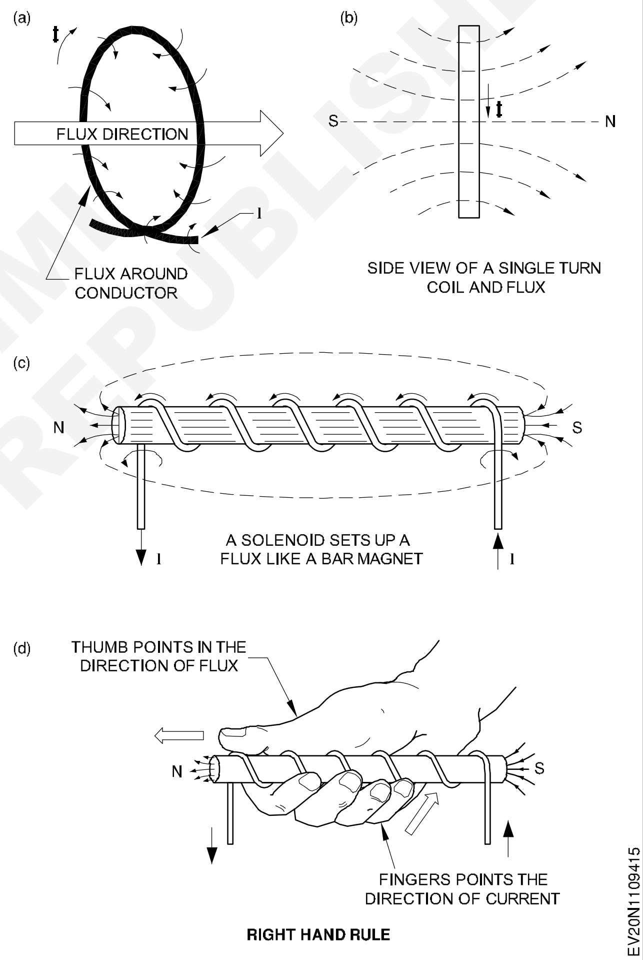
Magnetic field around a coil

Consider the effect of passing a current through a one-turn coil of wire as shown in Fig 5a.

Fig 5a and 5b shows the magnetic flux generated by the electric current passing through the centre of the coil. Therefore, a one-turn coil acts as a little magnet. It has a magnetic field with an identifiable N pole and S pole. Instead of a single turn, a coil may have many turns as shown in Fig 5c. In this case, the flux generated by each of the individual current -carrying turns, tends to link-up and pass out-of one end of the coil and back into the other end as shown in Fig 5c. This type of coil, also known as a solenoid has a magnetic field pattern very similar to that of a bar magnet.

The *right hand rule* for determining the direction of flux from a solenoid is illustrated in Fig 5d. When the solenoid is gripped with the right hand such that, the fingers are pointed in the direction of current flow in the coils, the thumb points in the direction of the flux as shown in Fig 5d. The coil now behaves like an electromagnet.

Fig 5



The solenoid acts like a bar magnet whether it has an iron core or not. Adding an iron core in a solenoid increases the flux density inside the coil. In addition, the field strength will then be uniform for the entire length of the core. It should be noted that, adding an iron core into a solenoid does not change the N and S pole positions of the solenoid.

When the direction of the current through the coil is changed, it changes the direction of magnetic lines, thereby changing the poles of the solenoid.

Applications of electromagnet

Electromagnets are used in various applications such as electrical circuit breakers, relays, door bells etc.

Faraday's law

Whenever a conductor cuts magnetic lines of force, an *emf* is induced in the conductor. This is known as Faraday's law of *Electromagnetic Induction.*

Lenz's Law

The basic principle used to determine the direction of induced voltage or current is given by *Lenz's Law*.

> **Lenz' law states that the direction of induced current is such that the magnetic field set-up due to the induced current opposes the action that produced the induced current.**

Solenoid: A wire coil used as an electromagnetic is known as a solenoid, it also refers to any devices that converts electrical energy to mechanical energy through solenoid.

A solenoid is a coil of wire, in the form of a cork screw. According to the laws of electro magnetism, when electric current passes via wire a magnetic field is generated.

The solenoid induces a magnetic field from electric current and uses the magnetic field to achieve linear motion. A solenoid is a device comprised of a coil of wire, housing and a movable plunger. When electrical current is introduced a magnetic field forms around the coil which draw the plunger in.

The coil is made of many turns of tightly wound copper wire. When an electrical current flows through this wire and it is created a strong magnetic field. Then this housing usually made of iron or steel surrounds the coil of iron. The surrounding coil concentrating the magnetic field is generated by the coil and then plunger is attracted to the stop through the concentration of the magnetic field providing the mechanical force to do work.

Solenoids are used in automobile systems like a engine starter motor, activate four wheel drive system, fuel injection system, door lock system, car air flow control AC systems and many more systems etc.

Solenoid application is used in various fields like medical, industrial uses, main parts of solenoid is nut, housing and coil.

Relays:

In addition to solenoids, one other most popular application of electromagnets is in what are called electromagnetic relays in Fig 6.

Construction and operation of a simple relay

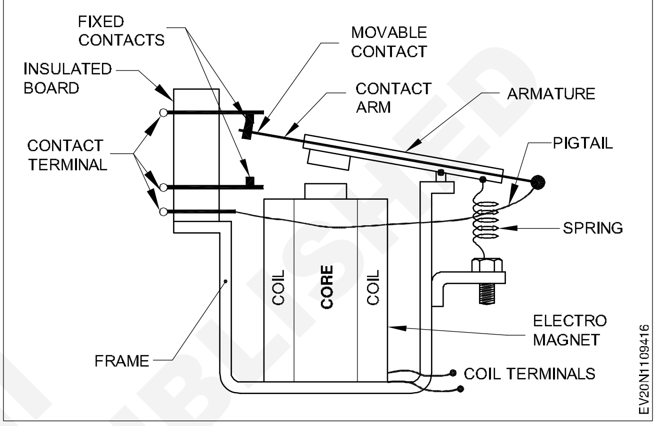
Electromagnetic relay is basically a switch or a combination of switches operated by magnetic force generated by a current flowing through a coil.

Essentially, a typical relay shown in Fig 7 consists of the following parts;

- an electromagnet comprising of a core and coil
- a movable armature,pivoted and held in tension by a spring
- a set of contacts
- a frame to mount all these components.

As shown in Fig 6, a typical relay consists of a core surrounded by a coil of wire. This is mounted on a metal frame. The movable part of the relay is the armature.

Fig 6



One end of the armature is hinged and connected to a spring. On the armature is mounted a contact arm carrying movable contacts. The fixed relay contacts and its terminals are mounted on an insulated terminal board.

When the relay is OFF or not energized, the contact arm touches the top contact. When the relay is energized by applying voltage to the coil terminals, the metallic armature is attracted. The armature and contact arm assembly move downward so that the contact arm mounted on the armature touches the bottom contact. Thus, the relay is doing the function of a single pole, double throw (SPDT) switch.

On removing the voltage applied to the coil, the spring attached to one end of the armature returns the armature to its original position and the contact arm touches the top contact.

Operating delay of relays

When an energizing voltage is applied to a relay coil, the relay does not work instantaneously. It takes some time, usually a few milliseconds to operate. Reasons for this delay are given below:

- Due to inductance of the relay coil, current grows slowly and takes some time to reach the required current value.
- Due to inertia, the armature takes sometime to move from one position to another.

When rated voltage is applied to terminals of a relay coil, the gradual build up of current in the coil is due to the initial opposition to the current flow by the self-inductance of the coil. After some delay, when sufficient magnetization is built up and when the force of attraction is sufficient to overcome the opposition of the tension due to return spring plus, tension of contact springs, the armature is attracted and it closes the relay contacts. The relay is then said to be energized or pulled-in or picked.

Once the relay is energised then, only a small amount of energy is required to maintain it in energized condition. The rest of the electrical energy is wasted as heat.

When the current through the coils falls below a certain value, the relay gets de-energised and the return spring pulls the armature back. This is called as relay drop-out.

From above it can be seen that, very little amount of electrical power is consumed for the switching of relay whereas most of the power is consumed while holding.

Parts of a Relay

Each part of a relay is as important as the other in the overall performance of the relay. Details of the parts of a relay and their purpose are given below:

Frame and core : One of the main function of the relay frame is to provide a base for mounting other relay parts. But, the most important function is, the frame forms a part of the complete magnetic path between the armature and core. The core, frame and armature are made of an easily magnetizable material such as iron.

Hinges : The hinges connect the armature to the frame. A good hinge must be as free from friction as possible. They must also be strong enough to support the weight of the armature and contacts. The hinges must provide low reluctance to the magnetic flux in its path from the core through the frame and the armature.

Return springs : The springs are usually very thin and cannot concentrate any large amount of flux. Spring steel, which has a lower reluctance than other materials acts to retain its magnetism and remain attracted to the core after the relay is de-energised. Springs also have a disadvantage of being stiff and are likely to break after a few operations.

Relay coil : The coil is usually wound on a former and slipped over the magnetic core in the relay frame. This permits easy replacement of damaged coils by new ones.

Coil Specifications

Generally relays are made to operate at different voltages such as, 6, 12, 18, 24, 48, 100 or 240 volts AC or DC. A coil resistance chart is usually given with relays which helps in calculating the coil current and power dissipation. Maximum wattage, maximum permissible temperature and the wattage for satisfactory operation, are specified along with relays.

Operate current – is the minimum current required to energize a relay.

Hold current – is the minimum coil current required to continue to hold the relay energized.

Release current – is the maximum current which releases the relay.

Relay coils are always insulated from the frame of the relay. The electrical resistance between the coil and the body is a measure of the isolation of energising voltage from the ground. Similarly, the electrical resistance between the coil and the contacts is a measure of the electrical isolation between the energising driving and the driven circuits. These resistances will be of the order of hundreds or thousands of megohms.

Relay contacts

The contacts on a relay are the parts that actually perform the electrical switching of the controlled circuits. Also, these contacts are the ones that cause most trouble and require frequent maintenance as compared to any other part of a relay.

Contact materials and design

The relay contacts are made of material which are very good conductors as well as corrosion-resistant.

An arc is created when the contacts open and close. This arc burns and oxidises the contacts. An oxide coating make the contacts either poor conductors or non-conductors. For this reason, contacts are made of silver, palladium and palladium-iridium alloys, gold alloys, gold plated silver, tungsten and alloys of other highly corrosion-resistant materials that do not oxidize easily.

Even with these materials, some oxidation still takes place. To get rid of the oxide, the contacts are designed to have a wiping action. As the contacts close and open, the surfaces rub together. This action rubs off any oxide or dirt which might cause poor contact.

Contacts come in many shapes and sizes, and in a variety of contact arms. These contact arms are generally called contact springs because they maintain good contact pressure.

Size of the contacts determines the current handling capability. The larger the contacts, the more current they can switch without excessive deterioration.

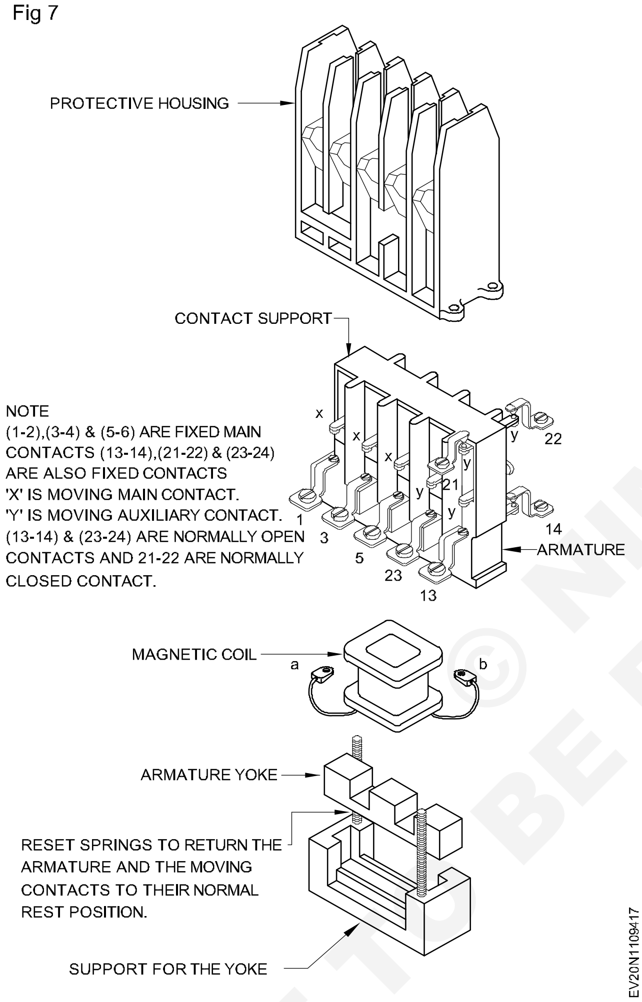
The contact arms or springs are made thick and wide enough to carry the current for which the contacts are rated. They are also made spongy enough to ensure good contact. If the springs are too soft they may vibrate when the relay opens, causing contact bounce when the contacts open and close repeatedly. This bounce can also occur on closing. The bouncing of contacts is always undesirable. Contact debouncing circuits are used to overcome the undesirable effects of contact bouncing in sensitive circuits such as digital electronic circuits.

Contactors: The contactor forms the main part in all the starters. A contactor is defined as a switching device capable of making, carrying and breaking a load circuit at a frequency of 50 cycles per second or more. It may be operated by hand (mechanical), electromagnetic, pneumatic or electro-pneumatic relays.

The contactors shown in Fig 1 consist of main contacts, auxiliary contacts and no-volt coil. As per Fig 1, there are three sets of normally open, main contacts between terminals 1 and 2, 3 and 4, 5 and 6, two sets of normally open auxiliary contacts between terminals 23 and 24, 13 and 14, and one set of normally closed auxiliary contact between terminals 21 and 22.

Auxiliary contacts carry less current than main contacts. Normally contactors will not have the push-button stations and O.L. relay as an integrated part, but will have to be used as separate accessories along with the contactor to form the starter function. The main parts of a magnetic contactor are in Fig 7

Fig 7



Multimeter

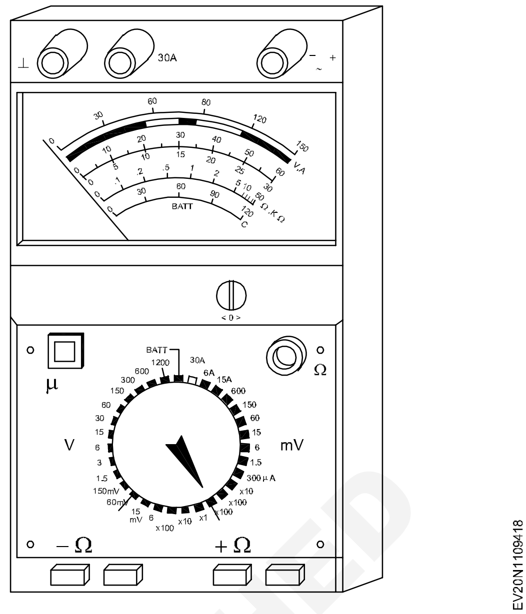
The three most commonly measured electrical quantities are current, voltage and resistance. Current is measured by an ammeter, voltage by a voltmeter and resistance by an ohmmeter.

A single instrument used for measuring all the above three quantities 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 kΩ/ volts and for the DC voltage range it is 20 kΩ/ volts. The lowest range of DC is more sensitive than the other ranges.

Fig 8 show typical multimeters.

Fig 8



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. (Fig 9,10,11)

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, as shown in Fig 10.

Fig 9

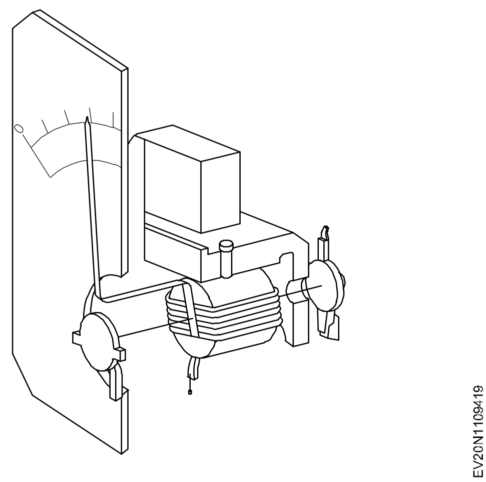


Fig 10

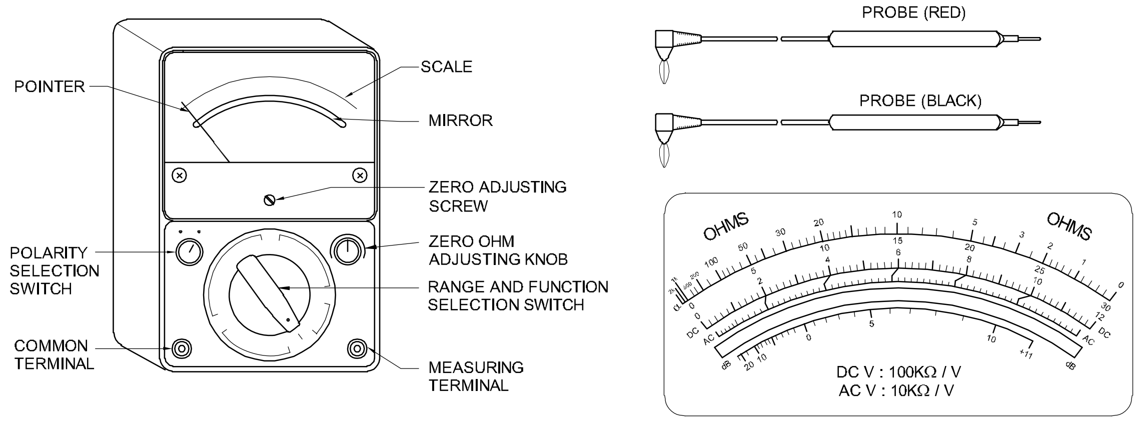
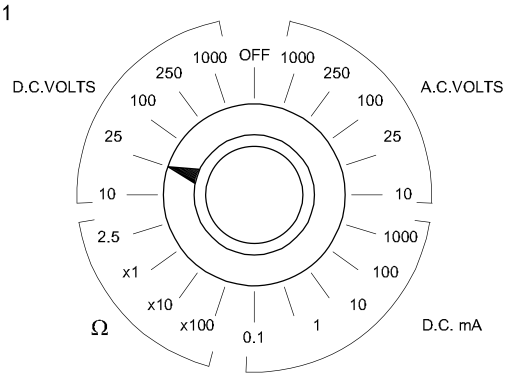


Fig 11



FUNCTION AND RANGE SWITCH

Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch.

The meter is set to the required current, voltage or resistance range - by means of the RANGE switch.

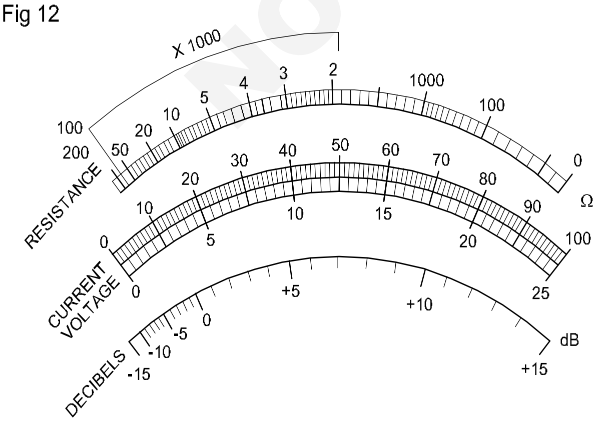
The example in Fig 11 shows the switch set to 25V DC of a meter having the function and the range selected by a single switch.

Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 12)

Fig 12



The scale of current and voltage is uniformly graduated.

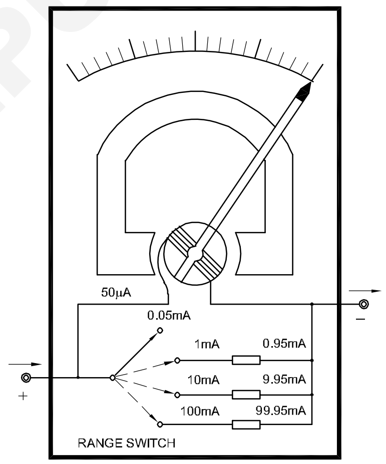
The scale of the ohmmeter is non-linear. That is, the divisions between zero and infinity (∞) are not equally spaced. As you move from zero to the left across the scale, the divisions become closer together.

The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter is shown in Fig 13.

Fig 13



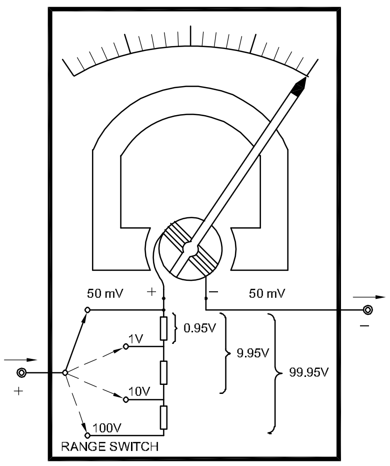
Shunt resistors across the meter movement bypass current in excess of 0.05 mA at FSD. A suitable value of shunt resistor is selected through the range switch for the required range of current measurement.

A circuitry when working as a voltmeter is shown in Fig 14.

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 is shown in Fig 15.

Fig 14



To measure resistance, the leads are connected across the external resistor to be measured as shown in Fig 14.

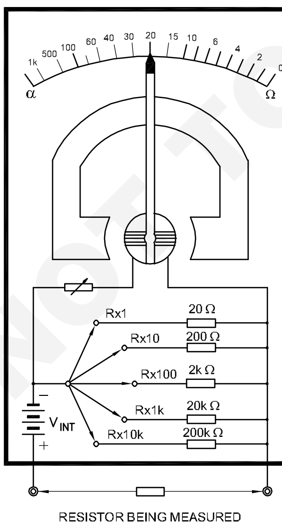
This connection completes the circuit, allowing the internal battery to produce current through the meter coil, causing deflection of the pointer, proportional to the value of the external resistance being measured.

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.

Fig 15



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. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range.

Digital Multimeter

Digital multimeters are high input impedance and better accuracy and resolution. It converts an input analog signal into its digital equivalent and displays it. the analog input signal might be digital voltage, an a.c. voltage, a resistance or an a.c/d.c current.

Measurement of resistance using multimeter

A moving coil meter can be used to measure unknown resistance by using a circuit configuration. With the test probes short circuited, the ohms adjust control is turned so that the current through the total circuit resistance deflects the meter to the full scale. Now by connecting the test probes across the unknown resistance, the current is decreased, and the deflection on the scale gives you the resistance value. Ohms law states the output current is proportional to the applied voltage. Unit of resistance is ohms.

Measurement of voltage

The moving coil meter has constant resistance so that the current through the meter is proportional to the voltage across it. so the current meter can be used to measure voltage. To extent, the voltage range of the meter, it is necessary to add resistance in series with the meter circuit. In order to measure a.c. voltage, rectification is required. The principle of generating a.c. is by electromagnetic induction is higher. While measuring unknowing voltage levels with multimeter, always range switch should be set to the highest available range and work down from there Unit of voltage is volts.

Measurement of current:

The moving coil meter is sensitive to the current and is therefore an ammeter. For d.c. measurement, the meter is placed in series with the circuit. So the circuit must be broken to connect the ammeter and it becomes the part of the circuit. For A.C. measurement, rectifier type meters are used which will respond to the average value of the rectified alternating current. Unit of current is amperes.

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. In this instrument the value of current could be calculated from the tangent of the deflection produced by the current, the radius and number of turns of wire used and the horizontal component of the earth's magnetic field. No previous calibration or comparison is necessary in this type of instruments. These instruments are used only in standard laboratories.

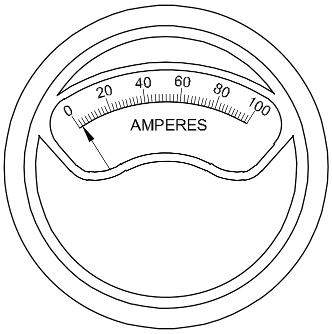
Secondary instruments: In these instruments the value of electrical quantity (voltage, current, power, etc.) to be measured can be determined from the deflection of the instruments on the calibrated dial. These instruments should be calibrated in comparison with either an absolute instrument or with 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, as shown in Fig 16, indicate the value of voltage, current power etc. directly on a graduated dial. Ammeters, voltmeters and wattmeters belong to this class.

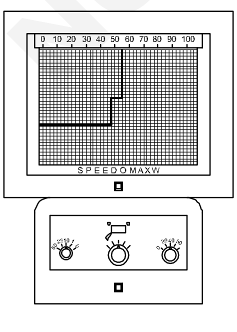
Fig 16



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.

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 17 shows such a recording instrument.

Fig 17



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 deflection 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.

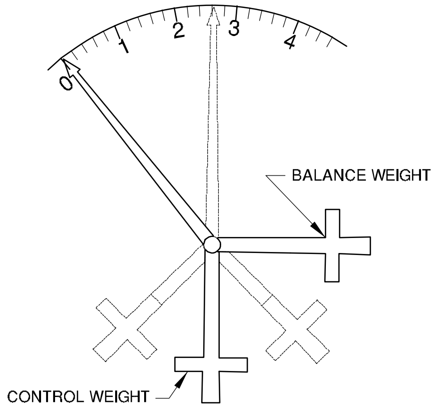
The controlling force could be produced by any one of the following ways.

- Gravity control
- Spring control

Gravity control: In this method, small adjustable weights are attached to the opposite extension of the pointer as shown in Fig 18. 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.

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 as shown in Fig 18. When the instrument is connected to the supply, the pointer moves in a clockwise direction, thereby displacing the weights as shown in dotted lines in the figure. 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.

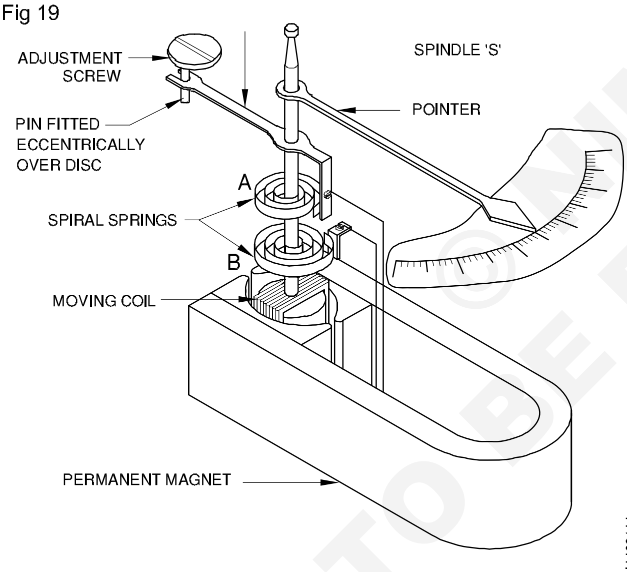
Fig 18



GRAVITY CONTROL

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 as shown in Fig 18. 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 19)

Fig 19



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:

- high resistance to fatigue (can be wound or unwound several times without loosing the tension)
- 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.

Ohm meter

Resistances could be broadly classified according to their values as low, medium and high resistances.

Low resistance: All resistances of the order of 1 ohm and below, may be classified as low resistances.

Example: Armature and series field resistances of large D.C. machines, ammeter shunts, cable resistance, contact resistance, etc.

Medium resistances: Resistances above 1 ohm and upto 100,000 ohms are classified as medium resistances.

Example: Heater resistance, shunt field resistance, relay coil resistance etc.

High resistances: Resistances above 100000 ohms are classified as high resistances.

Example: Insulation resistance of equipment, cables etc.

Medium resistances could be measured by instruments like Kelvin's bridge, Wheatstone bridge, Slide wire bridge, Post Office box and ohmmeter. Also special designs of the above instruments allow measurement of low resistances accurately.

However for measuring high resistances, instruments like megohmmeter or Megger is used.

Ohmmeter: The ohmmeter is an instrument that measures resistance. There are two types of ohmmeters, the series ohmmeter, used for measuring medium resistances, and the shunt type ohmmeter, used for measuring low resistances. The ohmmeter, in it basic form, consists of an internal dry cell, a P.M.M.C. meter movement and a current limiting resistance.

Before using an ohmmeter in a circuit for resistance measurement, the current in the circuit must be turned off and also any electrolyte capacitor in the circuit should be discharged, as the ohmmeter has its own source of supply.

Series type ohmmeter

Construction: A series type ohmmeter consists essentially of a P.M.M.C. (`D' Arsonval) movement 'M', a limiting resistance R_1 and a battery 'E' and a pair of terminals of A and B to which the unknown resistance 'R_x' is to be connected and shunt resistance R_2 is connected in parallel to meter 'M' which is used for adjusting the zero position of the pointer.

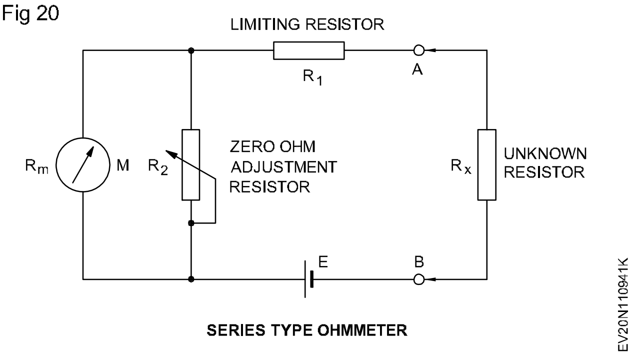
Working: When the terminals A and B are shorted (unknown resistor R_X= zero), maximum current flows in the circuit. Meter is made to read full scale current (I_{fsd})by adjusting the shunt resistance R_2. The full scale current position of the pointer is marked zero(0) ohm on the scale. When the ohmmeter leads (A & B terminals) are open, no current flows through the meter movement. Thereby the meter does not deflect and the pointer remains on the left hand side of the dial. Therefore the left side of the dial is marked infinity (∞) 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 greatly depends upon the condition of the battery. 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 20 provides an adjustment to counteract the effect of reduced battery voltage within certain limits. If the battery voltage falls beyond a certain value, adjusting the zero adjusting resistance R_2 may not bring the pointer to zero position, and, hence, the battery should be replaced with a good one.

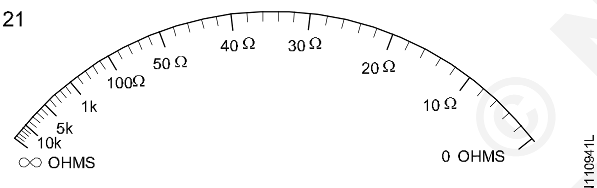
As shown in Fig 21, the meter scale will be marked zero ohms at the right end and infinite ohms at the left end.

Fig 20



SERIES TYPE OHMMETER

Fig 21



SERIES TYPE OHMMETER SCALE

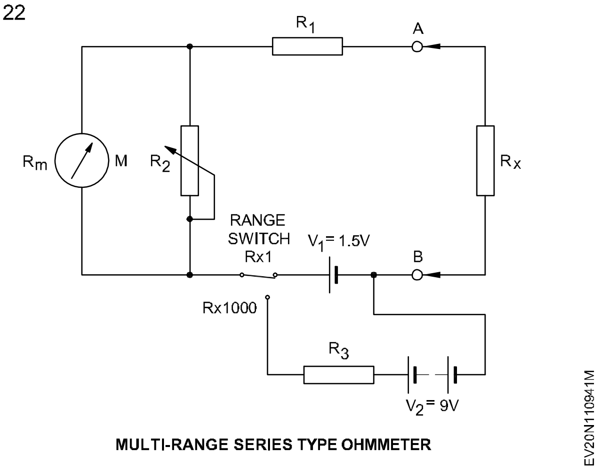
This ohmmeter has a non-linear scale because of the inverse relationship between the resistance and current. This results in an expanded scale near the zero end and a crowded scale at the infinity end.

Multiple ohmmeter range: Most of the ohmmeters have a range switch to facilitate measurement of a wide range of resistors, say from 1 ohm up to 100000 ohms. The range switch acts as the multiplying factor for the ohms scale. To get the actual value of measurement,the scale reading needs to be multiplied by the R_x factor of the range switch.

The range switch arrangement is provided either through a network of resistances powered through a cell of 1.5V or through a battery of 9 or 22.5 volts. The latter arrangement is shown in Fig 21. The resistance value of R_3 is so chosen that the full scale current is passed through the meter at the enhanced source voltage.

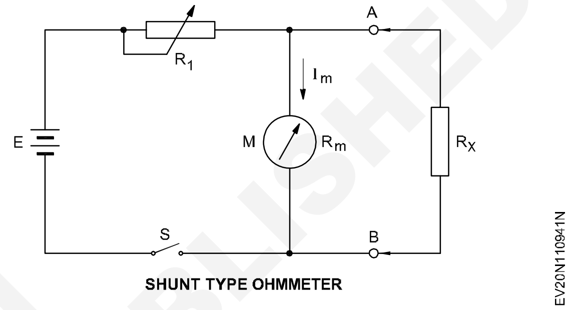
Use: This type of ohmmeter is used for measuring medium resistances only, and the accuracy will be poor in the case of very low and very high resistance measurements.

Fig 22



MULTI-RANGE SERIES TYPE OHMMETER

Fig 23



SHUNT TYPE OHMMETER

Shunt type ohmmeter: Fig 23 shows the circuit diagram of a shunt type ohmmeter. In this meter the battery 'E' is in series with the adjustable zero ohm adjust 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 spring-loaded push button type.

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 = μ (A and B open) the current flows only through the meter, and by a 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 the right hand side of the scale (full scale deflection current) as shown in Fig 23. When measuring resistance of intermediate values, the current flow divides in a ratio inversely proportional to the meter resistance and the unknown resistance. Accordingly the pointer takes up an intermediate position.

Semiconductors: Semiconductors are materials which have a conductivity between conductor and non conductor semiconductor may be compounds such as gallism arsenide or pure elements such as germanium or silicon.

Semiconductors are used in electronic circuits containing devices like transistors diode, photo sensors, micro controllers, integrated chips and much more are made up semiconductors.

Types of semiconductor

There are two types of semiconductors are used in automobile electronic circuits. They are as follows

1 intrinsic semiconductor

2 Extrinsic semiconductor further extrinsic semiconductor divided in two types

- N type semi conductor
- P type semi conductor

Properties of semiconductor.:

- Semiconductor act like insulator at zero Kelvin on increasing a temperature, they work as conductor
- Semiconductor can be modified by dropping to make semiconductor devices suitable for energy conversion, switches and amplifiers
- Very lesser power losses
- Semiconductors are possess very less weight and smaller in size
- Semiconductor's resistibility is higher than conductors but lesser than insulators.
- The resistance of semiconductor materials decreases with on increase in temperature.