# SURVEYOR

## NSQF LEVEL - 4

## 1st Year

## TRADE THEORY

**SECTOR :** CONSTRUCTION

**(As per revised syllabus July 2022 - 1200hrs)**



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 : Construction**

**Duration : 2 Years**

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

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# FOREWORD

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

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

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

Jai Hind

Addl.Secretary / Director General (Training)
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

# PREFACE

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

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 materials.

**Chennai - 600 032** **EXECUTIVE DIRECTOR**

# ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Surveyor** under **Construction** Sector for ITIs.

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

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

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

# INTRODUCTION

**TRADE PRACTICAL**

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 4 (Revised 2022) syllabus are covered.

The manual is divided into Sixteen modules.

The skill training in the shop floor is planned through a series of practical exercises centered 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.

| | |
|---|---|
| **Module 1** | **Safety** |
| **Module 2** | **Basic Engineering Drawing** |
| **Module 3** | **Chain Surveying** |
| **Module 4** | **Compass Surveying** |
| **Module 5** | **Computer Aided Drafting** |
| **Module 6** | **Plane Table Surveying** |
| **Module 7** | **Theodolite Survey** |
| **Module 8** | **Levelling Survey** |
| **Module 9** | **Road Project in Survey** |
| **Module 10** | **Computer Aided Drafting** |

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 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.

**TRADE THEORY**

The manual of trade theory consists of theoretical information for the Course of the **Surveyor** Trade Theory NSQF Level - 4 (Revised 2022) in **Construction**. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 4 (Revised 2022) syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

## CONTENTS

## CONTENTS

# LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

| S.No | Learning Outcome | Lesson No |
|---|---|---|
| 1 | Concept of drawing & sheet layout following safety precautions. | 1.1.01 - 1.1.09 |
| 2 | Draw lettering & numbering applying drawing instruments. | 1.2.10 - 1.2.11 |
| 3 | Draw plain geometrical figures, curves & conics. | 1.2.12 |
| 4 | Construct plain scale, diagonal scale, comparative scale, vernier scale. | 1.2.13 - 1.2.14 |
| 5 | Draw conventional signs & symbols used in surveying. | 1.2.15 - 1.2.16 |
| 6 | Perform site survey using chain/ tape & prepare a site plan. | 1.3.17 - 1.3.25 |
| 7 | Perform the site survey using prismatic compass. | 1.4.26 - 1.4.29 |
| 8 | Perform Auto Cad drawing. | 1.5.30 |
| 9 | Perform the site survey using the plane table. | 1.6.31 - 1.6.33 |
| 10 | Perform Theodolite survey. | 1.7.34 - 1.7.41 |
| 11 | Perform traverse survey by Theodolite & prepare a site map. | 1.7.42 - 1.7.47 |
| 12 | Determine RL and heights by levelling instruments of different points. | 1.8.48 - 1.8.58 |
| 13 | Perform a road project survey. | 1.9.59 - 1.9.62 |
| 14 | Perform AutoCAD drawing (single story building). | 1.10.63 - 1.10.65 |

## SYLLABUS

| Duration | Reference Learning Outcome | Professional Skills (Trade Practical) with Indicative hours | Professional Knowledge (Trade Theory) |
|---|---|---|---|
| Professional Skill 56 Hrs.;<br>Professional Knowledge 12 Hrs. | Concept of drawing & sheet layout following safety precautions. | 1. Demonstrate of tools & equipment used in the trade. (6 hrs.)<br>2. Occupational safety & Health. (6 hrs.)<br>3. Introduction of safety equipments and their uses. (10 hrs.)<br>4. Introduction of first aid, health, safety & environmental guidelines, legislations & regulations as applicable. (8 hrs.)<br>5. Personal Protective Equipment (PPE). (8 hrs.)<br>6. Hazard identification and avoidance, Safety signs for Danger. (4 hrs.)<br>7. Use of drawing instruments and equipments with care. (4 hrs.)<br>8. Method of fixing of drawing sheet on drawing board. (2 hrs.)<br>9. Layout of different size of drawing sheet and folding of sheets. (8 hrs.) | Importance of safety and general precautions related to the trade.<br>All necessary guidance to be provided to the newcomers to become familiar with the working of ITI system.<br>Importance of survey or trade<br>Job after completion of training.<br>Introduction of First aid.<br>Job responsibility of the trade.<br>• Overview the subject to be taught.<br>• List of the instrument equipments to be used during training<br>• Layout of drawing sheet<br>• Dimensions of drawing sheet. (12 Hrs.) |
| Professional Skill 56 Hrs.;<br>Professional Knowledge 18 Hrs. | Draw lettering & numbering applying drawing instruments. | 10. Lettering & numbering (Single & double stroke) (30hrs.)<br>11. Types of lines and dimensioning. (26hrs.) | Details layout of lettering, lines & dimensioning system. (18Hrs.) |
| Professional Skill 28Hrs.;<br>Professional Knowledge 06Hrs. | Draw plain geometrical figures, curves & conics | 12. Construction of plain geometrical figures, curves & conics. (28 hrs.) | Introduction of surveying, types of surveying, use, application principal. (06 Hrs.) |
| Professional Skill 28Hrs.;<br>Professional Knowledge 08Hrs. | Construct plain scale, diagonal scale, comparative scale, vernier scale. | 13. Drawing of: -<br>14. Construction of scales - plain, diagonal, vernier. (28 hrs.) | Knowledge of different types of scales, determine of R.F & uses of scales. (8Hrs.) |
| Professional Skill 28Hrs.;<br>Professional Knowledge 06 Hrs. | Draw conventional signs & symbols used in surveying. | 15. Drawing of conventional signs & symbols (10hrs.)<br>16. Free hand sketch of liner measurement instruments (18 hrs.) | Use & application of conventional signs & symbols. (06 Hrs.) |

| | | | |
|---|---|---|---|
| Professional Skill 84 Hrs.;<br>Professional Knowledge 18Hrs. | Perform site survey using chain/ tape & prepare a site plan. | 17. Practice of folding & unfolding of chain. (5 hrs.)<br>18. Equipment and instrument used to perform surveying & testing of chain. (5 hrs.)<br>19. Ranging (direct/ indirect) & distance measure with chain/ tape. (10 hrs.)<br>20. Offset taking & entering field book. (6 hrs.)<br>21. Overcoming obstacles in chaining. (6 hrs.)<br>22. Chaining on sloping ground. (10 hrs.)<br>23. Conduct a chain survey of a small area with all details and plotting the map. (20hrs.)<br>24. Calculating the area of site. (6 hrs.)<br>25. Prepare a site plan by the help of chain / tape. (16hrs.) | Uses of Chain/ tape, testing of a chain & correction. Ranging (direct & indirect), Principle of chain survey, application. Terms used in chain survey,<br>Offset, types of offsets, limit of offset, field book, types of field book, entry of field book method of chaining in slopping ground.<br>Field procedure of chain survey errors in chain survey, plotting procedure.<br>Calculation of area (regular & irregular figure)<br>Knowledge of site plan. (18hrs.) |
| Professional Skill 112 Hrs.;<br>Professional Knowledge 24 Hrs. | Perform the site survey using prismatic compass | 26. Temporary adjustment of prismatic compass. (10 hrs.)<br>27. Measure fore & back bearing of a line. (10 hrs.)<br>28. Measure true bearing of a line. (20 hrs.)<br>29. Prepare a closed & open traverse using prismatic compass measure the bearings, entry into field book, calculation of correct bearing and adjust. (Local attraction), determine the closing error and adjust. Plotting the same. (72hrs.) | Basic terms used in compass survey.<br>Instrument & it setting up.<br>Conversion of bearing web to R.B.<br>Calculation of included angle from bearing local attraction, magnetic declination and true bearing, closing error.<br>Adjustment of closing error, precaution in using prismatic compass. (24 hrs.) |
| Professional Skill 28 Hrs.;<br>Professional Knowledge 06Hrs. | Perform Auto CAD drawing | 30. Practice with AutoCAD using commands (28 hrs.) | Introduction to Auto CAD. Use AutoCAD command. (06 hrs.) |
| Professional Skill 84 Hrs.;<br>Professional Knowledge 18Hrs. | Perform the site survey using the plane table. | 31. Demonstration of instrument used for plane table surveying &their uses (alidade, U-fork, trough compass)<br>Set up the plane table (24hrs.)<br>• Centring<br>• Levelling<br>• Orientation<br>32. Practice the method of plane tabling (40hrs.)<br>• Radiation | Plane table survey, principle, merits & demerits<br>Instrument used in plane table survey setting up the plane table. (centering, levelling, orientation)<br>Methods of plane table survey (radiation, intersection, resection, traversing)<br>Error in plane table survey. (18hrs.) |

| | | | |
|---|---|---|---|
| | | • Intersection<br>• Resection<br>• Traversing<br>33. Determination of height by telescopic alidade (20 hrs.) | |
| Professional Skill56 Hrs.;<br>Professional Knowledge 18Hrs. | Perform Theodolite survey. | 34. Practice to set up the Theodolite(05hrs.)<br>35. Reading the vernier& booking (hor./ ver.) Angle. (05hrs.)<br>36. Perform permanent adjustment of Theodolite(05hrs.)<br>37. Measurement of horizontal angle by various methods. (10hrs.)<br>38. Setting out the angles. (5hrs.)<br>39. Measurement of vertical angle, deflection angle (10 hrs.)<br>40. Prolongation of line by various methods. (8hrs.)<br>41. Determination of height of inaccessible object by Theodolite. (8hrs.) | Introduction to Theodolite.<br>Types of Theodolite, parts of Theodolite, Terms used in Theodolite survey. Temporary adjustment of Theodolite, Angle measurement process. Reading of angles, field book entry of measured angles.<br>Permanent adjustment of Theodolite. (18hrs.) |
| Professional Skill 84Hrs.;<br>Professional Knowledge 24Hrs. | Perform traverse survey by Theodolite & prepare a site map. | 42. Traversing (closed & open) using Theodolite & tape/chain (15 hrs.)<br>43. Measurement of horizontal angles & bearing of a line. (15 hrs.)<br>44. Computation of coordinates from the bearing, angle length. (15 hrs.)<br>45. Preparation of gales traverse table (15 hrs.)<br>46. Computation of area using co-ordinates (15 hrs.)<br>47. Determine omitted measurements (09 hrs.) | Traversing using theodolite (closed & open), traverse computation, determination of consecutive coordinates, independent co-ordinate, checking & balancing of traverse, preparation of gales traverse table, computation of area using co-ordinates, calculation of omitted measurement (24hrs.) |
| Professional Skill 84Hrs.;<br>Professional Knowledge 18Hrs. | Determine of RL and heights of different points by levelling instruments. | 48. Practice in setting up of dumpy level and performing temporary adjustments (10 hrs.)<br>49. Practice in staff reading(05hrs.)<br>50. Practice in simple levelling (10 hrs.)<br>51. Practice differential levelling (fly levelling) (10 hrs.)<br>52. Practice reciprocal levelling. (10hrs.)<br>53. Carryout levelling field book. (02hrs.)<br>54. Equate reduction of level (rise fall method, height of instrument method) comparison of method. (10hrs.) | Introduction to levelling.<br>Types of levelling instrument.<br>Technical terms used in levelling<br>Temporary & permanent adjustment.<br>Different types of levelling<br>Entry of level book.<br>(Reduced level calculation method)<br>Curvature & refraction effect sensitivity of bubble tube.<br>Common error and their elimination.<br>Degree of accuracy. (18hrs.) |

| | | | |
|---|---|---|---|
| | | 55. Solve problems on reduction of level. (02hrs.)<br>56. Practice levelling with (auto / digital level) (10hrs.)<br>57. Practice profile levelling or longitudinal & cross section levelling, plotting the profile. (10 hrs.)<br>58. Check levelling (05hrs.) | |
| Professional Skill 56Hrs.;<br>Professional Knowledge 12Hrs. | Perform a road project survey.<br>shift | 59. Road project reconnaissance. (5hrs.)<br>60. Preliminary survey. (10 hrs.)<br>61. Final location survey including preparation of route map. (21 hrs.)<br>62. Profile or longitudinal &cross-sectional levelling & plotting. (20hrs.) | Types of surveys for location of a road. Points to be considered during reconnaissance survey. Classification of roads and terms used in road engineering, alignment of roads relative importance of length of road, height of embankment depth of cutting & filling, road gradients super elevation etc. (12hrs.) |
| Professional Skill 56 Hrs.;<br>Professional Knowledge 12Hrs. | Perform AutoCAD drawing (single story building) | 63. Prepare traverse drawing using Auto cad. (10 hrs.)<br>64. Prepare a simple building (20 hrs.)<br>65. Drawing using Auto cad. (26 hrs.) | Use AutoCAD command for drawings. (18hrs.) |

## Fire safety

**Objectives:** At the end of this lesson you shall be able to
- **state different type of fire**
- **state the different types of fire extinguishers and their basic function.**

**Fire safety :** Fire is the most common serious hazard that one faces in a typical chemistry laboratory. While proper procedure and training can minimize the chances of an accidental fire, you must still be prepared to deal with a fire emergency should it occur.

Typically, a fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

There are two main types of fire extinguishers :

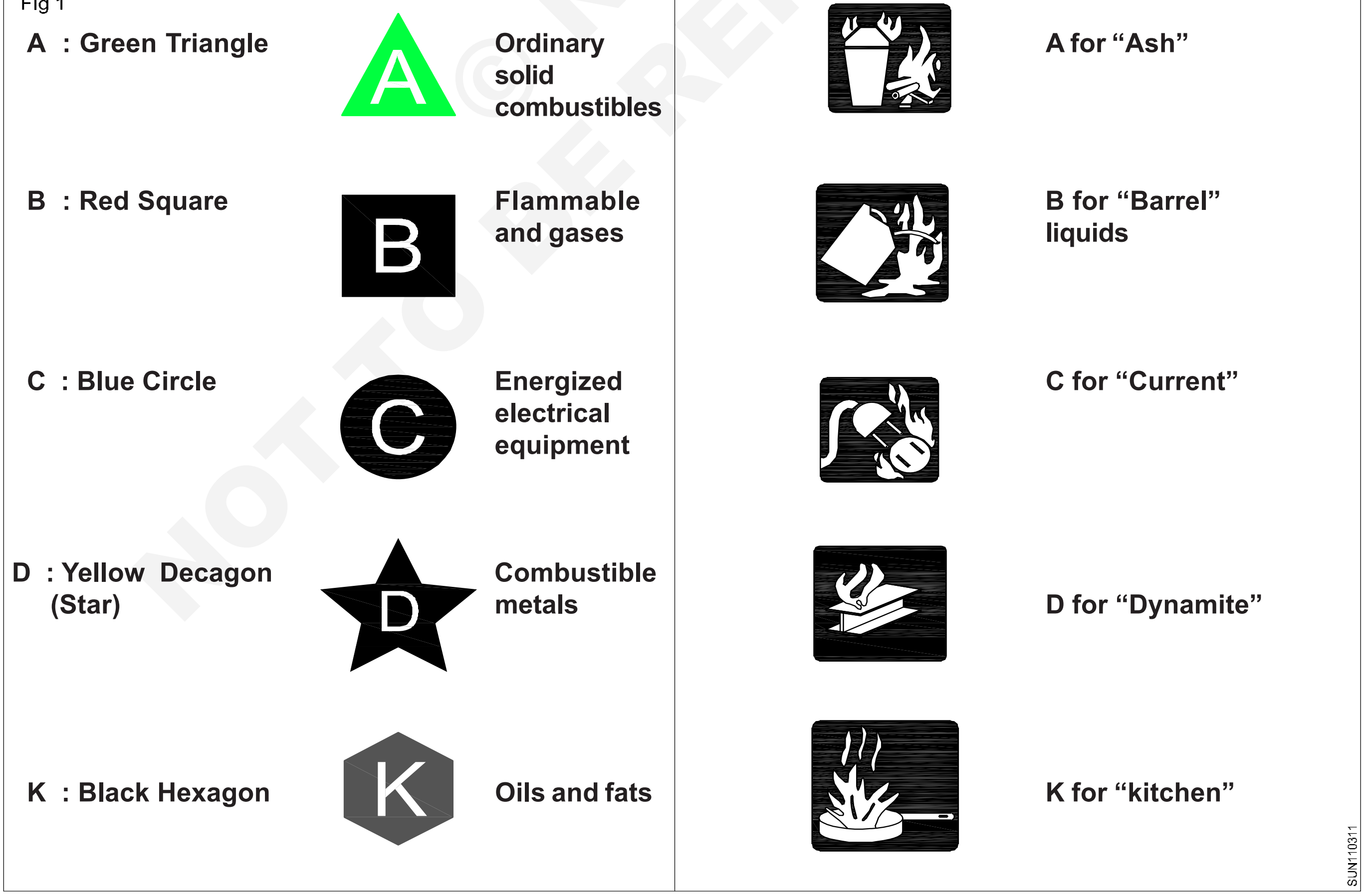
- Stored pressure
- Cartridge-operated.

In stored pressure units, the expellant is stored in the same chamber as the firefighting agent itself. Depending on the agent used, different propellants are used. With dry chemical extinguishers, nitrogen is typically used, water and foam extinguishers typically use air. Stored pressure fire extinguishers are the most common type.

**Carbon-dioxide extinguishers** contain the expellant gas in a separate cartridge that is punctured prior to discharge, exposing the propellant to the extinguishing agent. This type is not as common, used primarily in areas such as industrial facilities, where they receive higher-than-average use. They have the advantage of simple and prompt recharge, allowing an operator to discharge the extinguisher, recharge it and return to the fire in a reasonable amount of time. Unlike stored pressure types, these extinguishers use compressed carbon dioxide instead of nitrogen, although nitrogen cartridges are used on low temperature (-60 rated) models.

Cartridge operated extinguishers are available in dry chemical and dry powder and in water, wetting agent, foam, dry chemical (classes ABC and B.C.) and dry powder (class D) types in the rest of the world.

Fig 1



**Class A :** This is suitable for cloth, wood, rubber, paper, various plastics, and regular combustible fires. It is usually filled with 2 ½ gallons (9.46 litres) of pressurized water.

Class A fire extinguishers are designed to put out fires that have started from household items that are made out of materials that will quickly ignite. These materials include paper products and furniture made from wood. The Type A fire extinguisher contains water. The number on the canister represents how much water it contains. If there is a No. 1, the extinguisher will have a little more than I gallon of water. The higher the number, the more water it contains. The letter A stands for ash. A fire that burns from household items will leave ashes.

**Class B :** This is suitable for grease, gasoline or oil-based fire is usually filled with a dry chemical. Extinguishers smaller than 6lbs (2.72kg) are not recommended.

Class B fire extinguishers are used to put out fires that have started from highly flammable liquids. These liquids include any type of lacquer or oil-based paint products, paint thinners and lacquer thinners, oils and gasoline. According to the phoenix fire department, the letter B represents a barrel. Most of these chemicals are transported in a barrel-like container. The number on the extinguisher represents how many square feet it will cover. A 3 would represent 3 square feet, which is not a very large area. A larger fire could not be extinguished with this extinguisher.

**Class C :** This is suitable for electrical fires caused by appliances, tools and other plugged in gear. It can contain either halon or $CO_2$. Halon expensive and depletes the ozone layer and its use is restricted.

**Class C :** fire extinguishers are used to put out fires that have started from an electrical source. The source could be from appliances, lighting or your electrical system. This extinguisher uses carbon dioxide to put out the fire. Carbon dioxide will basically remove the oxygen from the air around the fire. Carbon dioxide is also used in some Type B extinguishers.

**Class D :** This is used for water-reactive metals such as burning magnesium and will be located in factories using such metals. It comes in the form of a powder that must cover the material to extinguish it.

**Class D :** Class D extinguishers are used to put out fires on metals that are capable of burning. These types of metals are found in the manufacturing industry only. This extinguisher uses a dry powder to put out the fire. You will not likely ever have a need for this type of extinguisher unless you work with titanium, sodium or magnesium.

**Class K :** This contains a special purpose wet chemical agent for use in kitchen fires and deep fryers to stop fires started by vegetable oils, animal fats, or other fats started in cooking appliances.

Many people have not heard of the Type K fire extinguisher. This extinguisher can be found in large kitchens. Many restaurants use large deep fryers full of cooking oils to deep fry foods. The typical Type B extinguisher would not be sufficient to put out a grease fire of this magnitude.

**Fire fighting methods**

Starvation/Blanketing - Elimination of fuel

Smothering - Limitation of oxygen

Cooling - Removal of temperature



## Accident & Safety

**Objectives:** At the end of this lesson you shall be able to
- **state the base principle for protective equipment**
- **state the accident prevention technique**
- **describe the controls of accidents & safety measures.**

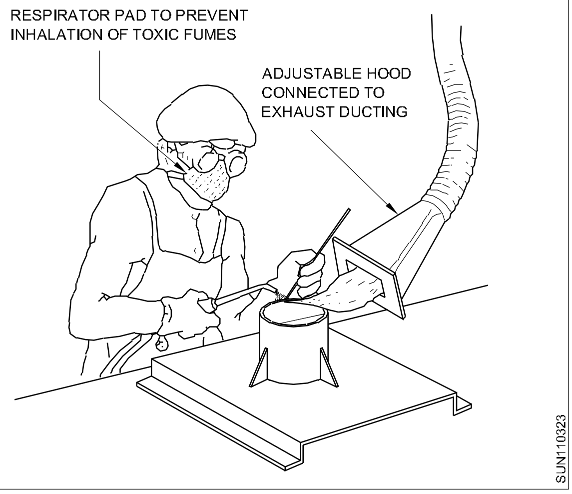
### Basic Principles for Protective Equipment (PPE)

Personal protective equipment, commonly referred to as "PPE", is a equipment worn to minimize exposure to serious workplace injuries and illnesses. (Fig 1). These injuries and illnesses may result from contact with chemical, radiological, physical, electrical, mechanical or other workplace hazards. Personal protective equipment may include items such as gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators or coveralls, vests and full body suits. (Fig 2 & Fig 3)

Fig 1

Fig 2


Fig 3




**Use of personal protective equipment :** All personal protective equipment should be of safe design and construction, and should be maintained in a clean and reliable fashion. It should fit well and be comfortable to wear, encouraging worker use. If the personal protective equipment does not fit properly, it can make the difference between being safely covered or dangerously exposed. When engineering, work practice and administrative controls are not feasible or do not provide sufficient protection, employers must provide personal protective equipment to their workers and ensure its proper use. Employers are also required to train each worker required to use personal protective equipment to know:

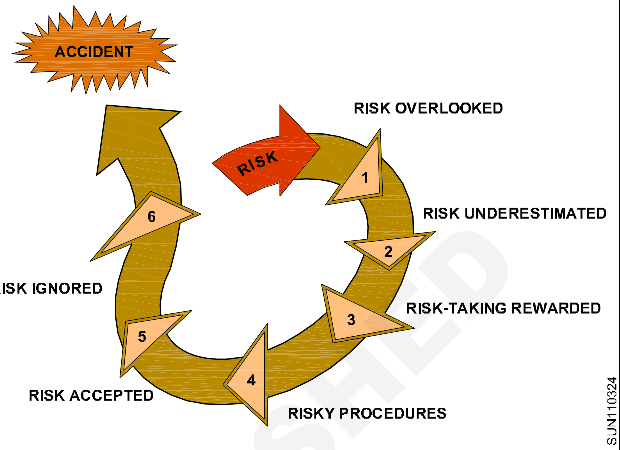
- When it is necessary?
- What kind is necessary?
- How to properly put it on, adjust, wear and take if off.
- The limitations of the equipment
- Proper care, maintenance, useful life and disposal of the equipment.

If PPE is to be used, a PPE program should be implemented. This program should address the hazards present; the selection, maintenance and use of PPE; the training of employees and monitoring of the program to ensure its ongoing effectiveness.

## Accident prevention techniques-control of accidents and safety measures

Accident are unplanned, undesired event, not necessarily resulting in an injury or illness, but damaging property and/or interrupting the activity in process. Accident happen at all jobs. There are certain accidents that are common to a job. All employees should be trained and reminded how to do their job correctly to prevent unnecessary injuries while at work. An accident can occur when a machine malfunction or a person isn't paying attention to the work they are suppose to be doing. Even a small accident can cause major problems for an employee and their employer. The best practice to avoid all types of accidents is to teach and promote a safe and happy workplace. (Fig 4)

Fig 4



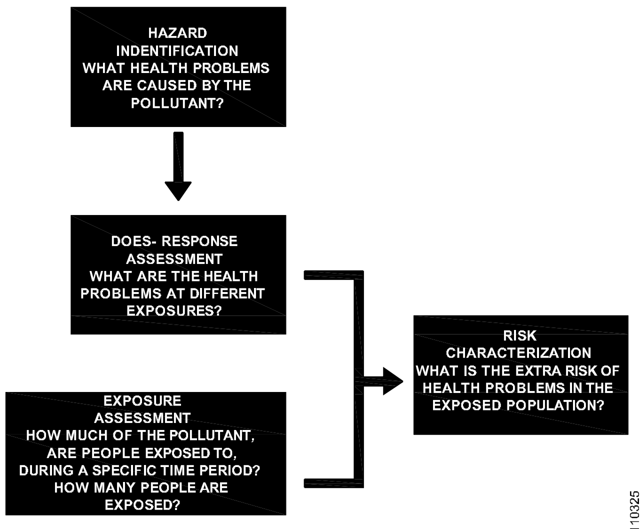

Accidents can happen anytime at any place they are more likely to happen when a person is participating in an unsafe act. That is why it is important to follow all safety rules and guidelines while working. If a taking a few more minutes to do the job safe is worth saving your life.

Overexertion in the workplace is a serious issue. Prevent damage to your back, knees and arms is very important. Train all employees on how to prevent overexertion by following safety rules and guidelines while completing workplace task.

Control of accidents are done by reducing exposure to a hazards through engineering, work practices, administration or protective equipment.

### Responsibilities

Fig 5




THE 4 STEP RISK ASSESSMENT PROCESS

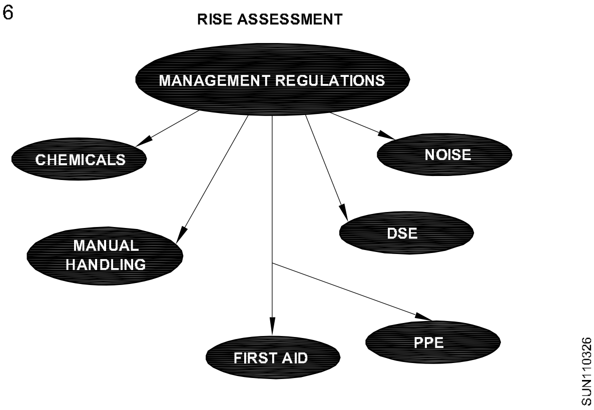
At department level the supervisors are made to instruct their employees regarding the requirements of this program, effectively enforce compliance of this program's procedures, including the use of disciplinary action, for any violations or deviations from the procedures outlined in this program; assure that the equipment required for compliance with this program is in proper working order, inspected and tested as required, and made available for use to their employees, promptly investigate and report all on-the-job accidents or job related health problems. (Fig 5)

**Recognizing and controlling hazards**

**Engineering controls** minimize employee exposure by either reducing or removing the hazard at the source or isolating the worker from the hazard. Engineering controls include eliminating toxic chemical and substituting non-toxic chemicals, enclosing work processes or confining work operations, and the installation of general and local ventilation systems. Work practice controls alter the manner in which a task is performed. Some fundamental and easily implemented work practice, controls include changing existing work practices to follow proper procedures that minimize exposures. While operating production and control equipment, inspecting and maintaining process and control equipment on a regular basis, implementing good housekeeping procedures, providing good supervision and mandating that eating, drinking, smoking, chewing tobacco or gum, and applying cosmetics in regulated areas be prohibited.

**Administrative controls,** include controlling employees' exposure by scheduling production and tasks, or both, in ways the minimize exposure levels. (Fig 6) For example, the employer might schedule operations with the highest exposure potential during periods when the fewest employees are present. When effective work practices or engineering controls are not feasible or while such controls are being instituted, appropriate personal protective equipment must be used. Examples of personal protective equipment are gloves, safety goggles, helmets, safety shoes, protective clothing and respirators. To be effective, personal protective equipment must be individually selected, properly fitted and periodically refitted, consciously and properly worn, regularly maintained and replaced, as necessary.

Fig 6




The employees have to comply with the procedures of this program, consult with their supervisor, when they have questions regarding the safety and health conditions of their workplace, report any accidents or job related injuries or illnesses to their supervisor and seek prompt medical treatment, if necessary.

Employees are responsible for exercising appropriate care and good judgment in preventing injuries and illnesses, adhering to all safety and health rules, policies and procedures and reporting all unsafe conditions, malfunctioning or unsafe equipment, work related accidents, injuries and illnesses, and unsafe work practices to their immediate supervisor. If that is not feasible, a report should be made to the head of their department, the plant operations safety officer, or a member of the work safe/be well committee.

## Familiarisation and information about the institute and trade

**Objectives:** At the end of this lesson you shall be able to
- **state the general training system**
- **state the information about the trade**
- **state the rules and regulation of the institute and trade.**

### Training system

### General

The Directorate General of Training (DGT) under Ministry of Skill Development & Entrepreneurship offers range of vocational training courses catering to the need of different sectors of economy labour market. The vocational training programs are delivered under aegis of National Council of Vocational Training (NCVT). Craftsman Training Scheme (CTS) and Apprenticeship Training Scheme (ATS) are two pioneer programs of NCVT for propagating vocational training.

Surveyor trade under CTS is one of the popular courses delivered nationwide through network of ITIs. The course is of two years duration. It mainly consists of Domain area and Core area. In the Domain area-trade theory and practical impart professional skills and knowledge; while core area imparts workshop calculation and science, Engineering Drawing, and Employability Skills impart requisite core skills & knowledge and life skills. After passing out the training program, the trainee is being awarded National Trade Certificate (NTC) by NCVT which are recognized worldwide.

**Candidates broadly need to demonstrate that they are able to :**

- Read & interpret technical parameters /documentation, plan and organize work processes, identify necessary materials and tools.
- Perform work with due consideration to safety rules, Govt. Bye laws and environmental protection stipulations.
- Apply professional knowledge, core skills & employability skills while performing the work
- Check the work as per sketches and rectify errors
- Document the technical parameters related to the work undertaken.

**Options for employment are**

Employment opportunities for trainee from this trade as draftsman, surveyor and land surveyor shall be available in Central & State Government Departments.

Private sector opportunities shall be as Draftsman, Construction Supervisor with Architect, Civil Engineer, and Civil Contractor, Builders.

**Options for Self- Employment are**

The Trainee shall be able to independently undertake planning, drawing, estimation & costing and supervision of civil construction work. He can set up his own office for above work and also to supply Civil Construction materials.

**Rules and regulation of the institute and trade**

- The trainees who are all got admission in I.T.I has to follow same general rales stipulated by the institution, and those are given below
- The trainees who are all got admission in I.T.I has to follow same general rates stipulated by the institution, and those are given below
- He should try to earn good room from the institution
- The trainees should attend the institution to the correction in punctuality should be maintained.
- He should be very sincere and faithful not only to this instructor but also other instructors and staff the institute.
- He should attend were proper formal dress as specified by the institute.
- He should not wear loose clothes and this may be the cause for accident while crossing in shops floor.
- He should have good attitude and behave with good manner to all the staff members his fellow students and to this senior students.
- He should take part in the activities of the institute.
- He should maintain discipline of the class room and the institution.
- He should not spoil the environment of institute.

**Note: The above rules and regulation are also compulsory for the Girl trainees to adhere)**

# First Aid

**Objectives:** At the end of this lesson you shall be able to
- **explain how to take care of injured & sick persons at workplaces**
- **explain how to provide first aid & transportation to sick person**
- **state ABC of first aid**
- **state how to report an emergency.**

**Purpose of First Aid**

- To sustain life
- To prevent suffering
- To prevent secondary complications
- To promote speedy recovery
- To prepare for further medical treatment

Each separate work site or shop should have a fully stocked first aid kit available for injuries or emergencies. First aid kits will be regularly inspected to insure they are adequately stocked with consumables and equipment. All first aid kits should conform to the most recent guidelines for first aid kits.

For temporary work sites, first aid kits may be stored in gang boxes, on vehicles, or other similar locations, as long as easy access for all workers at the temporary site is maintained, each worker knows where the first aid kit is located, and the kit is maintained in accordance with.

In situations where workers are injured beyond the need for general first aid, medical treatment will be provided in accordance with the plant workplace health and medical treatment program. At anytime a potential life threating injury has been incurred, workers will contact local emergency response services immediately, by the quickest means available.

Workers receiving medical treatment or surveillance examinations may be supplied with copies of the written opinions of the examining physicians as required by regulation, or recommended by the physician. Medical records for employees must be kept strictly confidential with access restricted to information directly related to work activities. Generally, medical records will be kept in the control of the examining physician/staff of the first-aid centre.

In emergency situations, such as fires, criminal, terrorist or civil disturbances, situations involving spills of, releases of, or exposure to hazardous materials (e.g. Chemical, Biological, Radiological), situations of severe weather, such as storms, tornadoes, blizzards, etc., or the loss of utility services, such as electricity, water, heat etc., workers should take appropriate actions to safeguard their lives, the lives of building occupants, and if possible the property of the university. Workers are to contact the appropriate agency as outlined.

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

Imparting knowledge and skill through institutional teaching at younger age group in schools, colleges, entry point at industry level is now given much importance. Inculcating such habits at early age, helps to build good healthcare habits among people.

**ASSESSING THE SICK OR INjURED**

**PRIMARY SURVEY**

- Is an initial rapid assessment of a casualty to establish and treat conditions that are an immediate threat to life.

DANGER
RESPONSE
AIRWAY
BREATHING
CIRCULATION

**DR ABC**

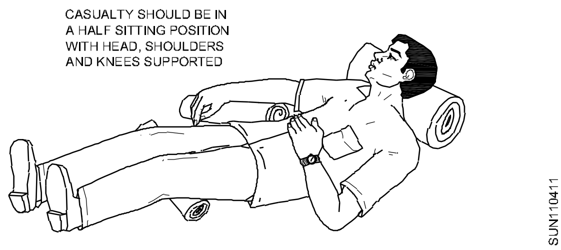
First-aid procedure often consists of a range of simple and basic life saving techniques that an individual performs with proper training and knowledge.

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 leant over on their side, which also has the effect of clearing the tongue from the pharynx. It also avoids a common cause of death in unconscious patients, which is choking on regurgitated stomach contents. The airway can also become blocked through a foreign object becoming lodged in the pharynx or larynx, commonly called choking. 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. Victim should be in half sitting position with head, shoulder & neck support. (Fig 1)

Fig 1




- **Promote recovery :** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

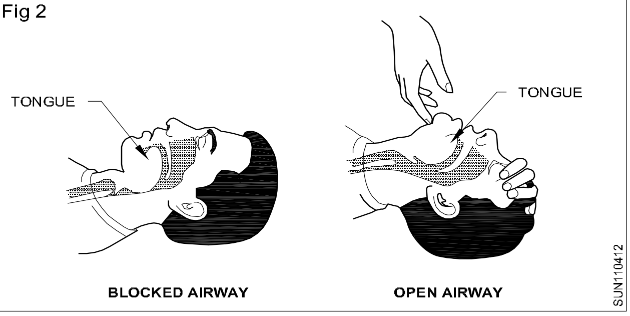
**Training :** Basic principles, such as knowing to use an adhesive bandage or applying direct pressure on a bleed, are often acquired passively through life experiences. However, to provide effective, life-saving first aid interventions requires instruction and practical training. This is especially true where it relates to potentially fatal illnesses and injuries, such as those that require Cardio Pulmonary Resuscitation (CPR), these procedures may be invasive and carry a risk of further injury to the patient and the provider. As with any training, it is more useful if it occurs before actual emergency, and in many countries, emergency ambulance dispatchers may give basic first aid instructions over the phone while the ambulance is on the way.

Training is generally provided by attending a course, typically leading to certification. Due to regular changes in procedures and protocols, based on updated clinical knowledge, and to maintain skill, attendance at regular refresher courses or re-certification is often necessary. First aid training is often available through community organizations such as the red cross and St. John ambulance.

**ABC or First-aid :** ABC stands for Airway, Breathing and Circulation

**Airway :** Attention must first be brought to the airway to ensure it is clear. Obstruction (choking) is a life-threatening emergency. (Fig 2)

Fig 2




**Breathing :** Breathing if stops, the victim may die soon. Hence means of providing support for breathing is an important next step. 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. (Fig 3 & Fig 4)

Fig 3

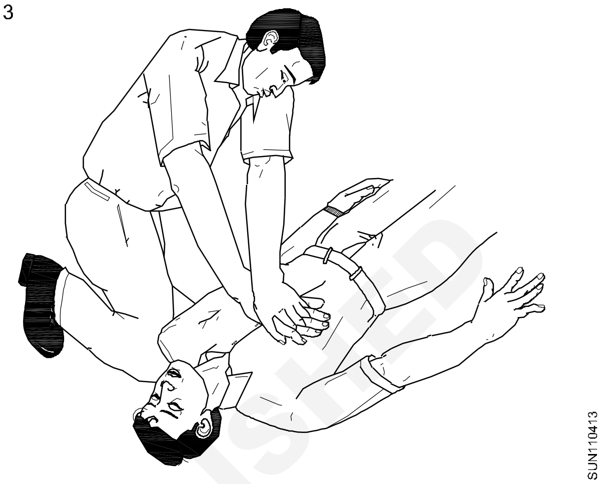



Fig 4

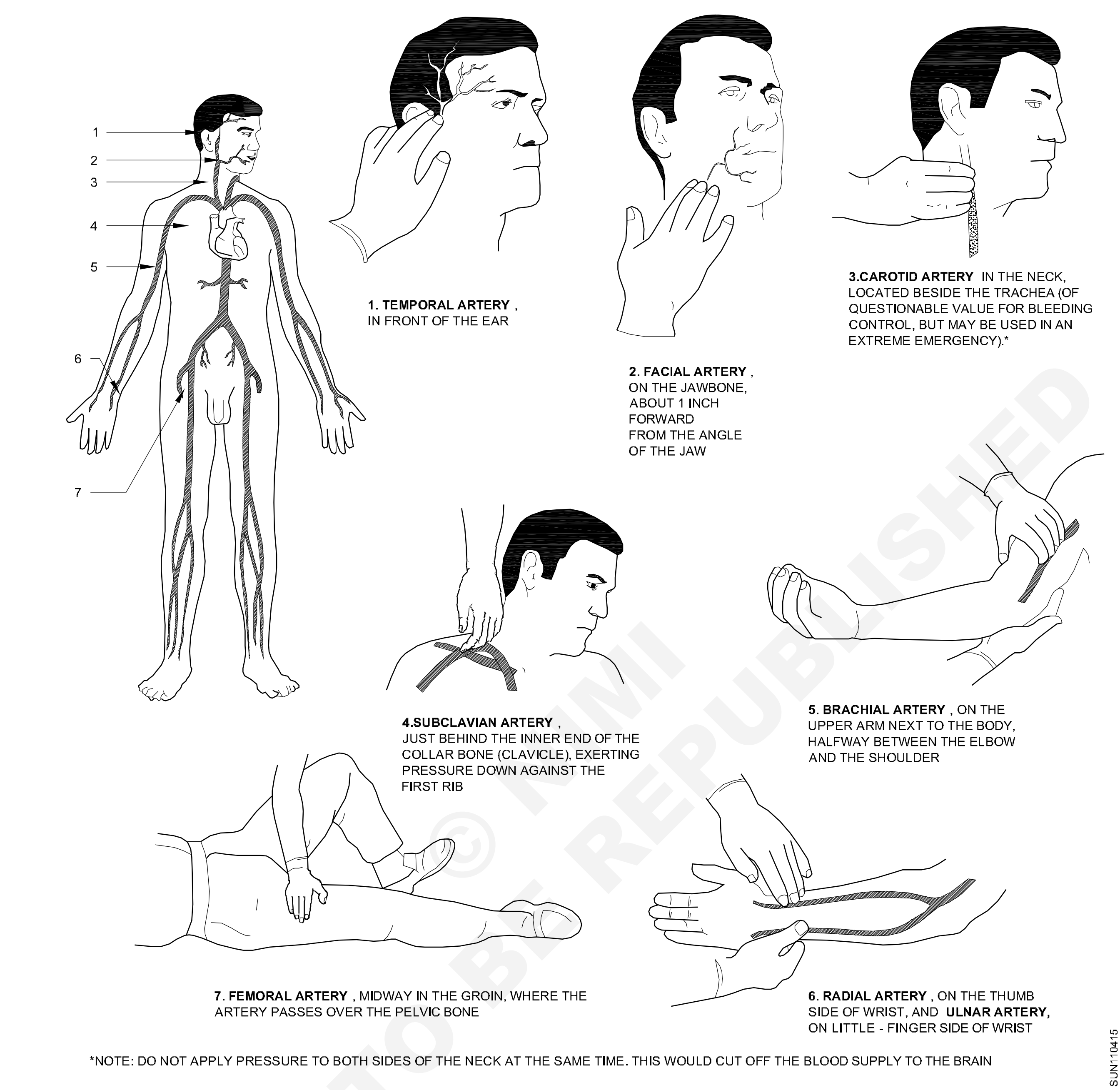

When providing first aid one needs to follow some rule. There are certain basic norms in teaching and training students in the approach and administration of first-aid to sick and injured. (Fig 5)

**Not to get panic :** Panic is one emotion that can make the situation more worse. People often make mistake because they get panic. Panic clouds thinking and causes mistakes. First-aider need calm and collective approach. if the first-aider himself is in a state of fear and panic gross mistakes may result. It's far easier to help the suffering, when they know what they are doing, even if unprepared to encounter a situation. Emotional approach and response always lead to wrong doing and may cloud one to do wrong procedures. Hence be calm and focus on the given situation. Quick and confident approach can lessen the effect of injury.

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

**Surroundings play vital role :** Different surrounding require different approach. Hence first-aider should study the surrounding carefully. In other words, one need to make sure that they are safe and are not in any danger as it would be of no help that the first aider himself get injured.

Fig 5






**Do no harm :** Most often, enthusiastically practiced First-Aid Viz. administering water when the victim is unconscious, wiping clotted blood (which acts as plug to reduce bleeding), correcting fractures, mishandling injured parts etc., would leads to more complication. Patients often die due to wrong FIRST-AID methods, who may otherwise easily survive. Do not move the injured person unless the situation demands. It is best to make him lie wherever he is because if the patient has back, head or neck injury, moving him would cause more harm.

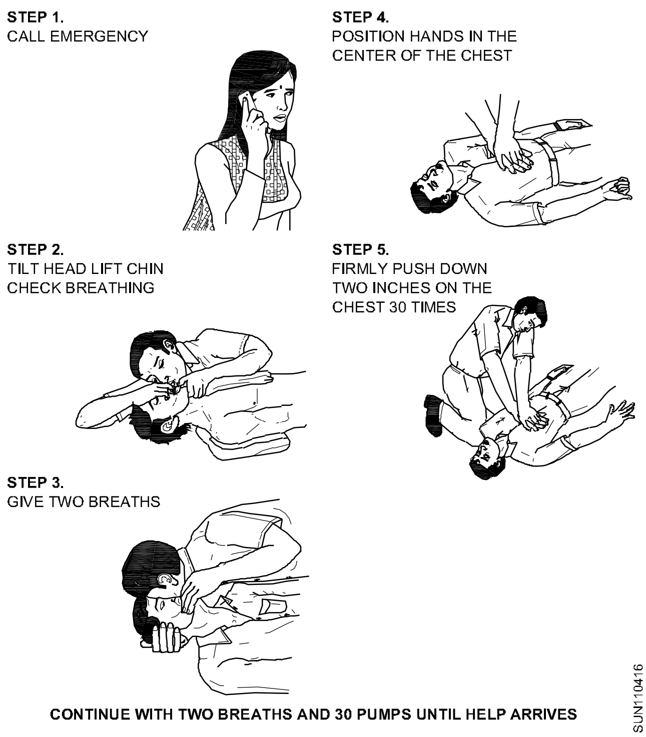
This does not mean do nothing. It mean to make sure that to do something the care givers feel confident through training would make matters safe. If the first-aider is not confident of correct handling it is better not to intervene of do it. Hence moving a trauma victim, especially an unconscious one, need very careful assessment. Removals of an embedded objects (like a knife, nail) from the wound may precipitate more harm (e.g., increased bleeding). Always it is better to call for help.

**Reassurance :** Reassure the victim by speaking encouragingly with him.

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

**Golden Hours :** India have best of technology made available in hospitals to treat devastating medical problems viz. head injury, multiple trauma, heart attack, strokes etc, but patients often do poorly because they don't gain access to that technology in time. The risk of dying from these conditions, is greatest in the first 30 minutes, often instantly. This period is referred to as golden period. By the time the patient reach hospitals, they would have passed that critical period. First-aid care come handy to save lives. It helps to get to the nearest emergency room as quickly as possible through safe handling and

Fig 6




transportation. The shorter that time, the more likely the best treatment applied. (Fig 6)

**Maintain the hygiene :** Most importantly, first-aider need to wash hands and dry before giving any first aid treatment to the patient or wear gloves in order to prevent infection.

Fig 7


**Cleaning and Dressing (Fig 7) :** Always clean the wound thoroughly before applying the bandage. Lightly wash the wound with clean water.

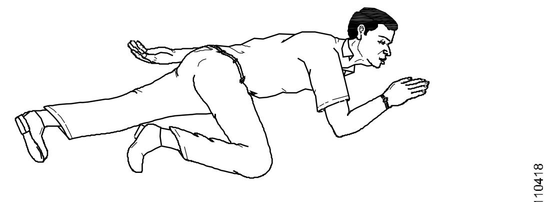
Not to use local medications on cuts or open wounds. They are more irritating to tissue than it is helpful. Simple dry cleaning or with water and some kind of bandage are best.

**Stay with the victim until help arrives :** Try to be a calming presence for the victim until assistance can arrive.

**Unconsciousness**

Loss of consciousness may threaten life if the person is on his back and the tongue has dropped to the back of the throat, blocking the airway. Make certain that the person is breathing before looking for the cause of unconsciousness. If the injuries permit, place the casualty in the recovery position with the neck extended.(Fig 8) Never give anything by mouth to an unconscious casualty. Unconscious also referred as **coma,** is a serious life threatening condition, when a person lie totally senseless and do not respond to calls, external stimulus. But the basic heart, breathing, blood circulation may be still intact, or they may also be failing if unattended it may lead to death.

Fig 8




THE RECOVERY POSITION

The condition arises due to interruption of normal brain activity. The causes are too many.

- Shock (Cardiogenic, Neurogenic)
- Head injury (Concussion, Compression)
- Asphyxia (Obstruction to air passage)
- Extremes of Body temperature (Heat, Cold)
- Cardiac Arrest (Heart attack)
- Stroke (Cerbro-vasular accident)
- Blood loss (Haemorrhage)
- Dehydration (Diarrohoea & vomiting)
- Diabetes (Low or high sugar)
- Blood pressure (Very low or vey high)
- Over dose of alcohol, drugs
- Poisoning (Gas, pesticides, bites)
- Epileptic Fits (Fits)
- Hysteria (Emotional, Psychological)

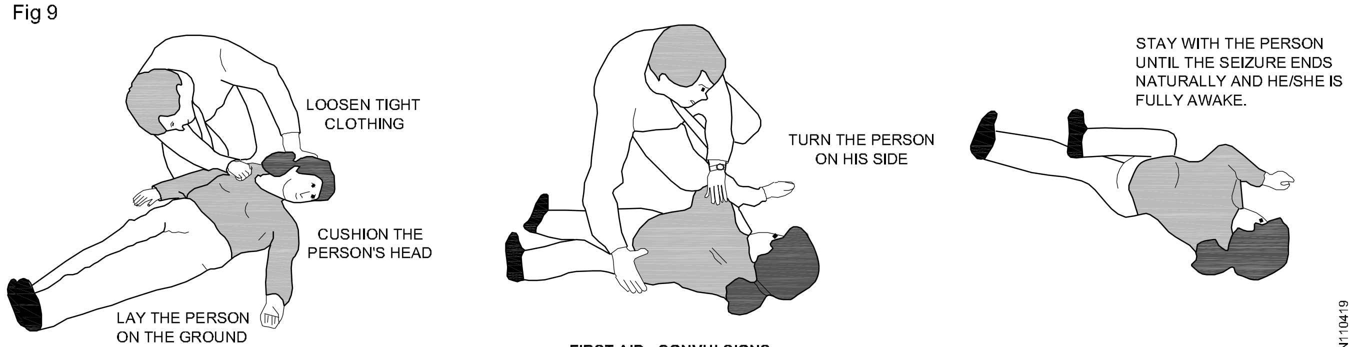
The following symptoms may occur after a person has been unconscious : (Fig 9)

- Confusion
- Drowsiness
- Headache
- Inability to speak or move parts of his or her body (see stroke symptoms)
- Light headedness
- Loss of bowel or bladder control (incontinence)
- Rapid heartbeat (Palpitations)
- Stupor

**First aid**

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

Fig 9

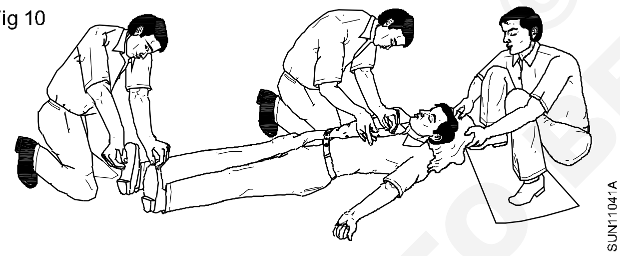



FIRST AID : CONVULSIONS

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 you see a person fainting, try to prevent a fall. Lay the person flat on the floor and raise the level of feet above and support.
- If fainting is likely due to low blood sugar, give the person something sweet to eat or drink when they become conscious. (Fig 10)

Fig 10




**Do Not**

- Do not give an unconscious person any food or drink.
- 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.

**First-aid box**

**Small, medium and large dressings :** These are sterile pads with bandages attached that can be used to control heavy bleeding and cover minor wounds. Triangular bandages - These are an extremely versatile piece of equipment. Folded into a pad, they can be used as a cold compress or as padding around a painful area. They can provide cover for burns or large scrapes and support broken bones.

**Adhesive bandage** (for small wounds), **Non-adhesive sterile dressings (various sizes), safety tape, adhesive tape and hypoallergenic tape.** Dressing can be cut to size and used to cover scrapes, burns and small wounds.

**Gauze swabs :** For use with water to clean wounds.

**Ace bandages, compression bandages, tubular bandage :** For use in providing support to sprains and strains.

**Disposable gloves :** For use in managing body fluids.

**Blunt-ended scissors : tweezers.**

**Transport safety :** Use one of the most safer methods.

**CPR (Cardio-Pulmonary Resuscitation) :** CPR can be life sustaining. If one is trained in CPR and the person is suffering from choking or finds difficulty in breathing, immediately begin CPR. However, if one is not trained in CPR, do not attempt as you can cause further injury. But most people do it wrong. This is a difficult procedure to do in a crowded area. Also there are many studies to suggest that no survival advantage when bystanders deliver breaths to victims compared to when they only do chest compressions. Second, it is very difficult to carry right man ever in wrong places. But CPR, if carefully done by highly skilled first-aiders is a bridge that keeps vital organs oxygenated until medical team arrives.

**Declaring death :** It is not correct to declare the victim's death at the accident site. It has to be done by qualified medical doctors.

**How to report an emergency?**

Reporting an emergency is one of those things that seems simple enough, until actually when put to sue in emergency situations. A sense of shock prevail at the accident sites. Large crowd gather around only with inquisitive nature, but not to extend helping hands to the victims. This is common in road side injuries. No passer-by would like to get involved to assist the victims. Hence first-aid management is often very difficult to attend to the injured persons. The first-aiders need to adapt multi-task strategy to control the crowd around, communicate to the rescue team, call ambulance etc., all to be done simultaneously. The mobile phones helps to a greater deal for such emergencies. Few guidelines are given below to approach the problems.

Assess the urgency of the situation. Before you report an emergency, make sure the situation is genuinely urgent. Call for emergency services if you believe that a situation is life-threatening or otherwise extremely disruptive.

- A crime, especially one that is currently in progress. If you're reporting a crime, give a physical description of the person committing the crime.
- A fire, if you're reporting a fire, describe how the fire started and where exactly it is located. If someone has already been injured or is missing, report that as varies - 100 for Police & Fire, 108 for Ambulance.
- A life-threatening medical emergency that requires immediate attention. If you're reporting a medical emergency, explain how the incident occurred and what symptoms the person currently displays.
- A car crash - Location, serious nature of injuries, vehicle's details and registration, number of people involved etc.

**Call emergency services :** The emergency number varies - 100 for Police & Fire, 108 for Ambulance.

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

**Give the dispatcher your phone number :** This information is also imperative for the dispatcher to have, so he or she is able to call back if necessary.

**Describe the nature of the emergency :** Speak in a calm, clear voice and tell the dispatcher why you are calling. Give the most important details first, then answer the dispatcher's follow-up questions as best you can.

**Do not hang up the phone** until you are instructed to do so. Then follow the instructions you were given.

**How to do basic first aid?**

Basic first aid refers to the initial process of assessing and addressing the needs of someone who has been injured or is in physiological distress due to choking, a heart attack, allergic reactions, drugs or other medical emergencies. Basic first aid allows one to quickly determine a person's physical condition and the correct course of treatment.

**Important guideline for first-aiders**

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

**Remember A-B-Cs :** The ABCs of first aid refer to the three critical things the first-aiders need to look for.

- Airway - Does the person have an unobstructed airway?
- Breathing - Is the person breathing?
- Circulation - Does the person show a pulse at major pulse point (Wrist, carotid artery, groin)

**Avoid moving the victim :** Avoid moving the victim unless they are in immediate danger. Moving a victim will often make injuries worse, especially in the case of spinal cord injuries.

**Call emergency services :** Call for help or tell someone else to call for help as soon as possible. if alone in 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 onto the side (recovery position) and open his airway.** |
|---|

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

Look, listen and feel for signs of breathing : Look for the victim's chest to rise and fall, listen for sounds of breathing.

If the victim is not breathing, see the section below.

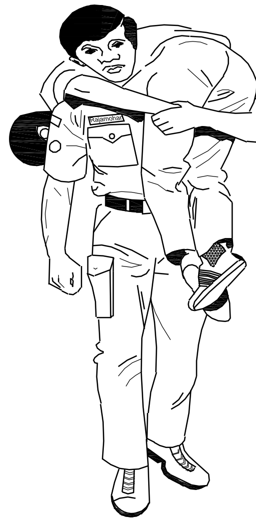
- If the victim is breathing, but unconscious, roll them onto their side, keeping the head and neck aligned with the body. This will help drain the mouth and prevent the tongue or vomit from blocking the airway.

**Check the victim's circulation :** Look at the victim's color and check their pulse (the carotid artery is a good option; it is located on either side of the neck, below the jawbone). if the victim does not have a pulse, start CPR.

**Treat bleeding, shock and other problems as needed:** After establishing that the victim is breathing and has a pulse, next priority should be, to control any bleeding. Particularly in the case of trauma, preventing shock is the priority. Some of the ways are mentioned in Fig 11, 12, 13 & 14 how to handle victims.

- **Stop bleeding :** Control of bleeding is one of the most important things to save a trauma victim. Use direct pressure on a wound before trying any other method of managing bleeding.
- **Treat shock :** Shock, a loss of blood flow to the body, frequently follows physical and occasionally psychological trauma. A person in shock will frequently have ice cold skin, be agitated or have an altered mental status, and have pale color to the skin around the face and lips. Untreated, shock can be fatal. Anyone who has suffered a severe injury or life-threatening situation is at risk for shock.
- **Choking victim :** Choking can cause death or permanent brain damage within minutes.

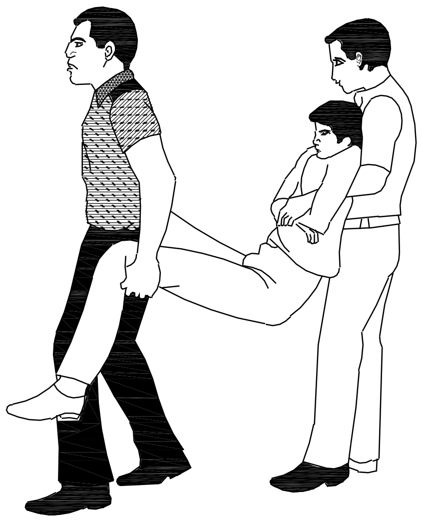
Fig 11



SUN11041B

FIRE-MAN LIFT METHOD

Fig 12



SUN11041C

FORE AND AFT METHOD

- **Treat a burn :** Treat first and second degree burns by immersing or flushing with cool water. Don't use creams, butter or other ointments, and do not pop blisters. Third degree burns should be covered with a damp cloth. Remove clothing and jewellery from the burn, but do not try to remove charred clothing that is stuck to burns.

Fig 13

SUN11041D

HAND SEAT METHOD

Fig 14

SUN11041E

HUMAN-CRUTCH METHODS

- **Treat a concussion :** If the victim has suffered a blow to the head, look for signs of concussion. Common symptoms are; loss of consciousness following the injury, disorientation or memory impairment, vertigo, nausea and lethargy.
- **Treat a spinal injury victim :** If a spinal injury is suspected, it is especially critical, not move the victim's head, neck or back unless they are in immediate danger.



## Basic provisions for OSH

**Objectives:** At the end of this lesson you shall be able to
- **state the basic provisions of safely, health, welfare under legislation of India.**

India has legislation on occupational health and safety for over 50 years. A safe and health work environment is the basic right of every worker. The constitutional provision for occupational safety and health under the Article 24 - No child below the age of fourteen years shall be employed to work in any factory or mine or engaged in other hazardous employment.

Article 39 (e & f) - The state shall in particular direct its policy towards securing.

e that the health and strength of workers, men and women, and the tender age of children are not abused and that citizens are not forced by economic necessity to enter vocations unsuited to their age and strength.

f That children are given opportunities and facilities to develop in healthy manner and in conditions of freedom and dignity and that childhood and youth are protected against exploitation and against moral and material abandonment.

Article 42 - The state shall make provision for securing just and human conditions of work and maternity relief.

**National policy**

Safety and health occupies a very significant position in India's constitution which prohibits employment of children under 14 in factories, mines and in hazardous occupations. Policy aims to protect the health and strength of all workers. It prevents employment in occupations unsuitable for the age and strength of the workers. It is the policy of the state to make provisions for securing just and humane conditions of work. The constitution provides a broad framework under which policies and programs for occupational health and safety could be established.

**National Legislation**

Legislation provides an essential foundation for safety. To be meaningful and effective legislation should be reviewed and updated regularly as scientific knowledge develops.

The most important legislation cover occupational safety, health and welfare are :

- The Factories Act 1948. amended 1954, 1970, 1976, 1987.
- The Mines Act, 1952.
- The dock workers (safety, health and welfare) Act, 1986.
- The plantation labour Act, 1951.
- The Explosives Act, 1984.
- The Petroleum Act, 1934.
- The Insecticide Act, 1968.
- The Indian Boilers Act, 1923.
- The Indian Electricity Act, 1910.
- The Dangerous Machines (Regulations) Act, 1983.
- The Indian Atomic Energy Act, 1962.
- The Radiological Protection Rules, 1971.
- The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989.

## Environment

**Objectives:** At the end of this lesson you shall be able to
- **state the meaning and definition of environment**
- **list out and explain the components of environment**
- **explain atmosphere and its composition**
- **state the relationship between society and environment**
- **state the factors responsible for destruction and natural disasters.**

Environment Education is a process which makes the world community conscious about the problem of the environment. By this way we may understand the problem and find its solution and may also protect future problems.

Environmental Education (EE) can be linked with three main components

- Education about the environment (Knowledge).
- Education for the environment (Values, attitudes & positive actions).
- Education through the environment (A resource).

**Meaning and definition of environment**

In general, the word **environment** refers the cover of our surroundings, which includes our earth, soil, water and the atmosphere situated on it. The environment is the important system which covers all the living and non-living system. So it is necessary every layman and literate person to know its meaning.

The word environment is composed of two words- **'environ'** and **'ment'** their meaning is 'to surround' or 'to enwrap', which gives the meaning of sense of situation of the surroundings or cover.

The dictionary meaning of the environment is the "particular surroundings in which living and non-living things exist".

In universal encyclopedia, it is defined as "Environment is the sum of all those condition, systems and influences which influence the development life and death of organisms and their species. On **5th June** every year **world environment** day is celebrated.

Some eminent scholars defined the environment as follows:-

According to **E.J.Ross,** "Environment is an external force which influences us"

According to **Dr. D.H. Davis,** "In relation to man environment means all those physical forms spread all around man on land by which he is influenced continuously.

According to **Kovits,** "Environment is the sum of all those external conditions which influences the development cycle of the organisms on the surface of the earth.

**Components of Environment**

The components of environment can be classified as shown in the flow diagram.

Land, water, air, soil etc are important inanimate (or) abiotic components. Man, animal, plants and other organisms are biotic components.

**Natural Environment**

The natural environment is the environment, which comes into existence without interference of man.

## Overview of the subject to be taught in each year

**Objectives:** At the end of this lesson you shall be able to
- **state the subject to be learned in each year.**

**Overview of the subject to be taught for each year**

During the two years duration, a candidate is trained on subject viz. Professional Skill, Professional Knowledge, Workshop Science & Calculation and Employability Skills. In addition to this, a candidate is entrusted to undertake project work and Extra Curricular Activities to build up confidence. The practical skills are imparted in simple to complex manner & simultaneously theory subject is taught in the same fashion to apply cognitive knowledge while executing tasks. The practical part starts with simple geometrical drawing and finally ends with preparing sanction plan of Residential / Public building; drawing of roads, bridges, railway tracks, dams and Estimation and costing of civil works at the end of the course.

The broad components covered under Professional Skill subject are as below.

**Job area after completion of training**

After completion of this training trainees maybe able to earn their livelihood. Environment of I.T.I is differs from the schools education. In I.T.I we concentrate more time in practical training i.e he has to obtain good skill in the trade in which he trained. Hence we can say I.T.I.s are institutions which lay the carpet for self job opportunity and differ job opportunity in public sector and private sector.

There are so many departments in public sector and private sector which provides the job opportunity for the trade of surveyor.

**The name of some public sectors are given below.**

- Central public works department
- Central archetech department
- Military Engineering service
- National High ways department
- Central geological department
- Survey of India
- Railways
- State P.W.D.
- Municipal councils
- Private building construction companies

Now Government of India passed an order in parliament those are all trained in particular group of trades such as D'man Civil, D'man Mechanic and Mechanic shop group of trades, they can join in 2nd year of diploma courses in the respective states.

Subject to be taught in the trade of surveyor for each year

**Ist Year**

- Occupational safety and health
- First Aid and introduction of PPF
- Use of drawing instruments and equipment, their care and maintenance
- Layout of drawing sheets and following of different size of drawing sheets.
- Lettering & dimensioning
- Plane and solid geometrical figures
- Read and use of plain, diagonal, comparative, vernier and scale of chords.
- Conventional signs and symbol of drawing
- Chain survey
- Chain surveying and preparation of site plan compass survey
- Observe the bearings of lines
- Traverse survey using compass
- Auto cad commands uses.

**Plane table survey**

- Orientation method
- Intersection method
- Resection method
- Traversing

**Theodolite survey**

- Horizontal angle measurement
- Vertical angle measurement
- Traverse

**Levelling survey**

- Types of levelling
- Types of instrument
- R.L. calculation
- Road project survey

- Auto cad commands & uses.

**WCS (1st Year)**

- Unit Fractions
- Square root, ratio and proportions, percentage
- Material science
- Mass weight density
- Heat & temperature
- Mensuration
- Trigonometry

**2nd Year**

- Tachometric survey using tachometer
- Introduction to contour
- Various methods of contour
- Contour gradient
- Introduction to curves.
- Types of curves.
- Various method of setting and curves.
- Simple curve, compound curves.
- Modern survey instruments.
- Use of total station.
- Working procedure of total station
- Digital plan meter uses
- Prepare Topographical map.
- Auto cad commands & survey software uses.
- Drawing simple conical projection
- Various types of cartographic projection for mapping.
- Introduction to GPS/GIS
- Introduction to DGPS
- Plotting contour lines with software cad
- Finding out cross sectional area of river measure velocity of flow.
- Handling of eco sounder.
- Marking tentative alignment
- Conduct reconnaissance/ preliminary survey.
- Various types of Building material, Type of Foundation
- Draw double storied residential building plan prepare detail estimate.

**WCS (2nd Year)**

- Area of cut out surfaces
- Algebra
- Profit & loss
- Estimation & Costing

# Drawing Instruments, Equipments and materials

**Objectives:** At the end of this lesson you shall be able to
- **state instruments, equipments and materials**
- **list out instrument, equipments and materials**
- **state the standard as per IS962: 1989**
- **to use different drawing instruments, equipments and materials**
- **follow Precautions in the use of instruments, equipments and materials.**

### Introduction

Engineering Drawing is the language of engineers, the accuracy and neatness of the engineering Drawing depends on the quality of the instruments, equipments and material used. Hence, preference should be given to standard instruments and equipments and surveyor should be able to use different drawing instruments.

### List of instruments

- Drawing board
- Tee-square or Mini Drafter
- Set-square
- Scale
- Protractor
- French curves
- Stencil
- Drawing instruments box

### List of equipments

- Drafting machine
- Computer for Auto CAD. (Monitor UPS, CPU, key board, mouse, etc.)
- Plotter/Printer

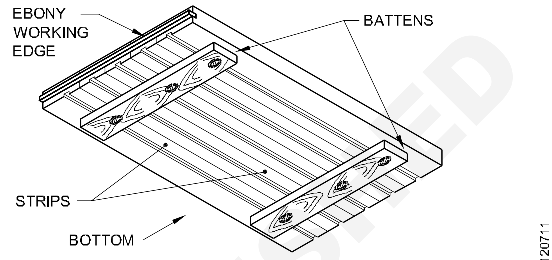
### List of materials

- Drawing papers
- Drawing pencils
- Rubber/ Eraser
- Drawing papers fasteners (Drawing pins, Cello tape)
- Tracing paper or tracing film

### Drawing board (Fig 1)

The standard size should be as per IS: 1444-1963/1977 of Bureau of Indian Standards.

Fig 1



DRAWING BOARD

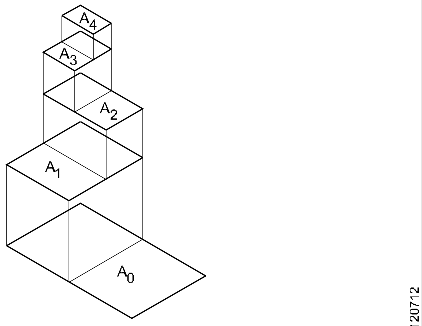
| Sl. No. | Drawing Boards | | Drawing sheets to be used with designation |
|---|---|---|---|
| | Designation | Sizes in mm ( L x W x T ) | |
| 1 | BO | 1500 x 1000 x 25 | AO |
| 2 | B1 | 1000 x 700 x 25 | A1 |
| 3 | B2 | 700 x 500 x 15 | A2 |
| 4 | B3 | 500 x 350 x 15 | A3 |

**The following precaution may be taken in handling the drawing boards:**

- Always keep an extra sheet on the top surface of the drawing board.
- Do not keep anything on the top flat surface of the drawing board.
- Take sufficient care in up keeping the straightness of the ebony edge.

**Drawing papers: (Fig 2)**

Fig 2



HALVING AND DOUBLING

| Designation | Trimmed size (mm) | Untrimmed size (mm) |
|---|---|---|
| A0 | 841 x 1189 | 880 x 1230 |
| A1 | 594 x 841 | 625 x 880 |
| A2 | 420 x 594 | 450 x 625 |
| A3 | 297 x 420 | 330 x 450 |
| A4 | 210 x 297 | 240 x 330 |
| A5 | 148 x 210 | 165 x 240 |

The standard size as per Bureau of Indian standard (B.I.S)

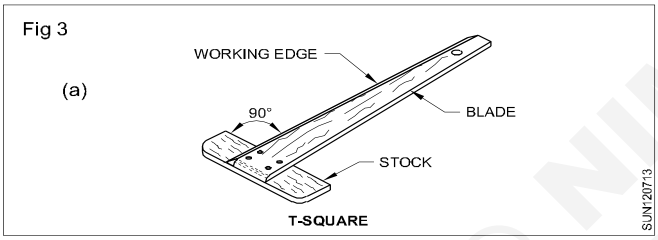
1 The size of the drawing sheets to be used depends on the size of the object to be drawn and the scale to be used.

2 The length of the drawing sheet can be horizontal or vertical while drawing.

3 A2 size of drawing sheet is most convenient for drawing purposes in the class room.

4 The width to length ratio of drawing sheet is $1:\sqrt{2}$

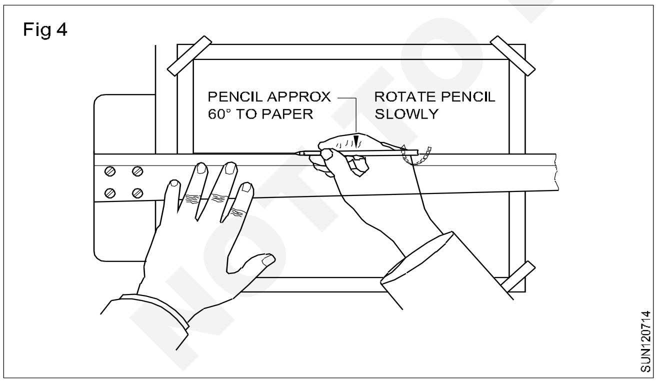
5 Area of A0 drawing sheet is 1.00 square metre.



T-SQUARE

## T-square (Fig 3)

It consists of two parts, a long strip called blade and a short strip called head or stock. The blade is fitted with an ebony or plastic piece on its upper edge to form a working edge.




**The following precautions may be taken in handling the T-square: (Fig 4)**

1 When not in use, T-square should be left flat on the drawing board or suspended from the hole at the end of the blade.

2 Clean the blade with moist cloth to remove lead particles.

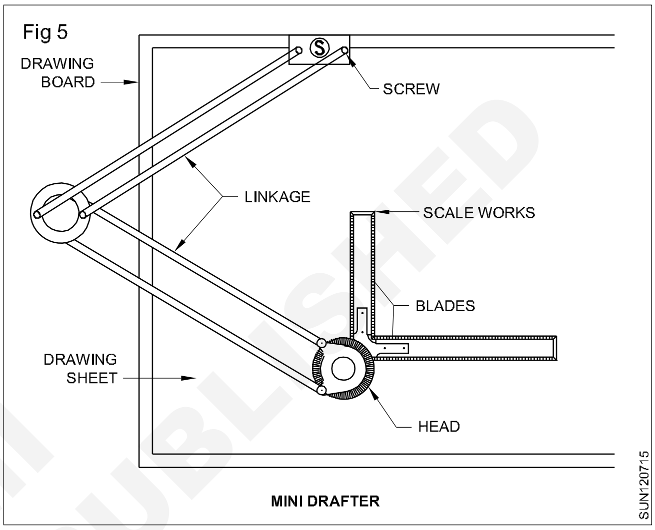
3 Do not use T-square as a hammer to drive in the drawing pins etc.

4 Do not use the ebony edge as a straight edge for cutting paper with knife.

5 Ensure that the screw heads are tight.

| |
|---|
| **T-square is used to draw only horizontal lines. Do not use lower edge of the T-square to draw horizontal lines. While drawing horizontal lines, the pencil should be slightly inclined towards the right. Vertical and inclined lines are drawn with the help of set squares.** |

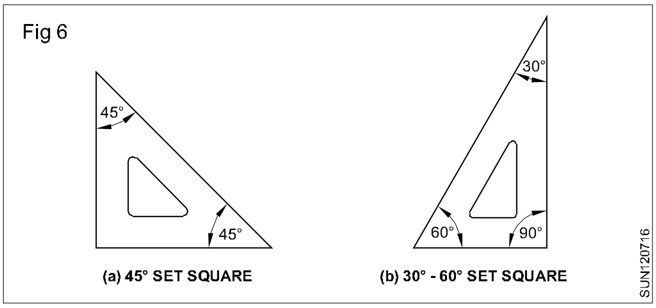
## Mini drafter(Fig 5)



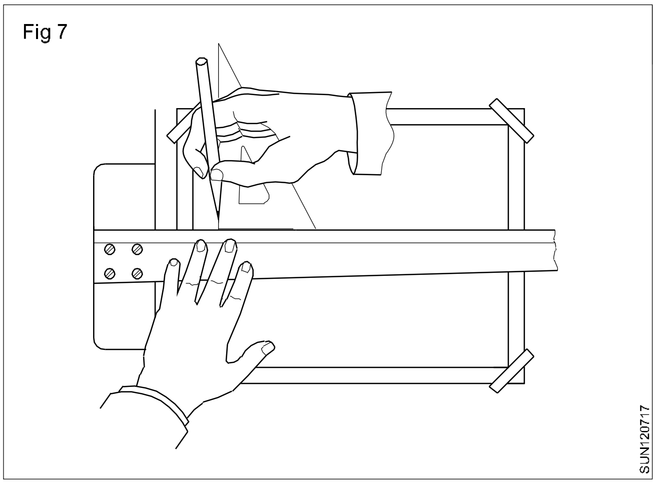
MINI DRAFTER

It is a simple and small shaped instrument of the drafting machine. Now-a-days these are mostly used by the engineering students. All the working functions of T-Square, Set-Square, Protractor, Scales and their merits are co-ordinated in a Mini-Drafter.

## Set-square (Fig 6 and Fig 7)



(a) 45° SET SQUARE (b) 30° - 60° SET SQUARE



It is made of transparent celluloid plastic in triangular shape They are available in two types, $30^0$-$60^0$ and $45^0$-$45^0$.

**Engineer's scales (Table)**

It is used to make full size, reduced size or enlarged size drawings conveniently, depending upon the size of the object and that of the drawing sheet. They are made of cardboard, plastic and as recommended by Bureau of Indian Standards, are available in set of eight scales. They are designated from M1 to M8.

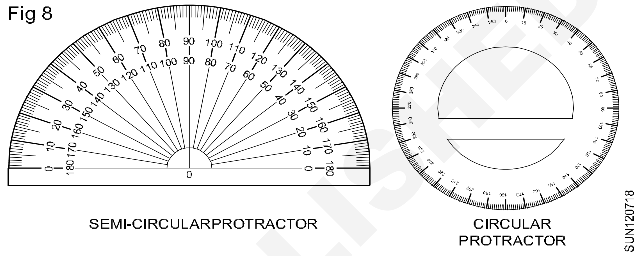
**Table**

| Designation | Description | Scales |
|---|---|---|
| M1 | Full size | 1:1 |
| | 50 cm to a metre | 1:2 |
| M2 | 40 cm to a metre | 1:2.5 |
| | 20 cm to a metre | 1:5 |
| M3 | 10 cm to a metre | 1:10 |
| | 05 cm to a metre | 1:20 |
| M4 | 02 cm to a metre | 1:50 |
| | 01 cm to a metre | 1:100 |
| M5 | 5 mm to a metre | 1:200 |
| | 2 mm to a metre | 1:500 |
| M6 | 3.3 mm to a metre | 1:300 |
| | 1.66 mm to a metre | 1:600 |
| M7 | 2.5 mm to a metre | 1:400 |
| | 1.25 mm to a metre | 1:800 |
| M8 | 1 mm to a metre | 1:1000 |
| | 1.5 mm to a metre | 1:2000 |

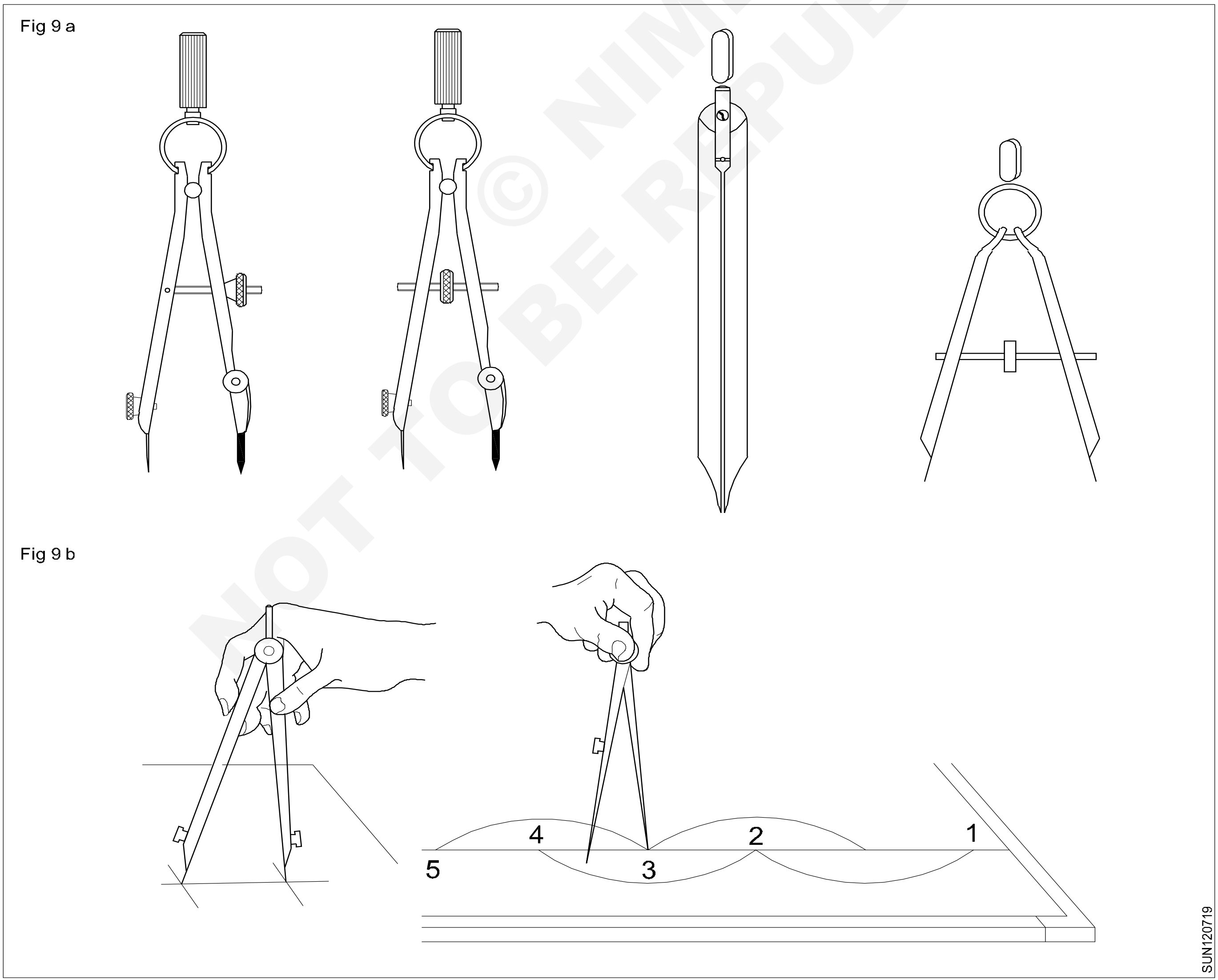
**Protractor: (Fig 8)**

It is made of transparent celluloid plastic, available in semi circle or circle.

Fig 8



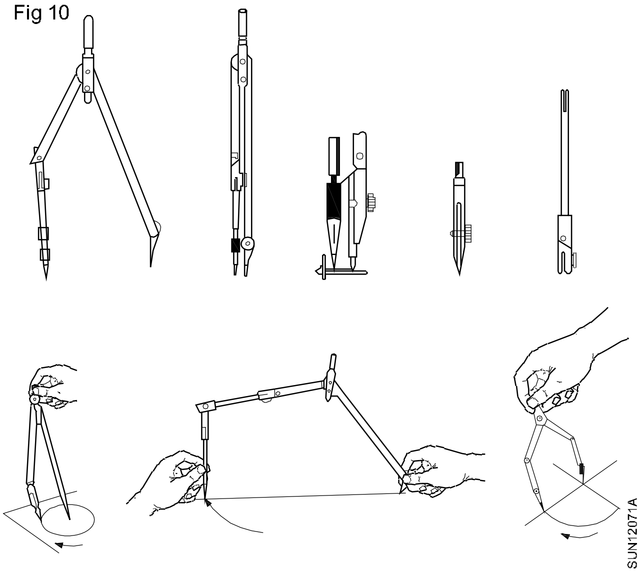

**Compass (Fig 9)**



It is used for drawing circles both in pencil and in ink. It consists of two legs hinged at one end. One leg is attached with a steel needle by means of a screw while the other leg is provided with a socket to accommodate interchangeable attachments.

**Dividers (Fig 10)**

Fig 10




Dividers are similar to the compass and are made in square, flat and round forms. They are used for:

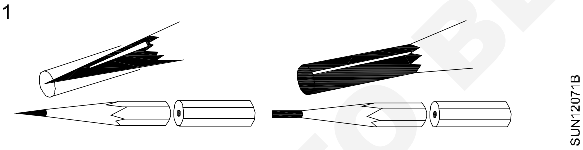
1 Dividing curved or straight lines into any number of equal parts.

2 Transferring dimensions from one part of the drawing to another part.

3 Setting dimensions form the scale to the drawings.

**Drawing pencils (Fig 11)**

Fig 11




These are in many grades. The grade HB denotes medium soft. The grade H denotes the degree of hardness in an increasing order. Similarly, grade B indicates the degree of softness in an increasing order.

**The lead of the wood pencil may be sharpened in the following ways**

1 Cylindrical

2 Conical

3 Wedge (Chisel edge)

4 Bevel

Mechanical clutch pencil is very common in use. This is very simple, easy to use, requires no sharpening time and even cheaper in long run. Hence, this type of pencil is preferred by professional surveyor. Students using these types of pencils will save a lot of time.

1 Only a sharp pencil can make quality drawing and hence, sharpen the pencil as and when it is necessary.

2 Sharpen the pencil only where there is no grade mark.

3 In a compass H pencil sharpened to bevel point, having its wedge shaped side slopping outside, is used.

4 As a general guide, use:

I HB pencil for sketching

II H for outlines, visible lines, finishing, dimensioning, lettering, arrows etc.

III 2H for construction lines, dimension lines, centre lines, section lines etc.

**Selection of pencils**

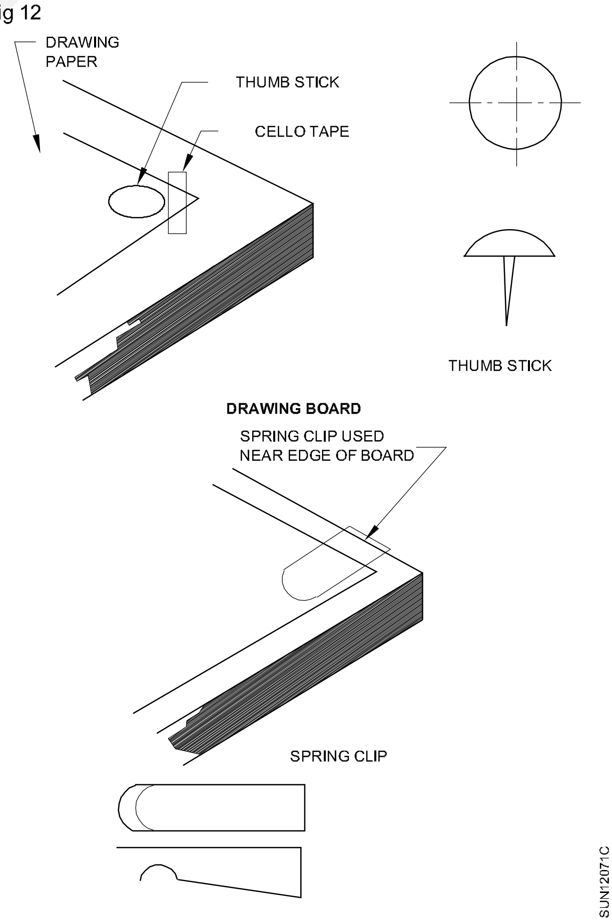
- HB- For free hand works
- H- For making drawing and lettering
- 2H- for drawing construction lines, dimensions lines, section lines and centre lines.
- 3H, 4H- For drawing minute details
- B- For shading

**Eraser**

Soft pencil erasers are ideal for erasing pencil marks. This eraser will not destroy the surface of the paper and hence drawing can be re-penciled.

**Fastener: (Fig 12)**

Fig 12



Following materials are used to fix the drawing sheet on the drawing board.

- Thumb pins
- Cello tapes
- Fold back gap spring clips.

**Template**

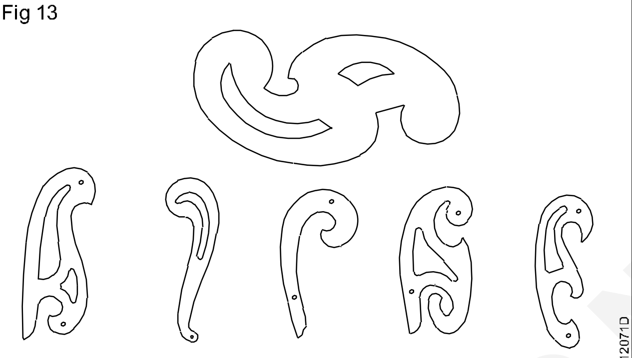
Templates are available for drawing circles, arcs, ellipses, triangles, squares and other polygons. Also, symbols used by various engineering faculties, such as architectural, mechanical, electrical, chemical etc. are now available in the form of templates.

**Stencils**

Stencil is a thin flat piece of celluloid used to write letters and numerals. This helps the draftsmen to write neatly and uniformly and at a faster rate.

**French curves (Fig 13)**

Fig 13




FRENCH CURVES

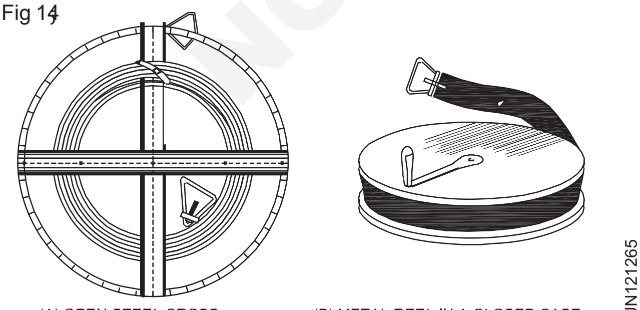
A French curve is a curved ruler used for drawing irregular curves that are neither circles nor circular arcs. It is made of wood, plastic or transparent celluloid. There are different forms and sizes of French curves.

**Flexible curve**

Flexible curve is made out of materials having flexibility. It is made of lead bar enclosed in rubber and can be bent into any shape to form a curve. It helps to draw smooth curve passing through any given points. Flexible curves of various sizes are now available in the market.

**Steel Tape (Fig 14)**

Fig 14




(A) OPEN STEEL CROSS (B) METAL REEL IN A CLOSED CASE

1 It is used for accurate work.
2 It is lighter weight and easier to handle than the chain.
3 It is 20m or 30m long.
4 It is made from ribbon of steel 16mm wide.
5 The brass handles are provided at the ends of the chain with swivel joint.
6 It is wound on an open steel cross or a metal reel in a closed case.
7 The graduations are worked in two ways.
8 It is divided by brass studs at 0.2m and numbered at every 1m in the first portion and the last link is subdivided into cm and mm.
9 The graduations are etched as metres, decimeters and centimeters on one side and 0.2m links on the other side. Brass tallies are fixed at every 5 in length.

**Precautions in the use of instruments:**

Following precautions should be taken while doing the drawing works,

1 The lower edge opposite to the working edge of the Tee-Square should not be used for drawing horizontal lines.
2 T- Square should not be used as hammer to drive to drawing board pins.
3 Measuring scales should not be used as hammer to drive to drawing pins.
4 Drawing sheets should never be cut by blade or knife with the T-Square blade as the guide.
5 All the instruments and drawing sheet etc. Should be thoroughly dusted off and cleaned before starting the work.
6 No end of the pencil should be kept in mouth.
7 No oiling should be done to the joints of the instruments; otherwise, oil will give stains or spots on the drawing sheets.
8 Only required instruments should be kept on the drawing board. All extra instruments should be kept away in drawer.
9 Divider should not be used as pincer.
10 Soaking paper should not be used for drying the ink.
11 After completing the work all the instruments should be properly cleaned.

**Conclusions**

One should practice handling and using drawing instruments before attempting complex drawing problems. Developing correct drawing habits will enable to make continuous improvement in the quality of drawings. Each drawing will offer an opportunity for practice. Later on, good form in the use of instruments will become a natural habit.

# Layout of drawing sheet and title block

**Objectives:** At the end of this lesson you shall be able to
- **state the system of Layout of drawing sheet**
- **list the different layout for designated drawing sheet**
- **explain the Title block.**

**Lay out :** Layout is standard arrangement of placing margin, title block etc for a particular size of drawing paper. It was explained earlier that the size of drawing sheets and standardised and designated as A0, A1, A2,A3,A4 &A5.Different layout styles for drawing papers from A0 to A5 sizes as per IS : 10711 - 1983. (Figs 1 &2)

**Margin :** Margin enable the prints to be trimmed After fixing the drawing paper over the drawing board, before commencing the drawing , the layout is to be drawn. The drawing should be drawn within the layout boundary. The layout lines are called borders. 'borders' are enclosed by the margins from edges of the trimmed size of sheet.

It is recommended that within the borders on the left side have minimum width 20mm for the sheet sizes A0, A1 and 10mm for the sheet sizes A2, A3,A4& A5 for the space for filing. (Refer Figs 1& 2)

Fig 1

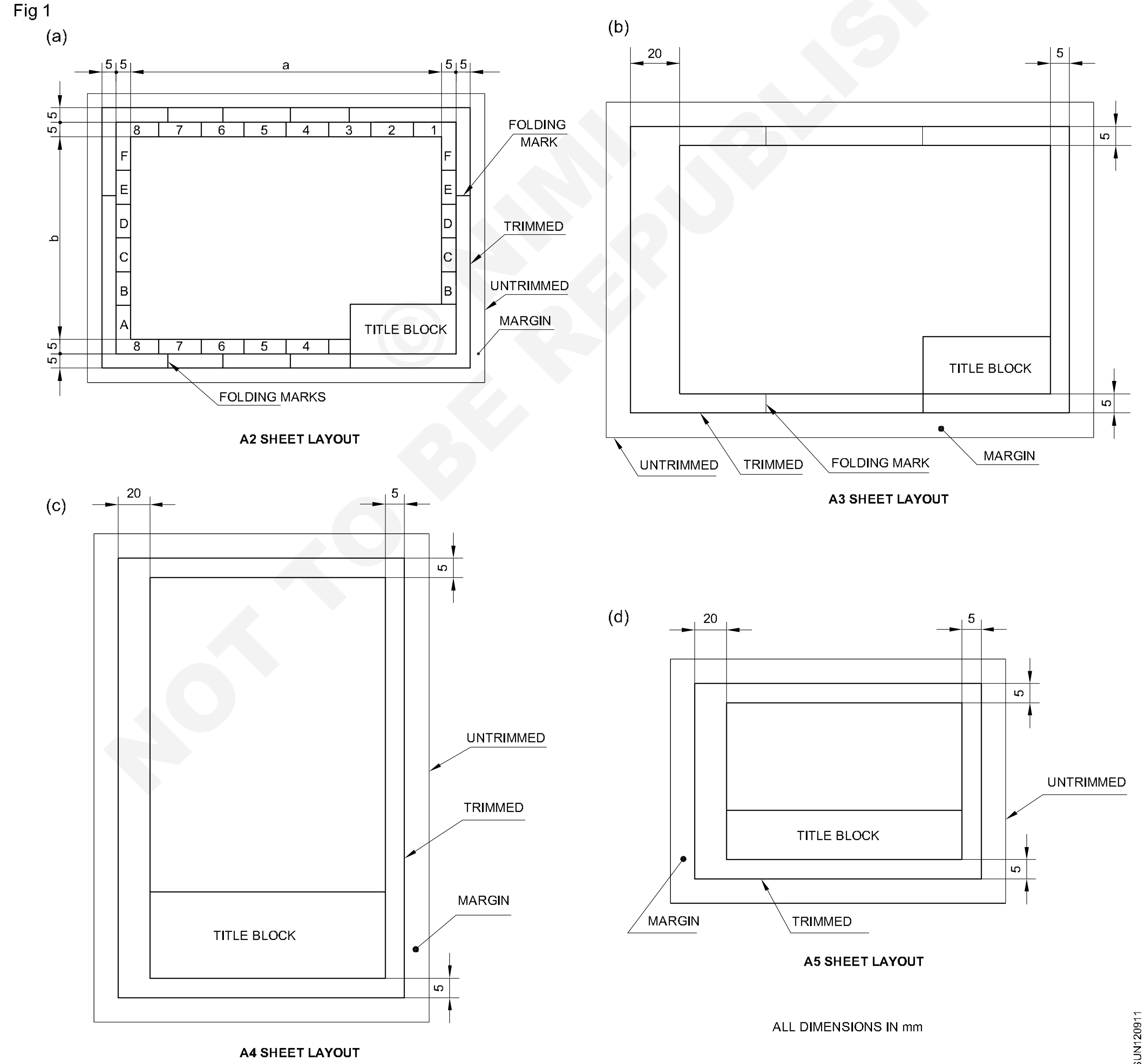
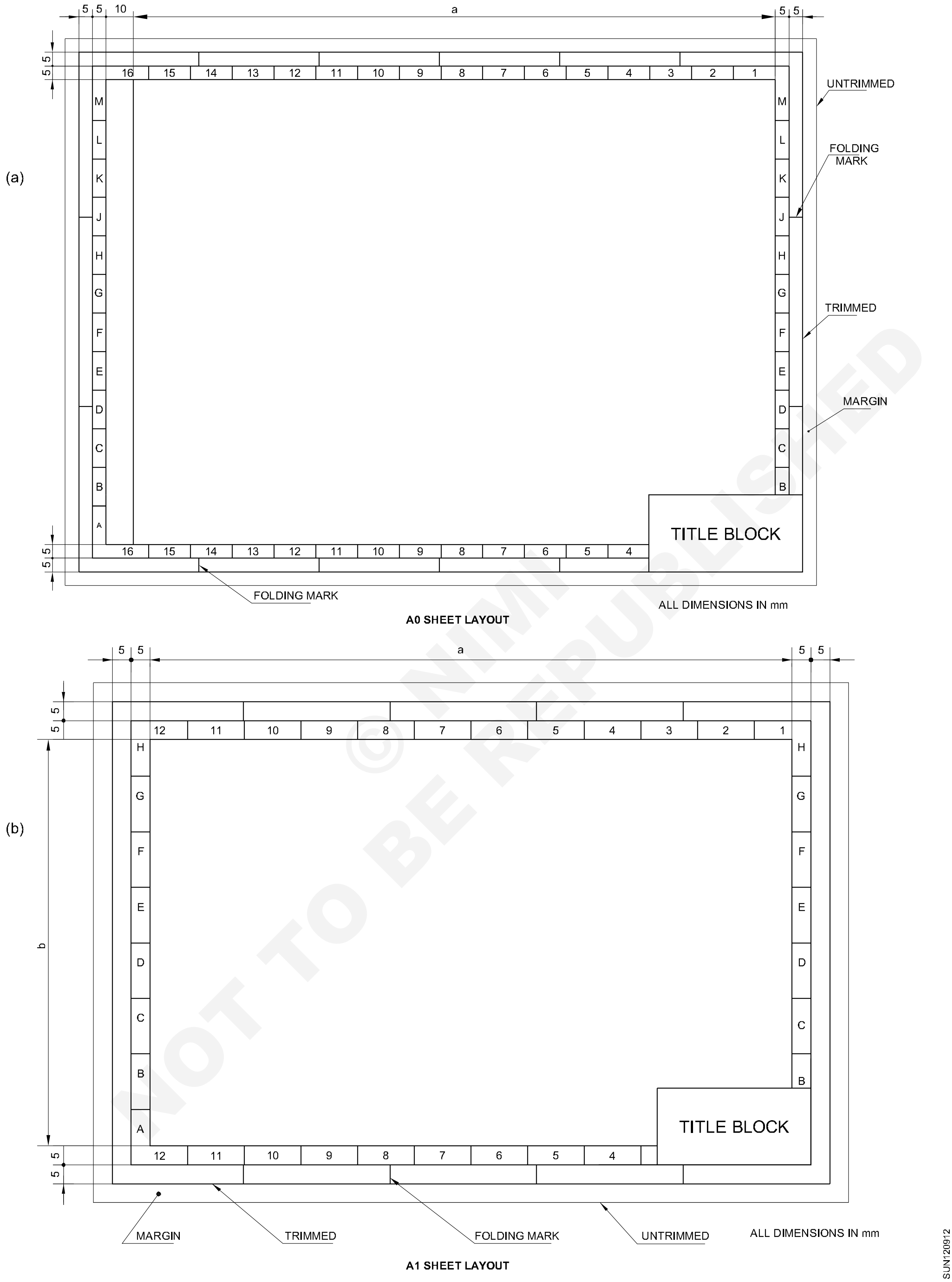


Fig 2

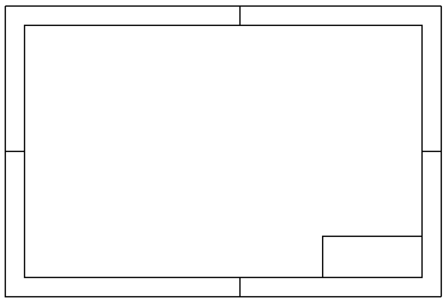





the sheet be taken horizontal or vertical depending upon the nature of the drawing as sheet type 'X' and sheet type 'Y'. (Fig 3 & 4)

**Frame :** The frame limiting the drawing space should be executed with continous thin line of 0.5mm.

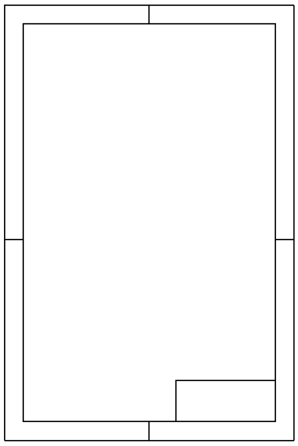
Fig 3



HORIZONTAL SHEET TYPE X

SUN120913

Fig 4



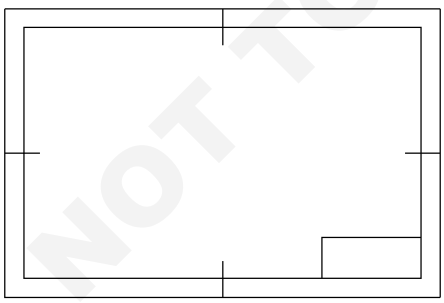
VERTICAL SHEET TYPE Y

SUN120914

**Title block** (Fig 5)**:** This is the block in which the particulars of the organisation. Name of the drawing and other particulars are printed. It is situated in the bottom right hand corner of the drawing sheet. Figs 1 & 2 shows the position of the title block. Contents of the title block and their relative position vary to suit individual concern.

**Centering marks** (Fig 6)**:** When the drawings on the drawing sheet are to be microfilmed (preserving by taking negatives) centering marks to be provided.

Fig 6



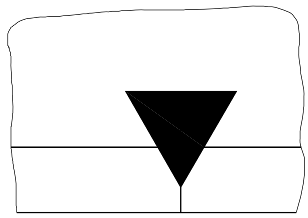
CENTRING MARKS

SUN120916

These marks shall be placed at the ends of the two axis of symmetry of trimmed sheet. It is executed with 0.5 mm minimum thick stroke, starting from the edges of the trimmed sheet. It shall extend approximately 5 mm beyond drawing frame.

**Orientation marks** (Fig 7)**:** Orientation marks are used in order to indicate the orientation of the drawing (arrow head) sheet on the drawing board. These marks consist of arrow heads and should be placed across the frame one at shorter side and one at longer side coinciding with the centering marks. One of the orientation marks always points towards the draughtsman.

Fig 7

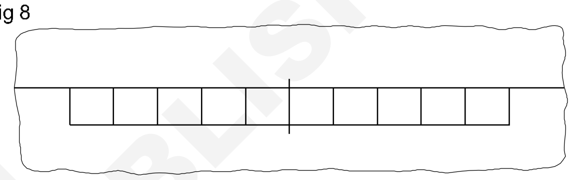


ORIENTATION MARKS

SUN120917

**Metric reference graduation** (Fig 8)**:** It is shown only on drawings without (metric) dimensions. It shall have minimum 100 mm long divided into 10 equal intervals max. width 5 mm. It should be executed with thin continuous line (0.5 mm) disposed symmetrically about a centering mark.

Fig 8

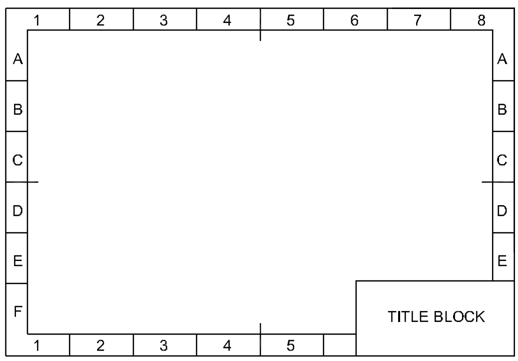


METRIC REFERENCE GRADUATION

SUN120918

**Grid reference** (Fig 9)**:** In order to facilitate easy location of features on large drawings (assembly) grid reference system is recommended. It is similar to lines of latitude and longitude on a map. The number of divisions shall be divisible by two. The length of any side of the rectangle of the grid shall not be less than 25 mm and not more than 75 mm along the frame. These are the special requirements for production of assembly drawings.

Fig 9

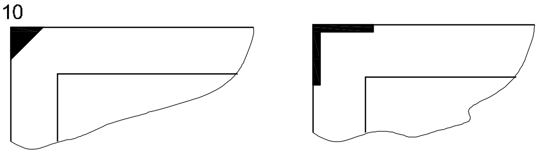



GRID REFERENCE SYSTEM

SUN120919

**Trimming marks** (Fig 10)**:** These marks are required for the sheets which require trimming. Example printed copies of drawings. In such cases the trimming marks are drawn on the drawing tracing sheet.

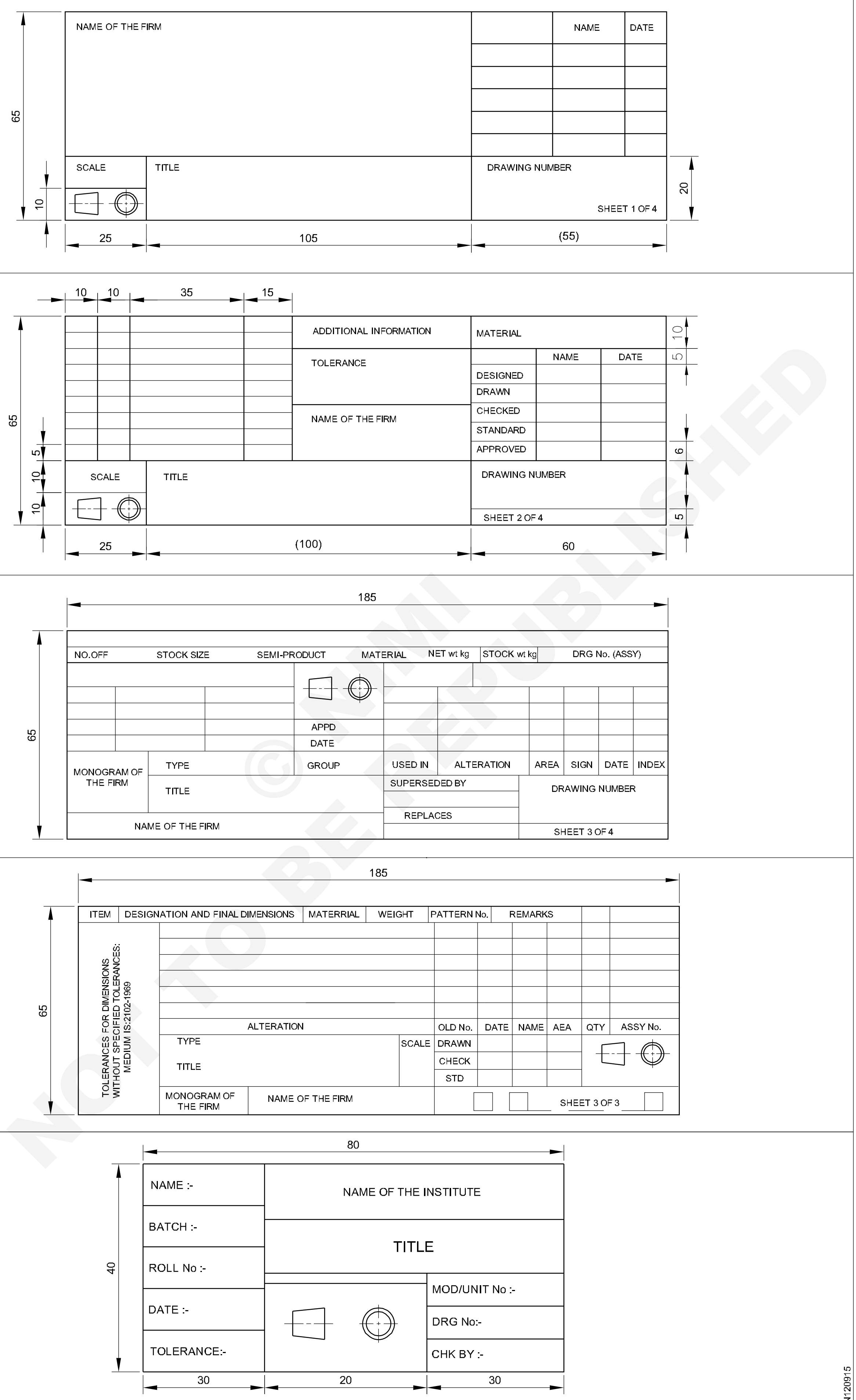
Fig 10



TRIMMING MARKS

SUN12091A

Fig 5




TITLE BLOCK TYPICAL LAYOUTS

# Folding of sheets

**Objectives:** At the end of this lesson you shall be able to
- **explain the method of folding in different size of drawing sheets.**

The purpose of folding the drawing sheet for storing to the correspondence files. For binding in special reports is illustrated in the file.

All the maps and plans are folded to final size for convenience of record in office files.

Method of fold the different sizes of drawing sheets.

Lower portion of the left-hand margin of the sheet may be cut after retaining 297mm long top portion in order to provide for filing the drawing in the files.

Plans may be opened out easily by holding firmly the top left-hand corner and pulling the bottom right-hand corner.

The following procedure shall be adopted in order

a) Always fold vertically first.

b) Fold horizontally next.

c) Folded drawing to be of A4 size.

d) Title block to be on the topmost fold for easy reference.

**A0-size**

Fold the A0-size sheet.

Folding vertically, from left side to right side.

1st fold 210mm

2nd & 3rd - fold each 109.5mm

Other 4th to 6th folding are 190mm each.

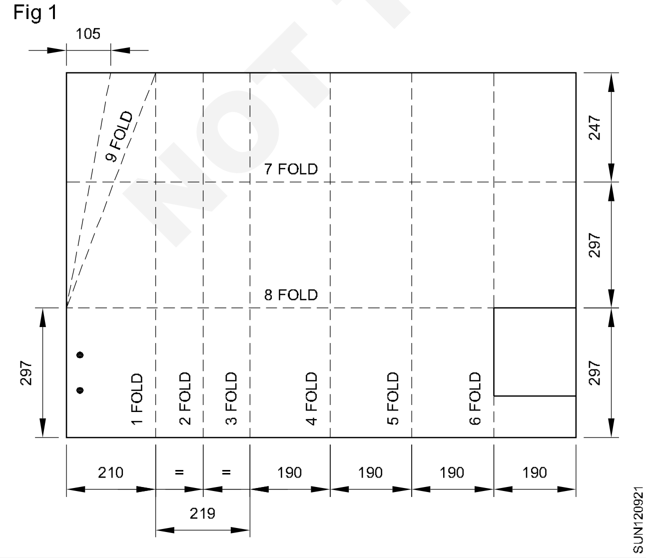
Fold horizontally 7th folding from the top to bottom 247mm.

8th folding is from the 7th folding point 297mm.

Title block will always come top of the right side corner.

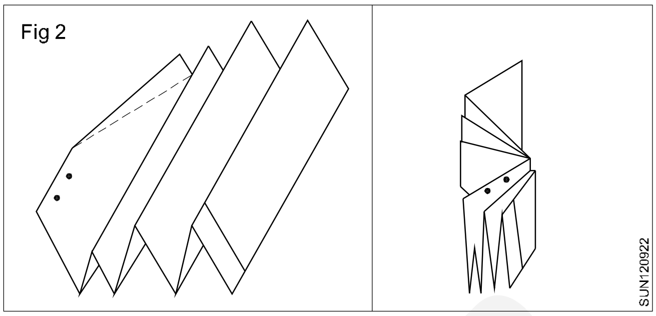
9th folding is top left side rectangular portion folded diagonally. (Fig 1)

Fig 1




After completion of folded the drawing sheet. (Fig 2)

Fig 2




**Fold the A1 Size sheet: (594 x 841)**

Folding vertically, from left side to right side.

1st fold 210mm

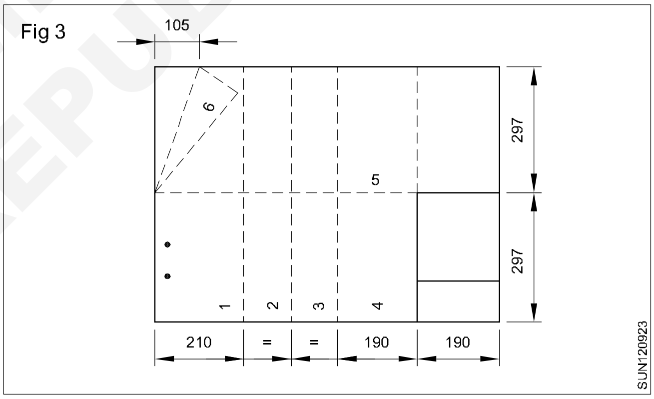
2nd & 3rd - fold each 125.5mm

Other 4th 190mm

Folding horizontally from top

5th folding 297mm. (Fig 3)

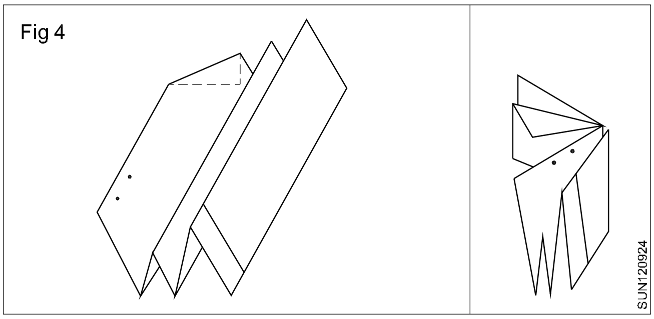
Fig 3




6th folding is top left side rectangular portion folded diagonally as shown in figure.

After completion of folded the drawing sheet. (Fig 4)

Fig 4




**Fold the A2 Size sheet: (420 x 594)**

Folding vertical, from left side to right side.

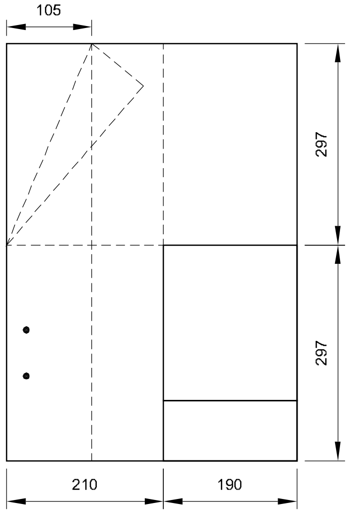
1st folding 210mm.

2nd folding 190mm from the right side.

Folding horizontally from bottom

3rd folding 297mm. (Fig 5)

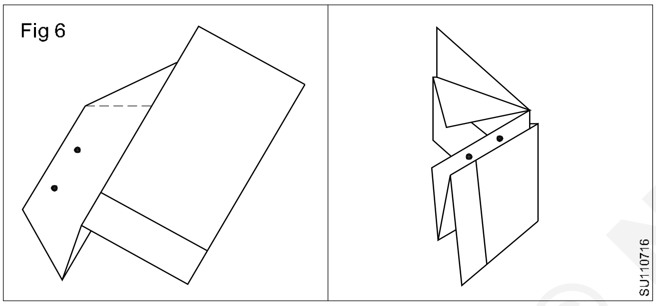
Fig 5




4th folding is top left side rectangular portion folded diagonally as shown in figure.

After completion of folded the drawing sheet. (Fig 6)

Fig 6




**Fold the A2 Size sheet: (594 x 420)**

Folding vertically from left side to right side.

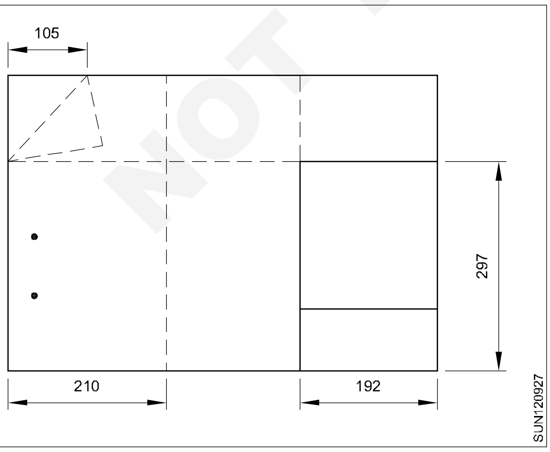
1st folding 210mm

2nd folding 192mm from the right side of the drawing sheet.

Folding horizontally from the bottom, 3rd folding 297mm.

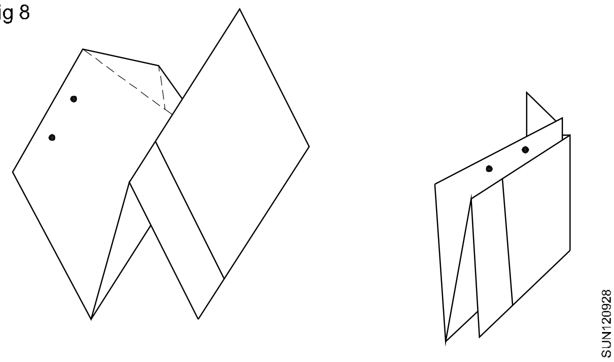
4th folding is top left side rectangular portion folded diagonally as shown in (Fig 7)

Fig 7




After completion of folded the drawing sheet. (Fig 8)

Fig 8




Fold the A3 size sheet: (297 x 420)

Folding vertically from left side.

1st folding 210mm.

2nd folding 190mm from the right side of the drawing sheet. (Fig 9 & 10)

**The method of folding the drawing sheet, the title block should appear at the right bottom of the folded sheet finally.**

Fig 9

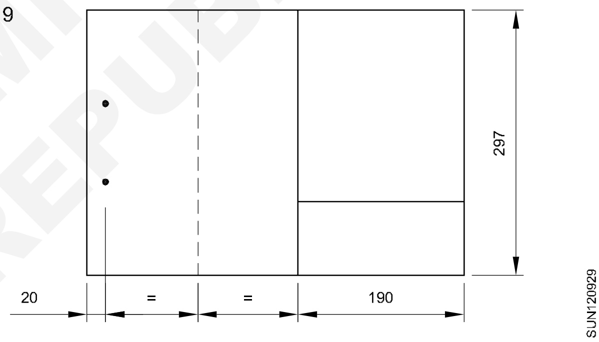
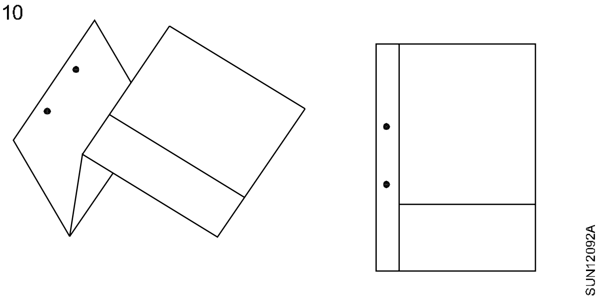



Fig 10



## Lettering styles

**Objectives:** At the end of this lesson you shall be able to
- **recognise different lettering styles**
- **designate the letters and numerals as per IS norms**
- **state standard proportion for height, width and spacing of letters.**

Apart from graphical elements (lines, arcs, circles etc) technical drawings will also contain written informations.

These written informations are referred as "lettering".

**Styles of lettering:** Many styles of lettering are in use to day. However, a few styles which are commonly used are shown in Fig 1.

Fig 1


**Standard heights/Width:** The standard heights recommended by BIS (IS:9609-1983) are in the progressive ratio of "square root 2". They are namely 2.5 - 3.5 - 5 - 7 - 10 - 14 and 20 mm. The height of lower case letter (without tail or stem) are 2.5, 3.5, 5, 7, 7, 10 and 14 mm.

There are two standard ratios for the line thickness "d". They are A & B. In A = line thickness (d) is h/14 and in B = line thickness (d) is h/10.

The width of different letters in terms of "d" is as follows:

**Lettering A**

| Width (W) | Capital letters | Width |
|---|---|---|
| 1 | I | 1d |
| 5 | J,L | 5d |
| 6 | C,E,F | 6d |
| 7 | B,D,G,H,K,N,O,P,R,S,T,U & Z | 7d |
| 8 | A,Q,V,X,Y | 8d |
| 9 | M | 9d |
| 12 | W | 12d |

**Lower case letters and numerals**

| Width (W) | Letters/Numerals | Width |
|---|---|---|
| 1 | i | 1d |
| 3 | j,l | 3d |
| 4 | f,t,l | 4d |
| 5 | c,r | 5d |
| 6 | a,b,d,e,g,h,k,n,o,p,q,s,u,v;3;5 | 6d |
| 7 | a,0 (zero), 2,4,6,7,0,8,9 | 7d |
| 9 | m | 9d |
| 10 | w | 10d |

The width of different letters in terms of stroke (line) is as follows:

**Lettering B. IS:9609**

| Width (W) | Capital letters |
|---|---|
| 1 | I |
| 4 | J |
| 5 | C,E,F,L |
| 6 | B,D,G,H,K,N,O,P,R,S,T,U & Z |
| 7 | A,M,Q,V,X,Y |
| 9 | W |

**Lower case letters and numerals**

| Width (W) | Letters/Numerals |
|---|---|
| 1 | i |
| 2 | l |
| 3 | j:l |
| 4 | c,f,r,t |
| 5 | a,b,d,e,g,h,k,n,o,,q,s,u,v,x,y,x |
| | 0,2,3,5 to 9 |
| | 0,2,3,5 to 9 |
| 6 | a,4 |

Fig 2 & 3 shows the sequence of printing single stroke capitals and lower capital letters in vertical style.

Fig 2

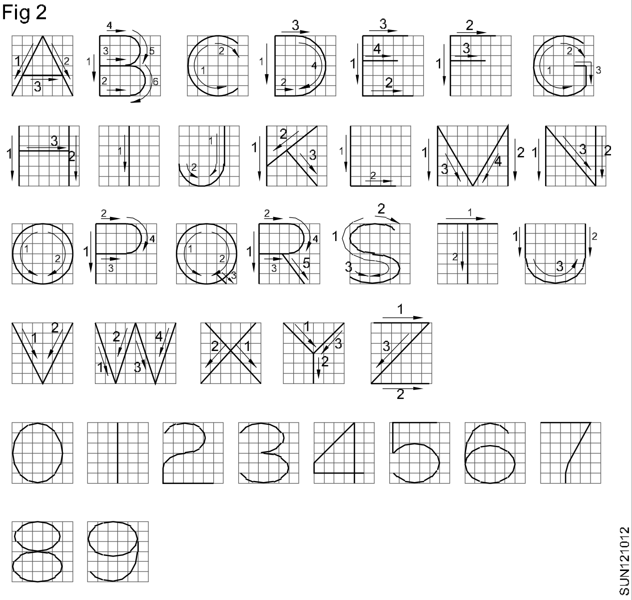
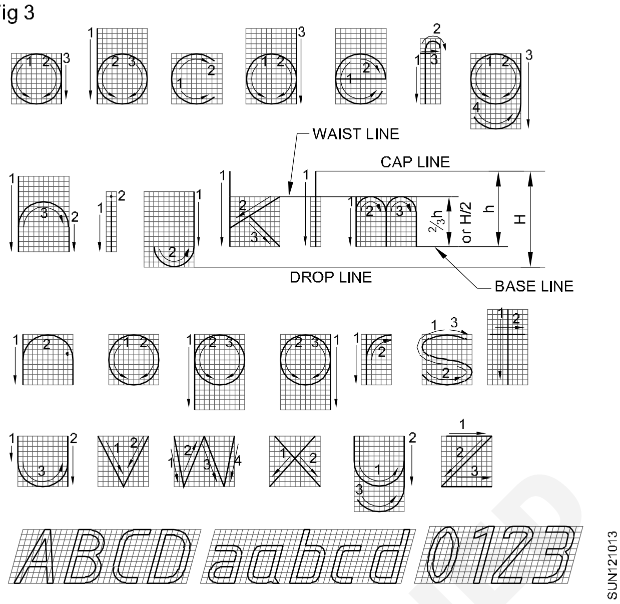


Fig 3




Inclined letters (Fig 3) are drawn at an angle of 15° towards right side, the proportion being the same as of vertical lettering.

Fig 3 shows single stroke/lower case letters also.

Standard letters to suit the nature of instructions, the sizes should be selected. All the lettering should be printed, so that they are read/viewed from the bottom of the drawing.

Lettering makes or mars the appearance and legibility of the drawing. Always maintain uniform lettering (letters and numerals) which can be reproduced within reasonable time with ease. In machine drawing ornamental lettering should never be used.

**Spacing of letters:** Recommended spacing between character, minimum spacing of base lines and minimum spacing between words as per Indian Standards (IS:9609-1983) is given below in figure No.4 and Table 1 & 2.

Fig 4

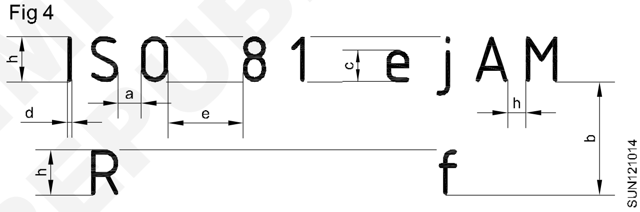





TABLE 1

| Lettering A (d = h/14) Characteristic | | Ratio | Values in millimetres Dimensions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lettering height Height of capitals | h | (14/14)h | 2.5 | 3.5 | 5 | 7 | 10 | 14 | 20 |
| Height of lower-case letters (without stem or tail) | c | (10/14)h | - | 2.5 | 3.5 | 5 | 7 | 10 | 14 |
| Spacing between characters | a | (2/14)h | 0.36 | 0.5 | 0.7 | 1 | 1.4 | 2 | 2.8 |
| Minimum spacing of base lines | b | (20/14)h | 3.5 | 5 | 7 | 10 | 14 | 20 | 28 |
| Minimum spacing between words | c | (6/14)h | 1.06 | 1.5 | 2.1 | 3 | 4.2 | 6 | 8.4 |
| Thickness of | d | (1/14)h | 0.18 | 0.25 | 0.35 | 0.5 | 0.7 | 1 | 1.4 |
| **The spacing a between two characters may be reduced by half if this gives a better visual effect, as for example LA, TV; it then equals the line thickness d.** | | | | | | | | | |

TABLE 2

| Lettering B (d = h/10) Characteristic | | Ratio | Values in millimetres Dimensions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lettering height Height of capitals | h | (10/10)h | 2.5 | 3.5 | 5 | 7 | 10 | 14 | 20 |
| Height of lower-case letters (Without stem or tail) | c | (7/10)h | - | 2.5 | 3.5 | 5 | 7 | 10 | 14 |
| Spacing between characters | a | (2/10)h | 0.5 | 0.7 | 1 | 1.4 | 2 | 2.8 | 4 |
| Minimum spacing of base lines | b | (14/10)h | 3.5 | 5 | 7 | 10 | 14 | 20 | 28 |
| Minimum spacing between words | c | (6/10)h | 1.5 | 2.1 | 3 | 4.2 | 6 | 8.4 | 12 |
| Thickness of lines | d | (1/10)h | 0.25 | 0.35 | 0.5 | 0.7 | 1 | 1.4 | 2 |

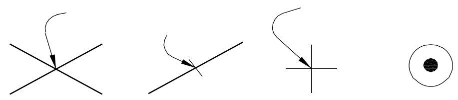
**The spacing between two characters may be reduced by half if this gives a better visual effect, as for example LA, TV: it then equals the line thickness d.**

## Types of Lines

**Objectives:** At the end of this lesson you shall be able to
- **define points and lines**
- **state the classification of lines**
- **state the different types of angles**
- **explain the method of measuring angles.**

A point represents a location in space, having no width or height. It is represented by drawing intersection of lines or a dot. (Fig 1)

Fig 1



POINT

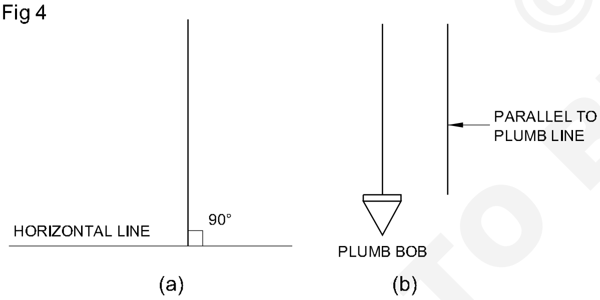
Line is the path of a point when it moves. It has no thickness and are of two types:

– Straight line

– Curved line

**Straight line :** It is the path of a point when it is moving in a particular direction. It has only length and no width. (Fig 2) Also a straight line is the shortest distance between two points. Straight line, depending on its orientation are classified as Horizontal, vertical and Inclined or Oblique line.

Fig 4




VERTICAL LINE

**Horizontal line (Fig 2) :** Horizontal lines are those which are parallel to a horizontal plane. Example of horizontal plane is the surface of a still water. (Fig 3)

Fig 5

INCLINED OR OBLIQUE LINE

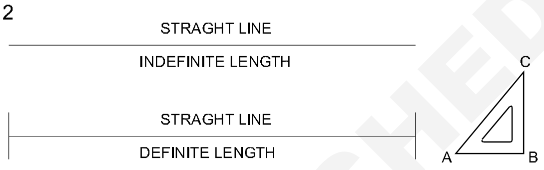
**Vertical line (Fig 4a ) :** Lines which are perpendicular to horizontal lines are called vertical lines. It can be treated as a line along the plumb line of the plumb bob or parallel to a plumb line. (Fig 4b)

Fig 6

CURVED LINES

**Inclined line or Oblique line :** A straight line which is neither horizontal nor vertical is called an inclined line. (Fig 5)

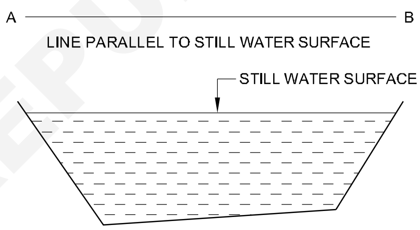
Fig 2




STRAIGHT LINE

**Curved line :** It is the path of a point which always changes its direction. Examples of curved lines are shown in(Fig 6)

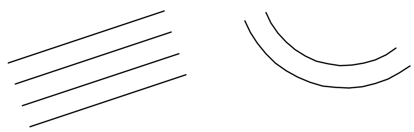
Fig 3




HORIZONTAL LINE

**Parallel lines :** They are the lines with same distance between them . They may be straight lines or curved lines. Parallel lines do not meet when extended. (Fig 7)

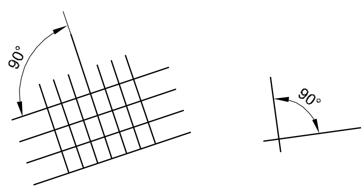
Fig 7



PARALLEL LINES

**Perpendicular lines :** When two lines meet at 90°, the two lines are said to be perpendicular to each other. One of this line is called as reference line. (Fig 8)

Fig 8




PERPENDICULAR LINES

# Method of Dimensioning

**Objectives:** At the end of this lesson you shall be able to
- **explain the types of dimensioning**
- **explain the elements of dimensions**
- **explain the methods of indicating dimensions**
- **explain the arrangement of dimensioning**

**Importance of dimensioning:** Any Component or product manufactured should be confirm to its specification. In fact, without specification of product, there cannot be production. In engineering industry, all manufacturing is controlled by the technical specification of product or components.

Technical specification provides complete information on the shape, size, tolerance, finish, material and other technical aspects such as heat treatment, surface coating and other relevant information required to manufacture a component. In most cases technical specifications of components is given in the form of a technical drawing while shape is described by various types of views i.e Orthographic, pictorial and perspective projection and size is given by dimensions.

**Definitions related to dimensioning**

**Dimension:** It is a numerical value expressed appropriate unit of measurement and indicated graphically on technical drawings with lines, symbols and notes.

**Elements of dimensioning**

– Extension line - a

– Dimension line - b

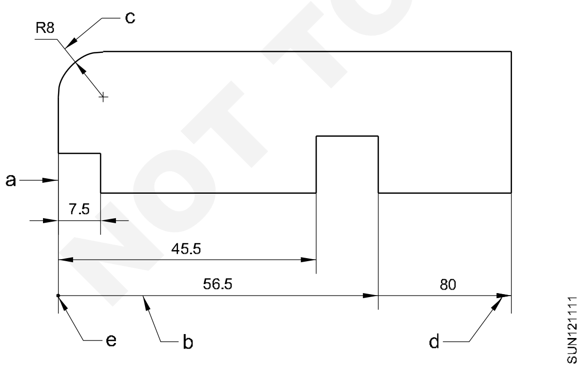
– Leader line - c

– Termination of dimension line

– The original (starting point) indication and the dimension (a).

**Extension line:** It is a thin line projecting from the feature and extending beyond the dimension line. (Fig 1)

Fig 1




It is normally perpendicular to the feature being dimensioned, but may be drawn obliquely as shown for dimensioning tapers, parallel to each other. (Fig 2)

When construction line are required to be shown for practical purposes of the intersecting projection lines extend beyond their point of intersection. (Fig 3)

Fig 2

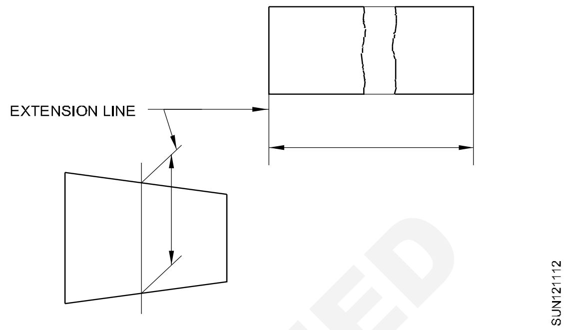
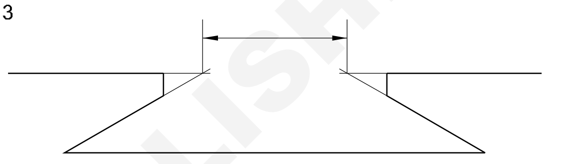
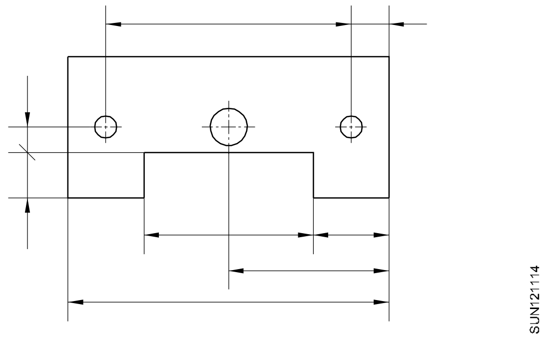



Fig 3



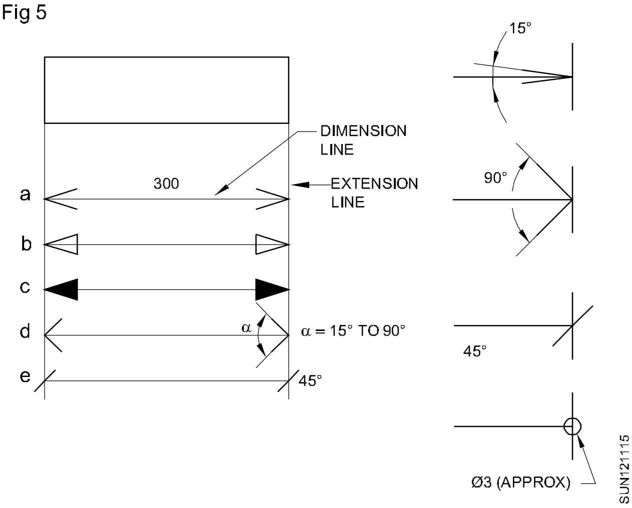

Extension lines (Projection lines) should not cross the dimension lines, but where not possible the lines should not break. (Fig 4)

Fig 4




**Dimension line:** These are thin continuous lines, terminated at ends by arrow heads, dots or oblique lines touching the extension line. (Fig 5)

Fig 5



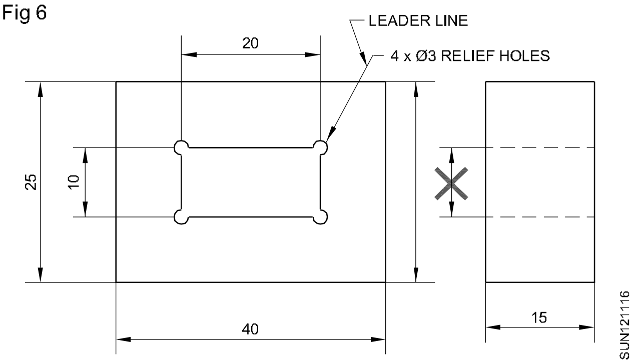
Dimension line may cut or cross another dimension line where there is no other way.

Dimension to the hidden lines be avoided. (Fig 6)

Arrow heads may be placed outside where space is insufficient.

**Leader line:** It is a thin continuous line. It connects a note or dimension with the features to which it applies. (Fig 6)

Fig 6




**Termination and Origin indication:** The size of the terminations (arrow heads/oblique strokes) shall be proportional to the size of the drawing. Only one style of arrow head shall be used on a single drawing. However, where the space is too small for the arrow heads, it may be substituted by a dot or by an oblique line. Arrow heads are drawn as short lines forming barbs at any convenient included angle between 15° and 90°. They may be open, closed or closed and filled in. Oblique strokes drawn as short line inclined at 45°. (Fig 5)

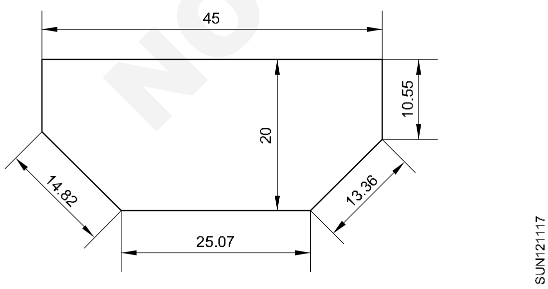
**Indicating dimensional values on drawings:** All dimensional values shall be shown on drawings in characters of sufficient size to ensure complete legibility on the original drawings as well as on reproductions made from micro-filming.

They shall be placed in such a way that they are not crossed or separated by any other line on the drawing.

**Methods of indicating values:** There are two methods used for indicating the values. Only one method should be used on any one drawing.

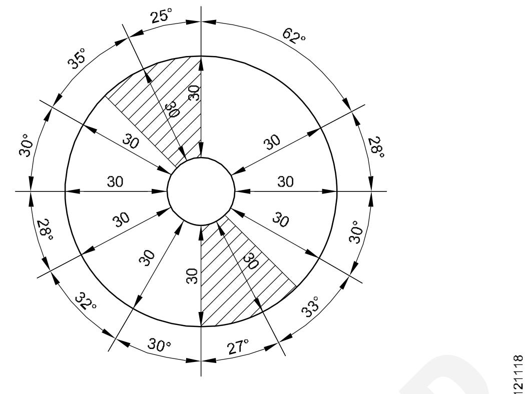
**Method 1**

Fig 7




Dimensional values shall be placed parallel to their dimension lines and preferably near the middle, above and clear of the dimension line. However, values shall be indicated so that they can be read from bottom or from the right-hand side of the drawing. Dimension lines are not broken. Dimensioning of angles also given in the same way. (Figs 7 & 8) This method is known as **aligned system** of dimensioning.

Fig 8




ANGULAR DIMENSIONING

**Method 2**

Dimensional values shall be indicated so that they can be read from the bottom of the drawing sheet. Non-horizontal dimension lines are interrupted, preferably near the middle so that the value can be inserted. (Fig 9 & 10). This method is termed as **unidirectional system** of dimensioning.

Fig 9

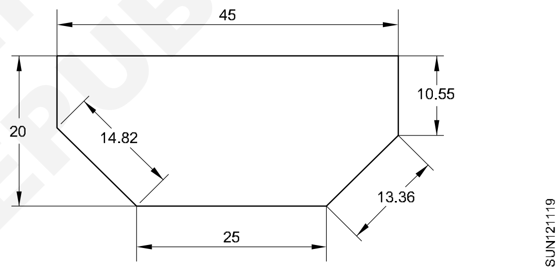
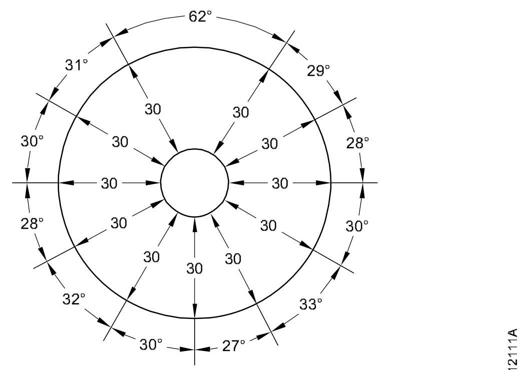



Fig 10




ANGULAR DIMENSIONING - METHOD 2

**Arrangement and indication of dimensions**

The arrangement of dimensioning on a drawing shall indicate clearly the design purpose.

The arrangements of dimensioning are:

– Chain dimensioning

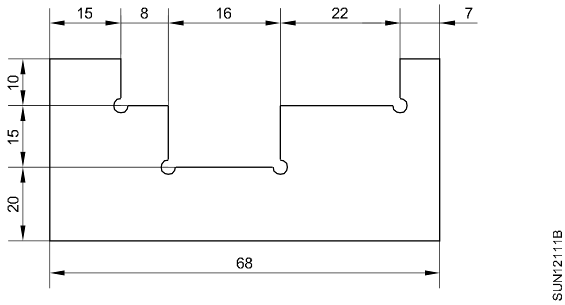
– Dimensioning from a common feature

– Dimensioning by co-ordinates

– Combined dimensioning.

**Chain dimensioning:** It is used where the possible accumulation of tolerances does not infringe (effect) on the functional requirement of the component. (Fig 11)

Fig 11

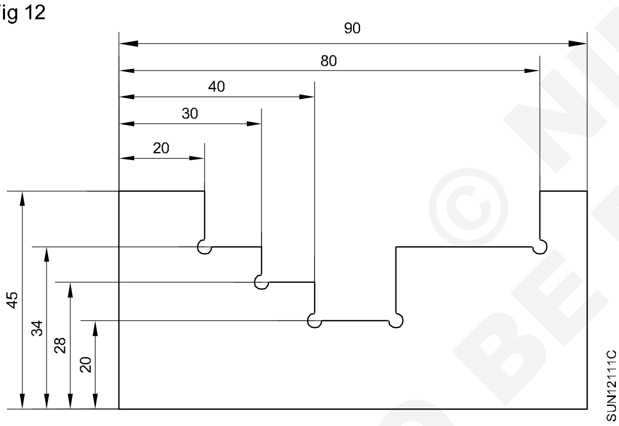



Dimensioning from a common feature is used where a number of dimensions of the same direction relate to a common origin.

Dimensioning from a common feature may be executed as parallel dimensioning or as superimposed running dimensioning.

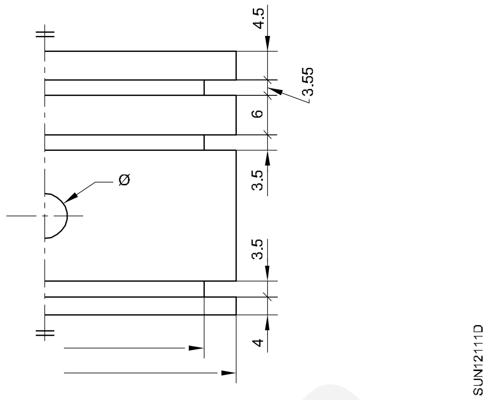
**Parallel dimensioning:** Dimensions of features are taken from one datum/common origin and are shown parallel to other and placed, so that the dimensional values can easily be added in Fig 12.

Fig 12



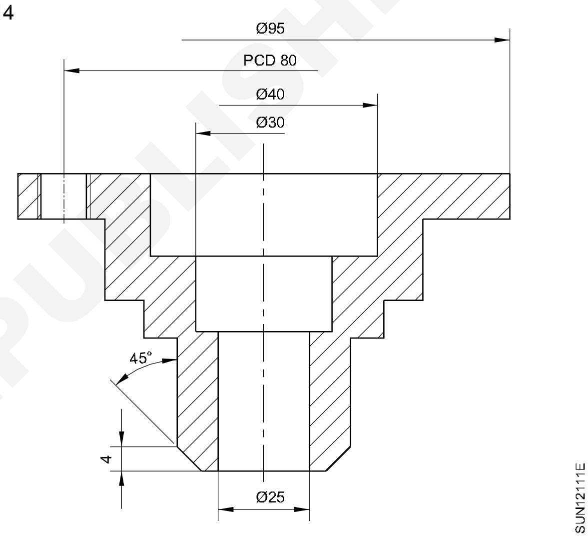

**Dimensioning smaller width:** Arrow heads are replaced by oblique lines. (Fig 13)

Fig 13




To avoid placing dimensions too far away from feature, dimension lines are drawn closer and not fully. (Fig 14)

Fig 14



## Construction of plain Geometrical figures

**Objectives:** At the end of this lesson you shall be able to
- **state the different types of angle**
- **state the method of measuring angle.**

**Angles :** Angle is the inclination between two straight lines meeting at a point or meet when extended. AB and BC are two straight lines meeting at B. The inclination between them is called an angle. The angle is expressed in degrees or radians.

**Concept of degree :** When the circumference of a circle is divided into 360 equal parts and radial lines are drawn through these points, the inclination between the two adjacent radial lines is defined as one degree. Thus a circle is said to contain 360°.(Fig 1)

**Acute angle :** IF an angle which is less than 90° is called an acute angle. (Fig 2)

**Right angle :** Angle between a reference line and a perpendicular line is called right angle. (Fig 3)

Fig 1

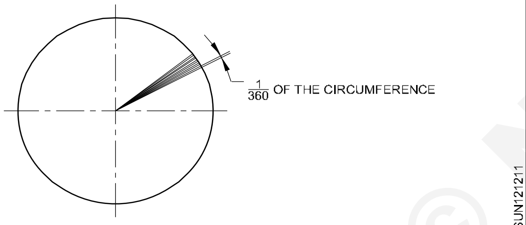
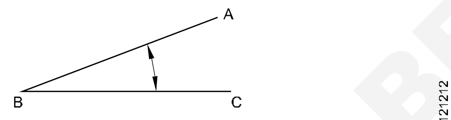
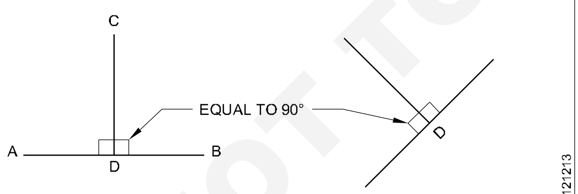



Fig 2




ACUTE ANGLE

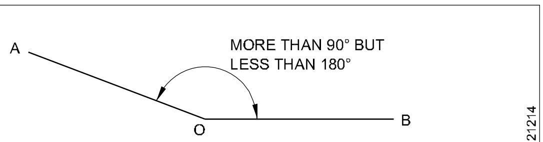
Fig 3




RIGHT ANGLE

**Obtuse angle :** This refer to an angle between 90° and 180°. (Fig 4)

Fig 4

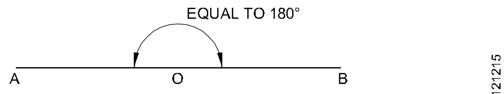



OBTUSE ANGLE

**Straight angle :** This refers to angle of 180°. This also called as the angle of a straight line. (Fig 5)

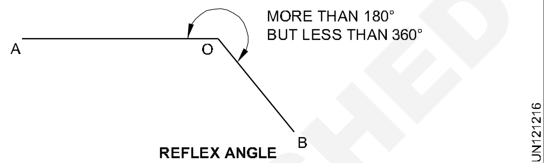
**Reflex angle :** It is the angle which is more than 180° (Fig 6)

Fig 5




STRAIGHT ANGLE

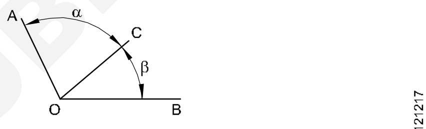
Fig 6




REFLEX ANGLE

**Adjacent angles :** These are the angles lying on side of a line. (Fig 7)

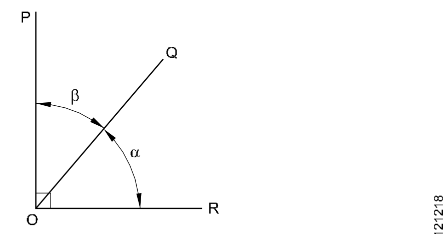
Fig 7




ADJACENT ANGLES

**Complementary angles :** When the sum of the two angles is equal to 90°, angle POQ + angle QOP+ angle POQ and angle QOR are complementary angles to each other.(Fig 8)

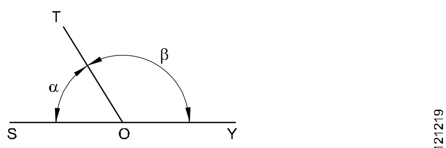
Fig 8




COMPLEMENTARY ANGLES

**Supplementary angle :** When the sum of the two adjacent angles is equal to 180°,example angle SOT + angle TOY = 180°,angle SOT and angle TOY are supplementary angles to each other. (Fig 9)

Fig 9



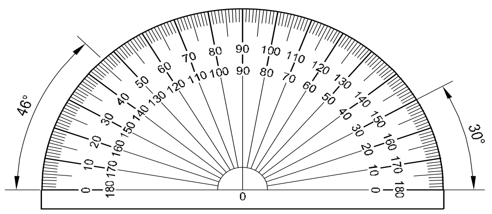

SUPPLEMENTARY ANGLES

**Protractor :** Protractor is an instrument for measuring angles. It is semi - circular or circular in shapes and is made of flat celluloid sheet. The details of graduation in a semi-circular protractor is shown in figure 10.

The angles can be set or measured from both sides, aligning the reference line and point '0' with the corner point of the angle.

Figure 10 shows how to read or set the angle protractor can also be used to divide a circle or drawing sectors.

Fig 10




## Triangles and their types

**Objectives:** At the end of this lesson you shall be able to
- **define triangles**
- **name the different types of triangles and state their properties.**

Triangle is a closed plane figure having three sides and three angles. The sum of the three angles always equals to 180°.

To define a triangle, we need to have a minimum of three measurements as follows.

– 3 sides or

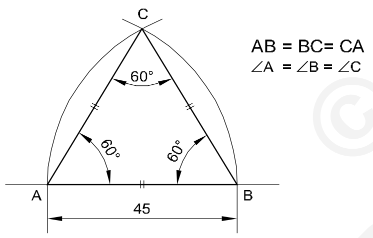
– 2 sides and one angle or

– 2 angles and one side

**Types of triangles**

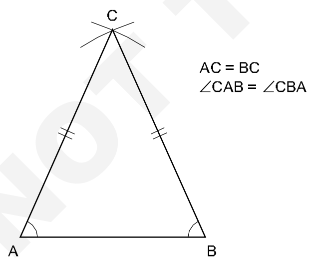
– Equilateral triangle is a triangle having all the three sides equal. Also all the three angles are equal (60°) (Fig 1)

Fig 1



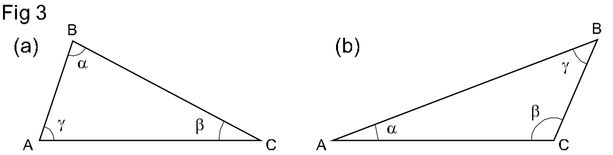

– **Isosceles triangle** has two of its sides equal. The angles opposite to the two equal sides are also equal. (Fig 2)

Fig 2



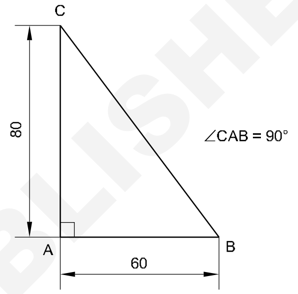

– **Scalene triangle** has all the three sides unequal in lengths. All the three angles are also unequal. (Fig 3)

Fig 3



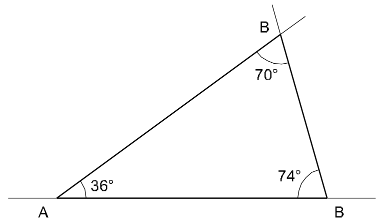

– **Right angled triangle** is one in which one of the angles is equal to 90° (Right angle). The side opposite to right angle is called hypotenuse. (Fig 4)

Fig 4




– **Acute angled triangle** is one in which all the three angles are less than 90°. (Fig 5)

Fig 5

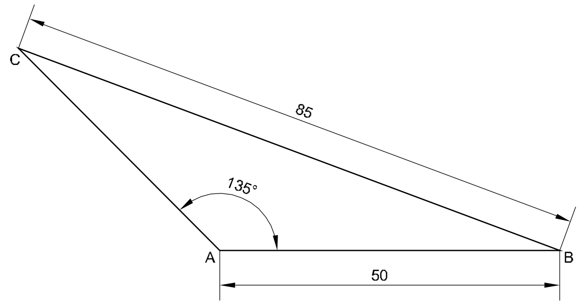



– Obtuse angled triangle has one of the angles more than 90°. (Fig 6)

**The sum of the three angles in any triangle is equal to 180°.**

**The sum of any two sides is more than the third side.**

Fig 6



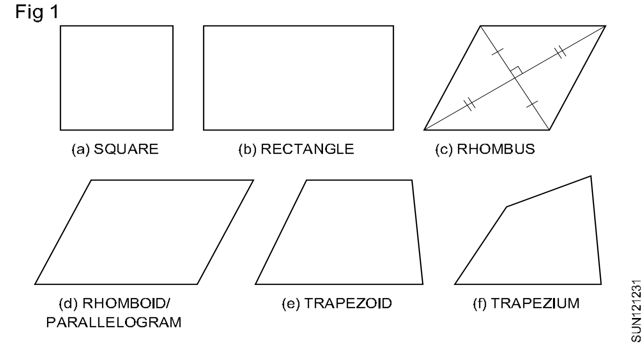
# Quadrilaterals and their properties

**Objectives:** At the end of this lesson you shall be able to
- **define a quadrilateral**
- **name the quadrilaterals**
- **state the properties of quadrilateral.**

Quadrilateral is a plane figure bounded by four side and four angles. Sum of the four angles in a quadrilateral is of interior angles is equal to 360°. The side joining opposite corners is called diagonal. To construct a quadrilateral of four sides, four angles and two diagonals minimum of five dimensions are required of which two must be sides. Quadrilaterals are also referred as Trapezoid.

**Types of quadrilaterals. (Fig 1)**

Fig 1




- Square
- Rectangle
- Rhombus
- Rhomboid/ Parallelogram
- Trapezoid
- Trapezium

**Square :** In a square all the four sides are equal and its four angles are right angles. The two diagonals are equal and perpendicular to each other.

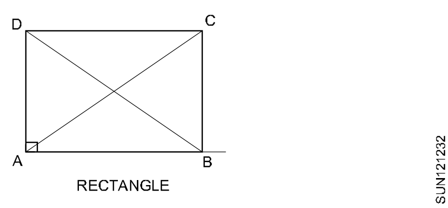
To construct square we need to know (a) length of the side or (b) length of the diagonal.

**Rectangle (Fig 2) :** In a rectangle, opposite side are equal and parallel and all four angles are right angles.

To construct a rectangle we need to know the length (a) two adjacent sides or (b) diagonal and one side.

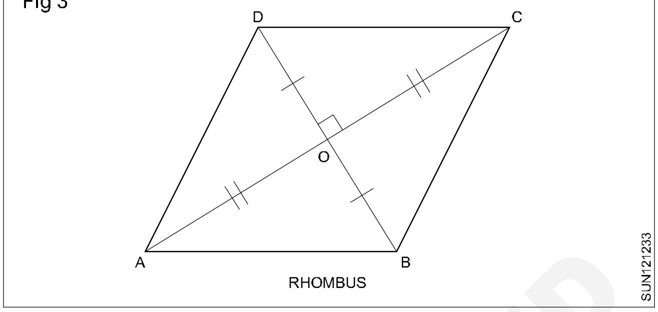
Fig 2 shows a rectangle ABCD. Sides AB = DC and BC = AD. Diagonals AC and BD are equal, bisect but not at right angles.

Fig 2




**Rhombus (Fig 3) :** In rhombus all the four sides are equal, but only the opposite angles are equal. ABCD is the rhombus where AB = BC = CD =AD.

Fig 3




Angle ABC = Angle ADC and BAD = Angle BCD.

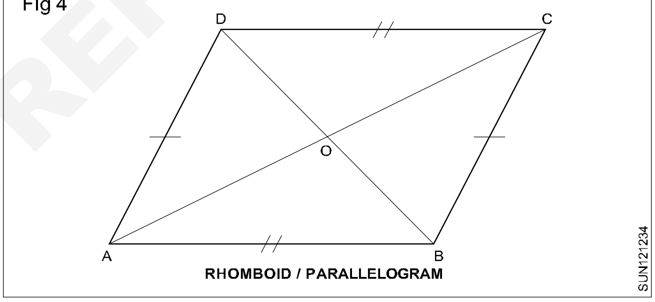
Diagonals AC and BD are not equal but bisecting at right angles.

AO = OC and BO = OD.

To construct a rhombus we need to know (a) two diagonals (b) one diagonal and an opposite angle or (c) one side and its adjacent angle.

**Rhomboid/ Parallelogram (Fig 4) :** In a parallelogram opposite sides are equal and parallel. Opposite angles are also equal. Diagonals are not equal but bisect each other.

Fig 4




Parallelogram is also known as rhomboid. To construct a parallelogram we need (a) two adjacent sides and angle between them or (b) one side, diagonal, and angle between them or (c) two adjacent sides and perpendicular distance between the opposite sides.

In the parallelogram ABCD, AB =DC; AD = BC

Angle DAB = angle DCB, angle ABC =angle ADC

Sides AB,CD and AD, BC are parallel.

Diagonals AC and BD are not equal but bisect at 0.

**Trapezoid (Fig 5) :** It is a quadrilateral, all the four sides are different and only two sides are parallel, all the four angles are different. The diagonals do not bisect at right angles.

ABCD is a trapezoid, sides AB and DC are parallel but not equal.

Diagonals AC and BD and AO = OC need not be equal.

Sides AD and BC may some times equal.

Fig 5

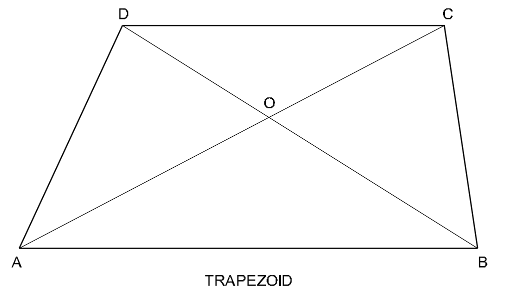
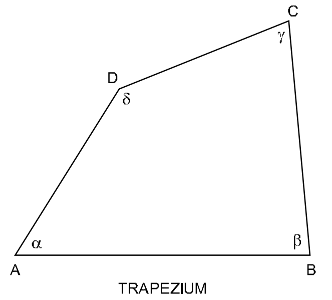



Fig 6




**Trapezium (Fig 6) :** It is a plane figure of 4 sides, and any two sides equals to each other.

## Polygon and their properties

**Objectives:** At the end of this lesson you shall be able to
- **define a polygon**
- **name the polygon in terms of the number of sides**
- **state the properties of polygon.**

Polygon is plane figure bounded by many (usually five or more ) straight lines. When all the sides are included angles are equal, it is called as a regular polygon.

**Names of polygons :** Polygons are named in terms of their number of sides are given below : (Fig 2)

| | Name | No. of sides |
|---|---|---|
| a | Pentagon | Five sides |
| b | Hexagon | Six sides |
| c | Heptagon | Seven sides |
| d | Octagon | Eight sides |
| e | Nonagon | Nine sides |
| f | Decagon | Ten sides |
| g | Undecagon | Eleven sides |
| h | Dodecagon | Twelve sides |

Fig 1

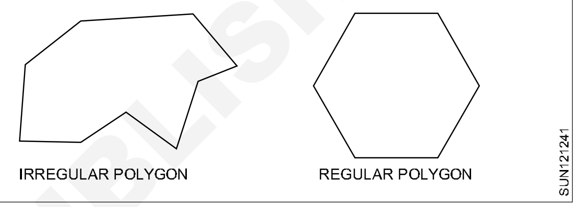
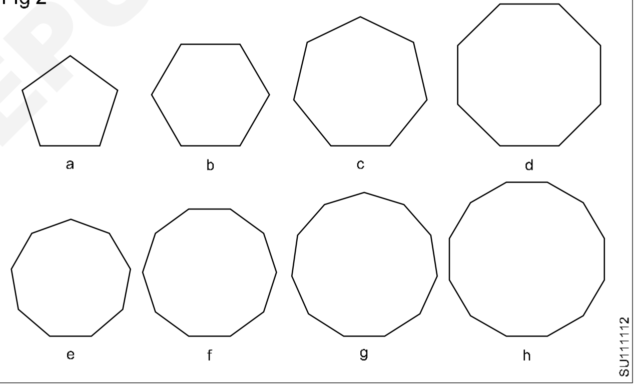



Fig 2






## Introduction about surveying

**Objectives:** At the end of this lesson you shall be able to
- **define surveying**
- **state the object of surveying**
- **state technical terms**
- **state the classification of surveying**
- **state the principles of surveying**
- **state the work of surveyor**
- **state the accuracy in chain survey**
- **state steel band.**

### Surveying

The art of determining the relative positions of the objects on the surface of the earth by taking measurements in both horizontal and vertical plane.

### Object of surveying

To obtain a map or a plan of the area to be surveyed.

Divisions:

The two main divisions of surveying are

1 Plane surveying

2 Geodetic surveying

The shape of the earth is elliptical in nature, but assumed to be a spheroid. The line joining of any two points on the earth surface is in an arc of a great circle. This is not a straight line measurement.

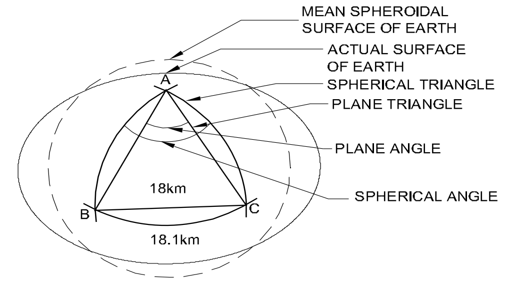
The survey in which the earth surface is assumed as plane and the curvature of earth is ignored is known as plane surveying.

The survey in which the curvature of earth is taken into account is known as Geodetic surveying. This is done by Great Trigonometrical Survey (GTS) of India.

| **Area less than 260 sq.km is treated as plane.** |
|---|

From the Fig 1

Fig 1




SHAPE OF EARTH

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As per plane surveying, the straight distance between B and C will be 18km

As per Geodetic surveying, the curved distance between B and C will be 18.1km

**Technical Terms**

The following technical terms are generally used in surveying

**Plan :** A plan is the graphical representation of the features on the earth surface or below the earth surface as projected on a horizontal plane. On a plan horizontal distances and directions are generally shown.

**Map:** The representation of the earth surface on a small scale is called a map. The map must show its geographical position of the earth.

**Topographical map:** The maps drawn in a large scale to identify the individual features and positions of various objects on the earth surface is called Topographical map.

**Triangulation:** The area to be surveyed is divided into a network of triangles and the length of its sides measured in the field and no angular measurements are required is known as Triangulation.

**Classification of surveying** (Fig 2)

**Marine/Hydrographical survey:** It is the survey, which deals the objects under the water.

**Aerial survey:** It is the survey in which to collect the details of cyclonic affected areas, flooded areas etc. is done by aeroplane in air.

**Astronomical survey:** It is the survey, which deals with the stars in the sky.

**Land survey**

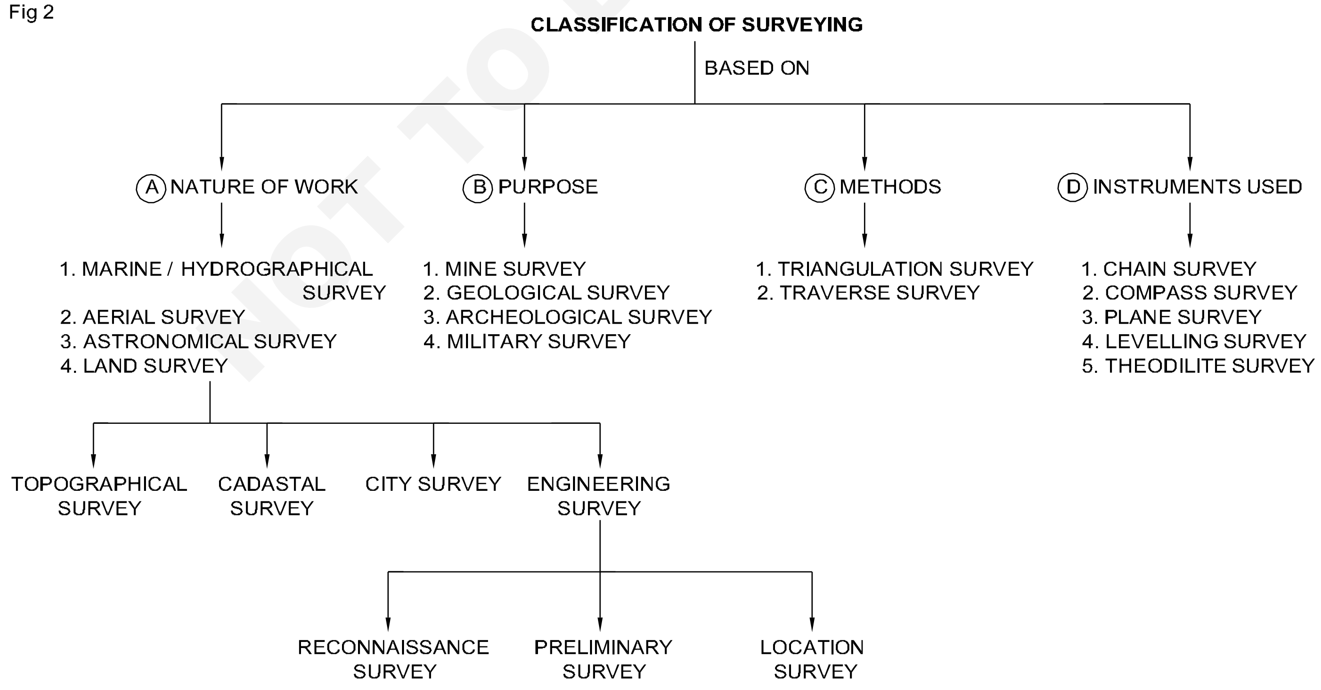
**Topographical survey:** It is the survey to determine the natural and artificial features on the earth.

**Cadastral survey:** It is the survey which deals the additional details of the boundaries of fields, houses etc.

**City survey:** It is the survey which deals the layout plots, roads, water supply and sewerage systems.

**Engineering survey:** It is the survey which deals with determining the quantities and collecting the data for the design of engineering projects such as roads, dams etc. reservoirs or work in connection with water supply sewerage etc.

Fig 2




CLASSIFICATION OF SURVEYING

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**Mine survey:** It is the survey which deals in exploring mineral wealth such as gold, coal, copper etc. with in the earth's crust.

**Geological survey:** It is to determine the different strata in the earth's crust.

**Archaeological survey:** It is the survey deals in unearthing the relics of the past.

**Military survey:** It is the survey for determining points of strategic importance both offensive and defensive.

**Principles of surveying**

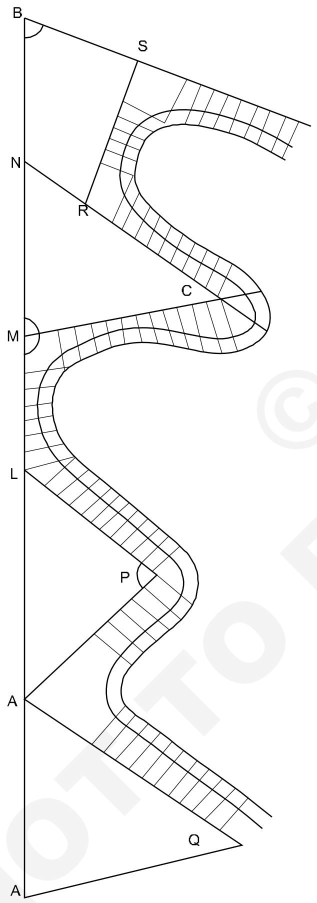
All survey works are based on the following two basic principles

1 To work from whole to the part.

2 To locate a point with respect to two reference points.

**1 To work from whole to the part (Fig 3)**

Fig 3




SURVEYING FROM WHOLE TO PART

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To survey an area, it is to establish the main control points with great precision.

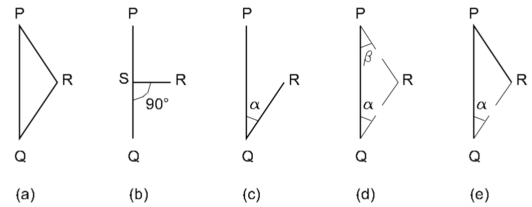
The main idea is to

– prevent the accumulation of errors

– control and localise minor errors.

**2 To locate a point with respect to two reference points (Fig 4)**

Fig 4




LOCATION OF A POINT

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To fix the position of new stations, atleast two independent positions are required.

The new stations are fixed from points already fixed by

– linear measurements

– angular measurements

– both linear and angular measurements

PQ is the reference line and R is the point to be located.

From Fig 4a, the distance PR and QR can be measured and the point R can be plotted by swinging two arcs with the same scale in which PQ has been plotted.

From Fig 4b, a perpendicular RS can be dropped on the line PQ and lengths PS and SR are measured. Then the point R can be plotted by using set square.

From Fig 4c, the distance QR and angle PQR can be measured as $\alpha$. Then the point R is plotted by means of a protractor or trigonometrically.

From Fig 4d, in this method angle RPQ ($\beta$) and RQP ($\alpha$) are measured by using an angle measuring instrument, then point R is plotted either by protractor or solution of triangle PQR.

From Fig 4e, in this method angle RQP ($\alpha$) and distance PR are measured. Then the point R can be plotted by using protractor and swinging an arc from P.

**Work of a surveyor**

- Taking measurements in the field.
- Recording field notes.
- Preparing survey maps, plans and sections.
- Calculating the areas and volumes.
- Designing the various structures.
- Handling of survey instruments.
- Care and maintenance of survey instruments.

## Types of scales

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of scales**
- **explain representative fraction (RF)**
- **list the types of scales**
- **explain plain, comparative scales, diagonal scale.**

**Introduction**

Engineering drawings are rarely drawn to the same size of the object. In the preparation of drawings of a building, It is not practically possible to make the drawing to the same size of the building. Here, the drawing is prepared to the reduced size and it is called reduced scale drawing.

Thus, the drawings prepared proportionately to the smaller or larger size than the actual size, are said to be made to a scale. Scale of a drawing may be defined as the ratio of linear dimension of the same object. Scales used in engineering practice are available in sets of 8 or 12 scales. same times the required scale will not be available. Then, it is necessary to construct a new scale.

Therefore, a convenient scale is always chosen to prepare the drawings of big as well as small object in proportionately smaller or larger sizes. So the scales are used to prepare a drawing at a full size, reduced size or enlarged size.

**Representative fraction**

Representative fraction may be defined as the ratio of the distance between any two points of the object on a drawing to the actual distance between the same points of the object and it is abbreviated as R.F.

Mathematically,

R.F = distance on drawing/Distance on object

**Reducing scale**

An actual length of 5m of a room is represented by 25mm length on drawing. Then,

R.F = distance on drawing/Distance on object

= 25mm/5m

= 25/5 x 100 x 10

= 1/200

Scale of drawing is 1: 200

**Enlarging scale**

An actual length of a typical terminal strip of 10mm is represented by 50mm length on drawing. Then,

R.F. = Distance on drawings/ Distance on object

= 50mm/10mm

= 5/1

Scale of drawing is 5:1

Full scale

An actual length of an electrical switch board of length 30mm, is represented by a 30 mm length on drawing. Then,

R.F.= Distance on drawing/ Distance on object

= 30mm/ 30mm

= 1/1

Scale of drawing is 1:1

**Scales used to scale drawn large parts in engineering drawings and architecture:**

1:40 1:100

1:50 1:150

1:65 1:200

1:80

**Typical scale for site plan-unit in m**

1:500,1:5000

1:1000,1:1000

1:2000,1:20000

**Scale need in surveys**

1:50000 1:200000

1:100000 1:50000

**Scales used in maps Units in m.**

1:1000000

**Recommended scales**

Scales recommended for use on engineering drawings are give below

| Full scale | Reduced scale | Enlarged scale |
|---|---|---|
| 1:1 | 1:2 | 10:1 |
| | 1:2:5 | 5:1 |
| | 1:5 | 2:1 |
| | 1:10 | |
| | 1:20 | |
| | 1:50 | |
| | 1:100 | |
| | 1:200 | |

Civil Engineers and Architect generally use reduced scales while Mechanical and Electrical Engineers use both reduced and enlarged scales according to the need of the problems.

**Metric Measurements**

Table 11:1

| | |
|---|---|
| 10 millimeters (mm) | 1 centimeter (cm) |
| 10 centimeter (cm) | 1 decimeter (dm) |
| 10 decimeters (dm) | 1 meter (m) |
| 10 meter (m) | 1 decameter (dam) |
| 10 decameter (dam) | 1 hectometer (hm) |
| 10 hectometer (hm) | 1 Kilometer (km) |

**Types of scales**

– Plain scale
– Diagonal scale
– Vernier scale
– Comparative scale
– Scale of chords (for angles)

To construct a scale the following information is essential

**RF of the scale**

– Units which it must represent example mm, cm, m, ft inches etc.
– the maximum length it must show
– Minimum length of the scale = RF x the maximum length required to be measured.

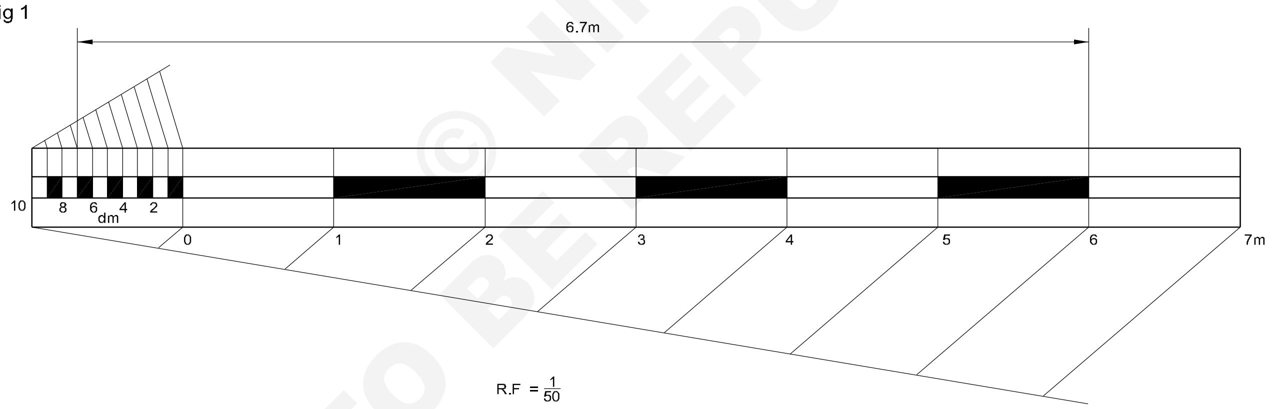
**Plain scales (Fig 1):** Scales are drawn in the form of rectangle, of length 15cm (can be upto 30cm) and width 5mm. It is divided into suitable number of parts. The first part of the line is sub - divided into smaller units as required.

Every scale should have the following salient features:

– The zero of the scale is placed at the end of the first division from left side.
– Form zero, mark further divisions are numbered towards right.
– Sub - divisions are marked in the first division from zero to left side.
– Names of units of main divisions and sub divisions should be stated/printed below or at the end of the divisions.
– Indicate the 'RF' of the scale.

A distance of 6.7 m will be shown as in the Fig 1.

Fig 1

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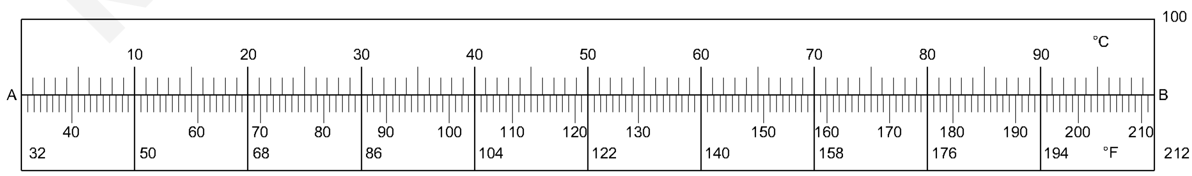
**Comparative scales (Fig 2) :** Comparative scale is a graphical device to compare or convert one variable into another. It compares two similar units in different systems. For example meters, yards, kilometers, miles, temperature in degrees, centigrade and Fahrenheit etc.

Fig 2 shows the construction of a comparative scale to convert Fahrenheit (F) into Celsius (Centigrade - C) and Celsius into Fahrenheit.

Fig 2




COMPARATIVE SCALE

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**Diagonal scale :** Plain scales cannot be used for taking smaller measurement. The distance between the consecutive divisions on a plain scale , at best can only be 0.5mm. In other words, the smallest measurement that can be taken. Using a plain scale of RF 1:1 is 0.5mm. If the RF of a plain scale is 1:5, the smallest measurement such a scale can take is 2.5 mm (0.5 mmx5).

To overcome this limitation two different types of scales are employed. They are

– Diagonal scale

– Vernier scale

**Principle of diagonal scale :** Diagonal scale relies on a " diagonal" to divide a small distance into further equal parts.

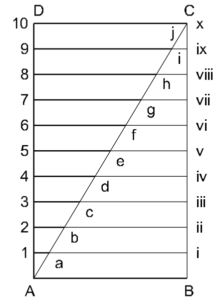
Principle of diagonal scale is based on the principle of similar triangles.

**Example :** A small distance AB is to be divided into 10 equal parts using diagonal scale.

AB is the line to be divided into 10 equal parts.

Diagonal scale is shown in the Figure 3.

Fig 3

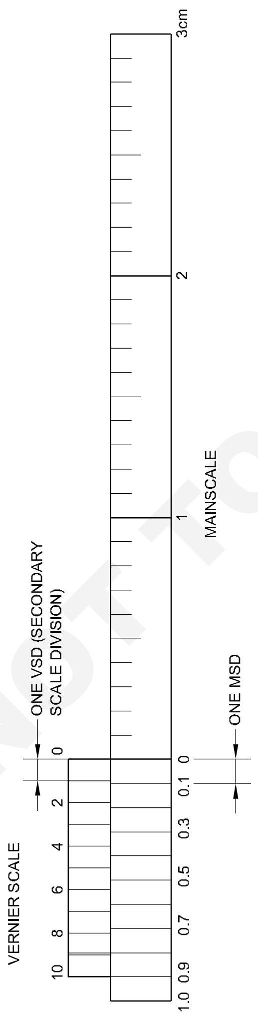



## Vernier scale

**Objectives:** At the end of this lesson you shall be able to
- **Explain vernier scale**

**Vernier scale ( Fig 1) :** As stated earlier vernier scales are yet another means of dividing a small dimension into a number of equal parts so as to facilitate taking smaller measurements than is possible by plain scales.

Fig 1




VERNIER SCALE LENGTH = 9 DIVISIONS OF MSD
LEAST COUNT = ONE MSD – ONE VSD

Vernier scale consists of two parts - secondary scale or vernier scale (VS) and primary scale or main scale (MS)

The smallest measurement that can be taken on the main scale is called main scale division (MSD)

Least count of the vernier scale is the fraction of the main scale division upto which the measurement can be taken.

To Arrive at the fraction of MSD, imaginarily MSD is divided into a number of equal parts (n)

$$n = \frac{MSD}{\text{Fractional part of msd}}$$

The length of the secondary scale depend upon the MSD and number of divisions (n) we have decided to make.

If one MSD is to be divided into 'n' parts, the length of the secondary scale (vernier) will be equal to the length of either (n-1) or (n + 1) parts of MSD.

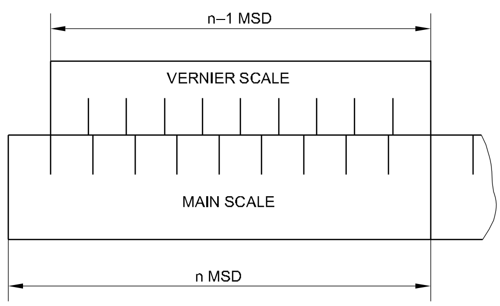
Length of the secondary scale is divided into 'n' equal parts.

There by one secondary scale (vernier) division is equal

to $\frac{(n-1)MSD}{N}$ or $\frac{(n+1)MSD}{N}$ as the case may be.(Fig 2,3)

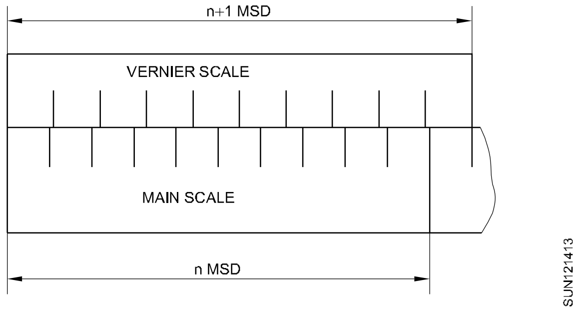
Direct or forward reading : Vernier scale is the scale constructed having -1 number of MSD as the secondary scale (vernier) length. (Fig 6)

Fig 2



Retrograde or backward reading : Vernier scale is the scale having n + 1 numbers of MSD as the secondary sacle (vernier) length.

Fig 3




According to direct reading vernier

| | | |
|---|---|---|
| 1Main scale division | -1 Secondary scale division (vernier) | $= \frac{1}{n}$MSD |
| 1cm | $- \frac{9}{10}$ | $= \frac{1}{10}$ cm |

According to backward reading vernier

| | | |
|---|---|---|
| 1 Secondary division (vernier) | - 1 Main scale division | $= \frac{1}{n}$MSD |
| 1.1 cm | - 1.0 cm | $= \frac{1}{10}$ cm |

MSD is the least count of the vernier scale

## Conventions (Signs) and symbols used in surveying drawing

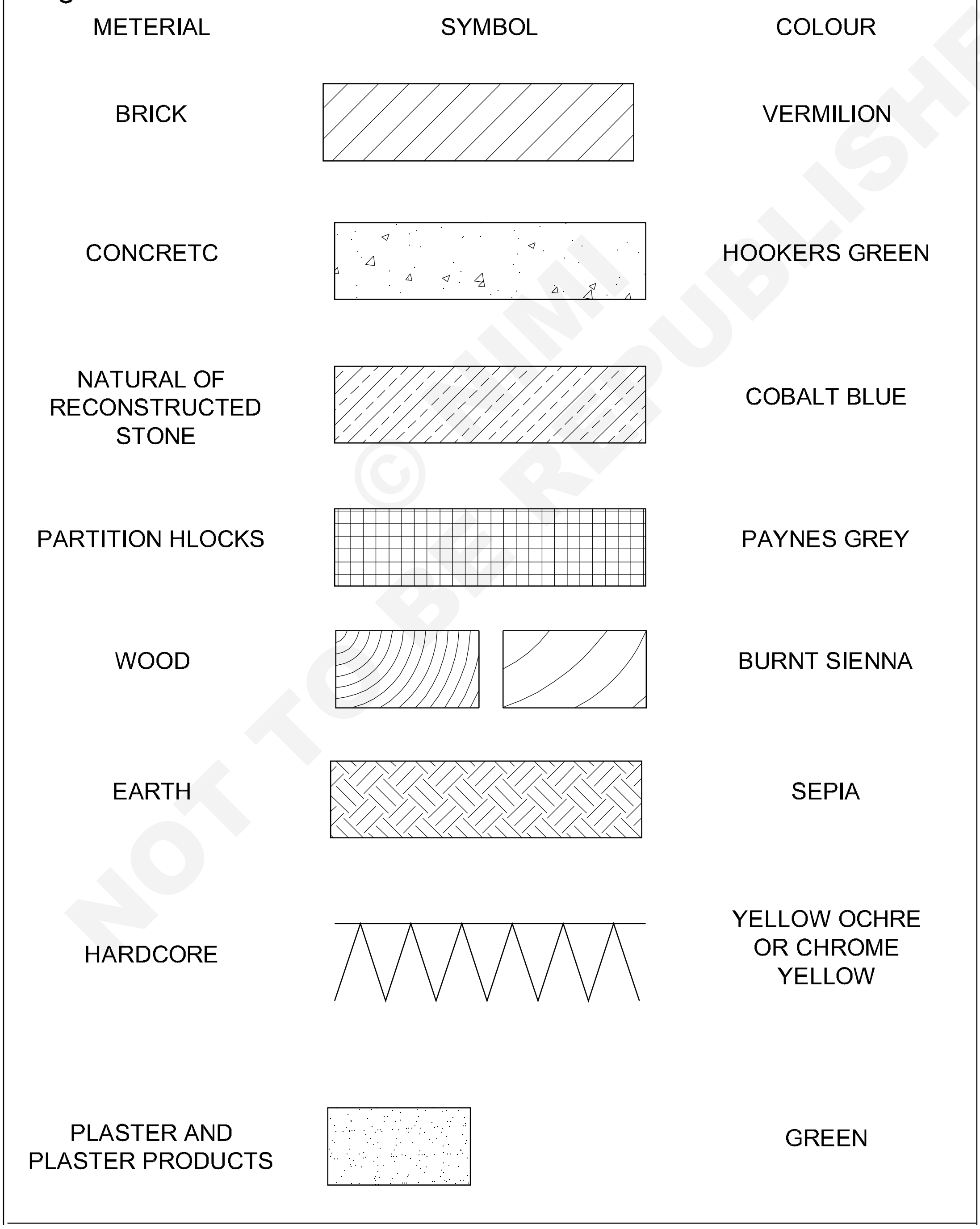
**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of conventions and symbols used in surveying**
- **uses of conventional signs & symbols.**

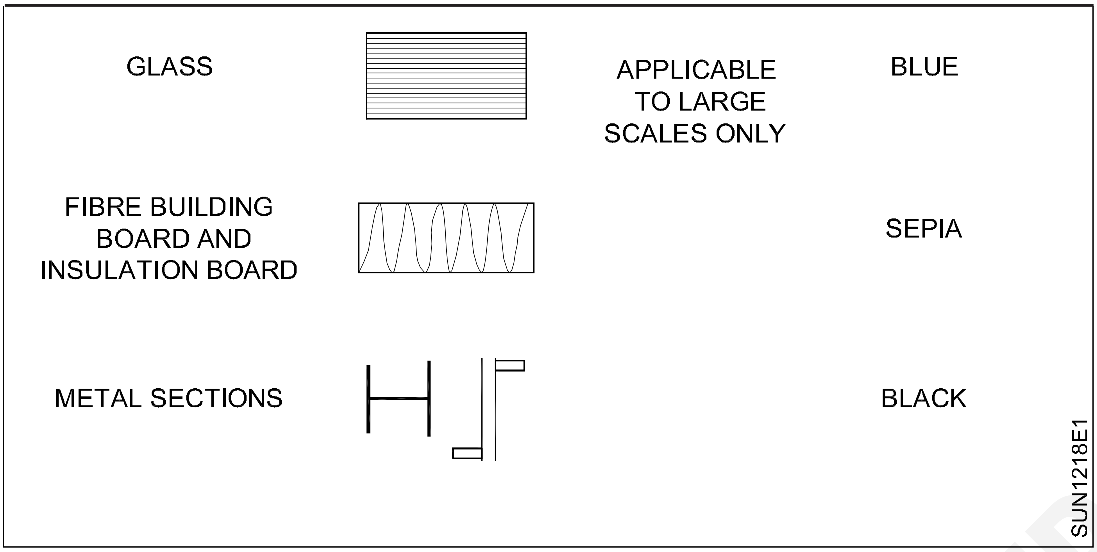
### Symbols for various materials

Hatching pattern can be used to indicate the material of the pant/object to differentiate difference material in sectional views.

BIS (Bureau of Indian standards) laid out standards (IS: 11663) on conventional representations of the materials and the some one given below. (Fig 1)

Fig 1






Conventional symbols and signs used in surveying.

In a map or drawings or plans or in land surveying, the objects or an area is depicted by symbols not by names.

The below mentioned maps and drawings.

It is difficult to draw the actual profile of the objects and include them in every drawings. So a convention is done that is widely accepted worldwide is used for the representations. It is defined by simple lines, curves and colors one used to describe the abstract of the various objects. (Fig 2)

Conventional representation is adopted in the cases where complete of the part would involve unnecessary drawing time or space.

**Methods of projection:** Two methods of projection are in practice.

– Symbol for 1st angle projection. (Fig 3)

– Symbol for 3rd angle projection. (Fig 4)

Fig 3

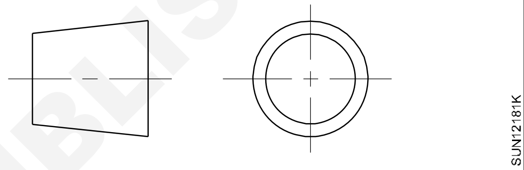
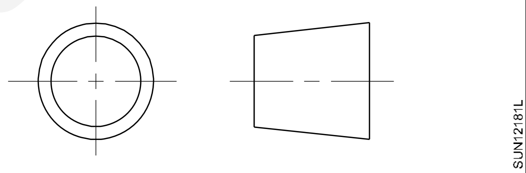



Fig 4



| SL. NO. | OBJECT | CONVENTIONAL SIGN | COLOUR |
|---|---|---|---|
| 1. | CHAIN LINE | | CRIMSON LAKE |
| 2. | TRIANGULATION STATION | A | CRIMSON LAKE |
| 3. | TRAVERSE STATION | A | CRIMSON LAKE |
| 4. | BENCH MARK | OR B.M. 10.000 | CRIMSON LAKE |
| 5. | BUILDING (PUCCA) | | CRIMSON LAKE |
| 6. | BUILDING (KATCHA) | | BURNT UMBER |
| 7. | TEMPLE, CHURCH, MOSQUE | | CRIMSON LAKE |
| 8. | WALL & GATE | | CRIMSON LAKE |
| 9. | BOUNDARY WITH PILLARS | | CRIMSON LAKE |
| 10. | DAM | | CRIMSON LAKE |
| 11. | CITY OR TOWN | | BUILDINGS - CRIMSON LAKE ROADS - BURNT SIENNA |
| 12. | CEMETRY | | BLACK |
| 13. | RIVER | | PRUSSIAN BLUE |
| 14. | CANAL OR STREAM (PERENNIAL) | | PRUSSIAN BLUE |
| 15. | CANAL OR STREAM (NON-PERENNIAL) | | EDGES - BLACK |
| 16. | CANAL WITH LOCK | | PRUSSIAN BLUE |
| 17. | LAKE OR POND | | PRUSSIAN BLUE |
| 18. | WELL | | PRUSSIAN BLUE |
| 19. | DRAIN (KATCHA) | | PRUSSIAN BLUE |
| 20. | DRAIN (PUCCA) | | DRAIN - PRUSSIAN BLUE DIRECTION - CRIMSON LAKE |
| 21. | WIRE FENCING | | BLACK |
| 22. | WOOD FENCING | | YELLOW |
| 23. | PIPE RAILING | | BLACK |
| 24. | BOUNDARIES | | BLACK |
| 25. | HEDGE | | HEDGE GREEN |
| 26. | TREE | OR | HEDGE GREEN |
| 27. | JUNGLE | | HEDGE GREEN |
| 28. | ORCHARD | | HEDGE GREEN |
| 29. | CULTIVATED LAND | | DRAINS - PRUSSIAN BLUE CULTIVATION - GREEN |
| 30. | BARREN LAND | | BLACK |
| 31. | ROUGH PASTURE | | BLACK |
| 32. | MARSH OR SWAMP | | BLACK |
| 33. | SAND HILL | | BLACK |
| 34. | EMBANKMENT | | BLACK |
| 35. | CUTTING | | BLACK |
| 36. | FOOTH-PATH | | BURNT UMBER |
| 37. | VILLAGE CART-TRACK | | BURNT UMBER |
| 38. | UNMETALLED ROAD | | BURNT SIENNA |
| 39. | METALLED ROAD | | BURNT SIENNA |
| 40. | RAILWAY SINGLE LINE | OR | BLACK |
| 41. | RAILWAY DOUBLE LINE | | BLACK |
| 42. | ROAD BRIDGE | | BURNT SIENNA |
| 43. | RAILWAY BRIDGE | | BLACK |
| 44. | ROAD & RAIL LEVEL CROSSING | | RAIL - BLACK ROAD - BURNT SIENNA |
| 45. | TELEPHONE OR TELEGRAPH LINE | | BLACK |
| 46. | ELECTRIC LINE | | BLACK |
| 47. | NORTH DIRECTION | N | BLACK |
| 48. | DEMARCATED PROPERTY BOUNDARY | | |
| 49. | UNDEMARCATED PROPERTY BOUNDARY | | |
| 50. | CULVERT | | |
| 51. | ELECTRIC LINE | | |

SUN1218E2

# Measurement of distance by a chain and chaining

**Objectives:** At the end of this lesson you shall be able to
- **state the methods of determining distance**
- **state chaining and chaining a line**
- **state unfolding the chain**
- **describe the reading the chain**
- **state folding the chain**
- **calculate the errors in chaining.**

### Measurement of distance

There are two main methods of determining distance.

Direct method and Computative

**Direct method:** The distances are actually measured on the ground by means of a chain, tape or other instruments.

**Computative:** The distances are obtained by calculation as in tachometry or triangulation.

### Pacing

For rough and speedy work, distances are measured by pacing (i.e) by counting the number of walking steps of a man. The walking step of a man is considered as 80cm (average). This method is generally employed in the reconnaissance survey of any project.

Measured distance: Length of pace x Number of paces

### Passometer

It is a small pocket instrument resembling a watch in size and appearance used for counting the number of steps automatically by some mechanical device. The mechanism requires that it should be carried vertically like in waist coat pocket and the mechanism being operated by the motion of the body.

### Pedometer

It is also a similar instrument and is used for the same purpose, but it registers the distance traversed by the person carrying it.

### Speedometer

It is an automobiles instrument which is also used to measure the distances approximately.

### Perambulator

It is a wheel fitted with fork and handle. It is wheeled along the line, the length of which is desires and the distance is registered automatically on the dials.

### Chaining

**Definition:** The operation of measuring a distance between two points with the help of a chain, or chain with tape is called chaining.

For ordinary works chain is used for measuring the distances but where great accuracy is required, a steel tape is invariably used.

### Identification and construction of metric chain

- It is a measuring instrument consists of
- i) 100 links in 20m chain and (Fig 1)
- ii) 150 links in 30m chain. (Fig 2)
- It is composed of 4mm dia. mild steel wire.
- Each link having 20cm in length and connected together by means of three circular rings to give flexibility to the chain. (Fig 3)
- Length of link is the distance between the centres of two consecutive middle rings. (Fig 4)
- Brass handles are provided at the ends of the chain with swivel joints so that the chain can be turned round without twisting.
- The outside of the handle is the zero point or the end point of the chain.
- The length of the chain is the distance from outside of one handle to the outside of the other handle.
- End links also includes the length of the handle.
- Chain has brass rings at every one metre length.
- Brass tallies are provided at every 5m length as shown in Fig 5

### Chaining a line

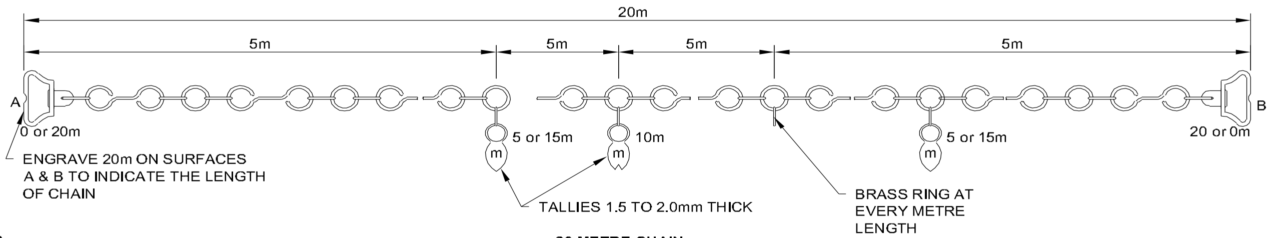
For a chaining operation two chain men are required.

– The chainman at the forward end of the chain is called leader and other chain man at the rear end is called a follower.

– The duties of leader and follower are tabulated under.

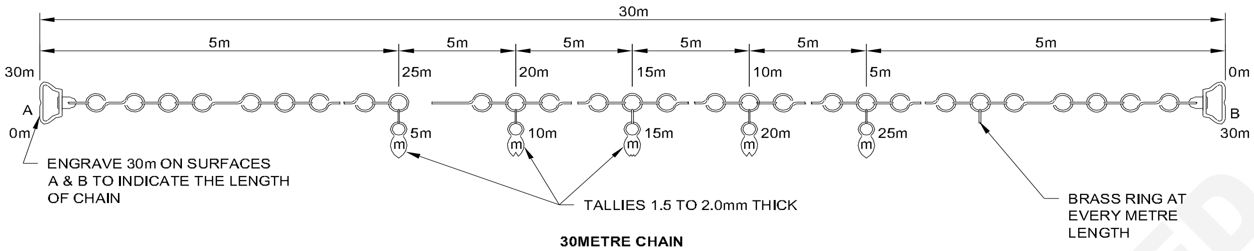
| Leader | Follower |
|---|---|
| To drag the chain forward | To direct the leader to be inline with the ranging rod at the end stations. |
| To insert an arrow at the end of every chain | To carry the rear end of the chain ensuring that it is dragged above the ground. |
| To obey the instructions of the follower | To pick up the arrows inserted by the leader |

Fig 1



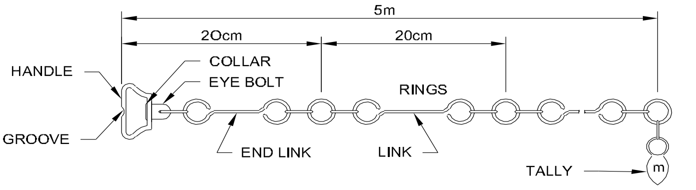

20 METRE CHAIN

Fig 2



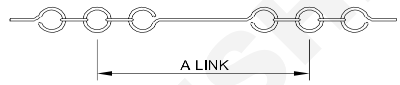

30METRE CHAIN

Fig 3



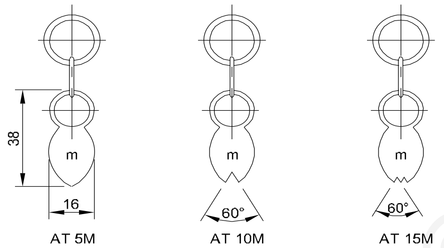

DETAILS OF A METRIC CHAIN

Fig 4




A LINK OF A CHAIN

Fig 5




SHAPE OF TALLIES IN 30m METRIC CHAIN

SUN132011



### Unfolding the chain

Before commencing the chain, the surveying or follower keeping both handles of the chain in his left hand, spread the chain with the forward direction with the right hand. The leader taking are handle of the chain in his hand and moves forward till the chain is fully extended.

### Reading the chain

– The chain is marked by tallies at every 5m length and small brass rings at every 1m length without having difficulty in reading the chain.

– In taking measurements, observe the tag immediately before the end point, which is being measured to and count the number of brass rings and links from it in the forward direction to the end point.

– In reading near the centre of the chain care must be taken to see the position of the central tag.

– To get the total distance add the above fractional part of the chain with the number of full chain, if distance exceeds more than one chain length.

### Folding the Chain

After the field work the chain should be folded into a bundle. The chain is folded by taking central two lines in the left hand until the handle of links is formed and lied up with a strip of leather.

### <u>Error in length due to in correct chain</u>

Correct or True distance =

In correct (or) measured distance ×

$$\frac{\text{Incorrect length of chain or tape}}{\text{Correct length of chain or tape}}$$

(or)

$$\text{True distance} = \text{Measured distance} \times \frac{L'}{L}$$

Where L = True length of chain or tape

L' = Incorrect length of chain or tape

**Error in area due to incorrect chain:**

True area = Measured area x $(L / L)^2$

**Error in volume due to incorrect chain**

True volume = Measured area x $(L / L)^3$

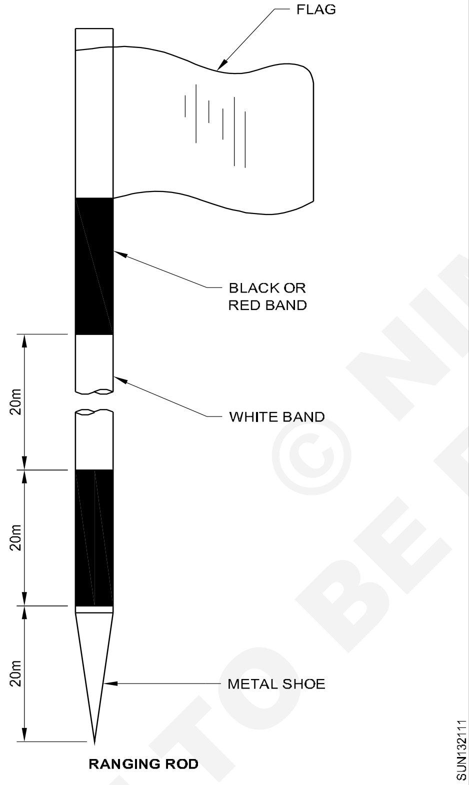
# Introduction about chain survey instruments

**Objectives:** At the end of this lesson you shall be able to
- **state the construction and uses of the following chain survey instruments.**

- Ranging Rod
- Offset Rod
- Arrows
- Wooden peg
- Plumb bob
- Measuring Tapes

**Ranging Rod** (Fig 1)

Fig 1

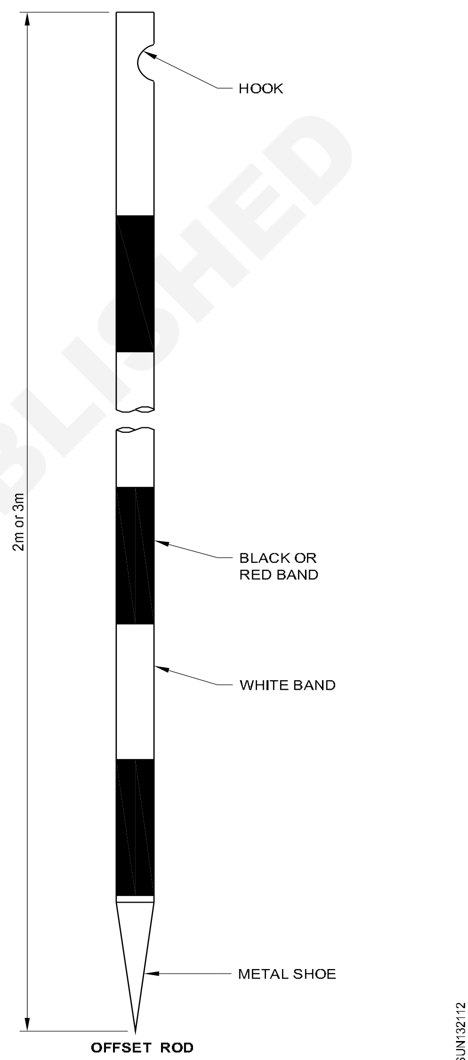



- It is a wooden/steel pipe of 2m or 3m in length with 3cm in diameter for steel and for wooden is 4 cmø.
- It is painted in red and white or black and white in 20 cm band width.
- Bottom of rod is fixed with a sharp metal shoe for fixing on ground.
- Flag is fixed on the top for visibility when it is more than 200m in distance.
- It is used for marking the position of station in chaining.
- If is also used for fixing intermediate points in ranging.

**Offset rod** (Fig 2)

- It is similar to the ranging rod with a hook at the top.
- It is used for pulling or pushing the chain through hedges and other obstruction.
- It is also used for aligning offset line and measuring short offset.

Fig 2



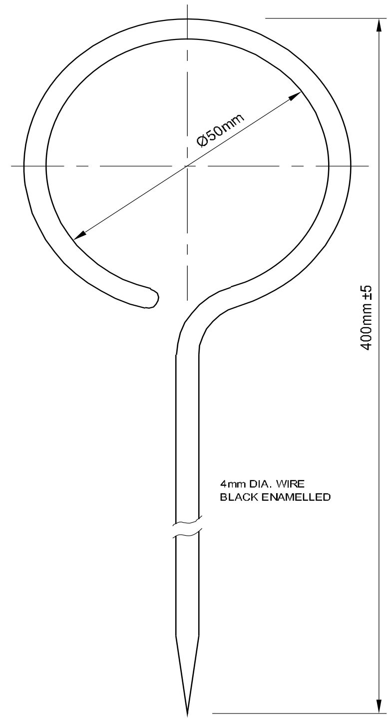

**Arrows**

- It is made up of 4mm steel wire and 40cm long as shown in Fig 3. It is pointed at one end for inserting into the ground. Another end bent into a ring for easy handling. Each metric chain shall accompanied with 10 arrows as shown in Fig 4.
- It is used to mark the ends of each chain during the process of chaining.

**Wooden peg** (Fig 5)

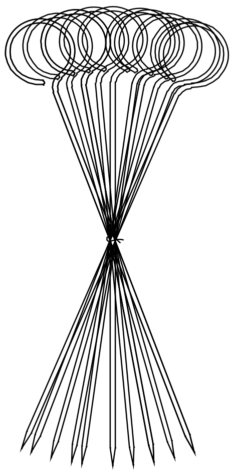
These are 15cm in length and tapered at one end. It is used to drive on the ground to mark the position of stations.

Fig 3



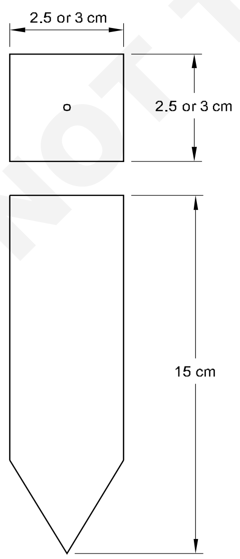

ARROW

Fig 4




ARROWS

Fig 5

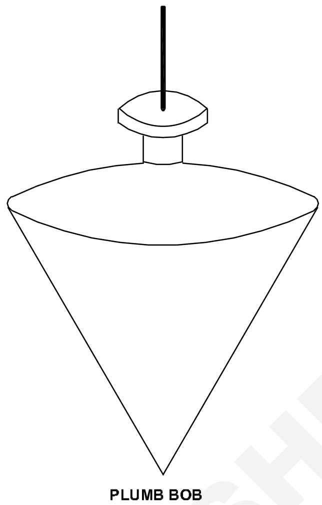



WOODEN PEG

**Plumb bob** (Fig 6)

While chaining along a sloping ground, it is used to transfer the points on the ground. It is also used as a centering aid in Theodolite, compass and plane table.

Fig 6




PLUMB BOB

**Measuring tape**

This is the instrument used for measuring distances

They are made of

1 Cloth or linen tape : It is 12 to 15mm wide and is made of linen cloth. It is available in lengths of 10m, 20m and 30m. At the end of this tape is provided with brass handle which is included in the total lengths of the tape.

   It is easily affected by dampness.

   It is used for taking measurement such as offsets.

2 Metallic tape

3 Steel tape

4 Invar tape

5 Fibre or plastic tape

**Metallic tape** (Fig 7)

– It is made up of linen and reinforced with fine brass or copper wire. It is covered in a leather case with winding device.

– It is available in 15m (50ft) and 30m(100ft)

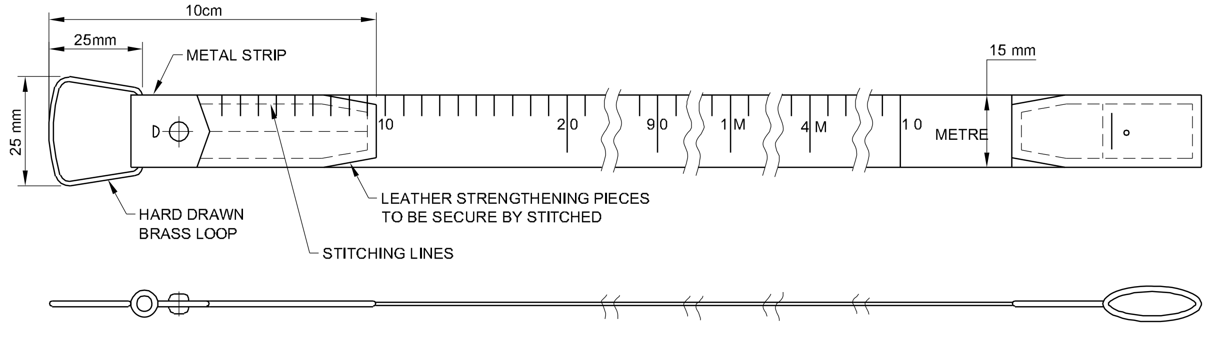
– Each metre length is divided into 10 parts (Decimetre) and each part is further subdivided into 10 parts (Centimetre)

– The other side of the tape is graduated with feet and inches.

– It is commonly used for taking offsets in chain surveying.

– This cannot be used for taking very accurate measurement

Fig 7




METALLIC TAPE

**Steel tape** (Fig 8)

– It is made of steel ribbon varying in width 6mm to 16mm and available in 1m, 3m, 5m, 10m,15m, 30m and 50m in length.

– Each metre is divided into 200 parts. (Each being 5mm) First 10cm length of the tape is divided into millimetre

– It is used for taking measurements and also used for testing chain lengths.

**Invar tape**

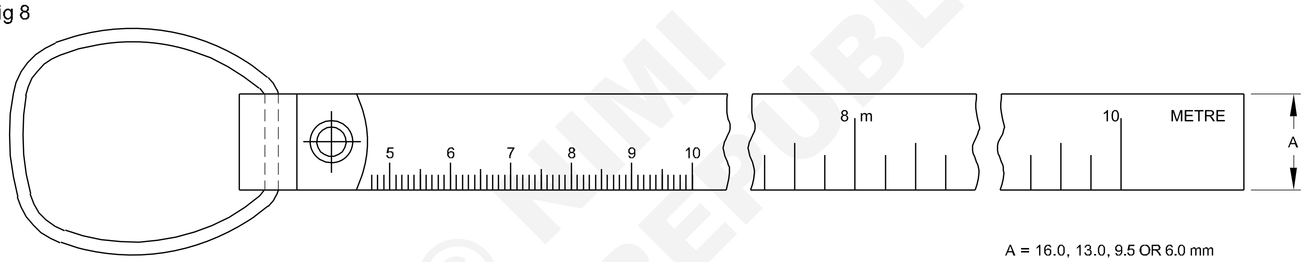
– It is made of an alloy steel (64%) and nickle (36%) and available in 30m, 50m and 100m lengths.

– It is easily kinked and broken, so care should be taken while taking measurements.

– It has very low coefficients of thermal expansion.

– It is only used for highest precision measurement like baseline in triangulation work.

Fig 8




STEEL TAPE



## Testing of metric chain (20m/30m)

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of checking the chain**
- **state the methods of testing**
- **list out the errors in the chain**
- **state the limits of error in chain**
- **explain the adjust the chain**
- **state Indian optical square.**

### Necessity of checking the chain

The length of chain changes due to wear and tear, mud sticking and change in temperature.

The length of chain increases due to

– Stretching of links and joints.

– Opening out of the rings.

– Wear of the wearing surfaces.

– rough handling in pulling it through hedges and fences.

The length of chain decrease due to bending of the links and mud-sticking.

Therefore it becomes necessary to check the chain before commencing the survey work. Before testing the chain the bent uplinks should be straightened and mud should be removed from the joints.

### Methods of testing chain

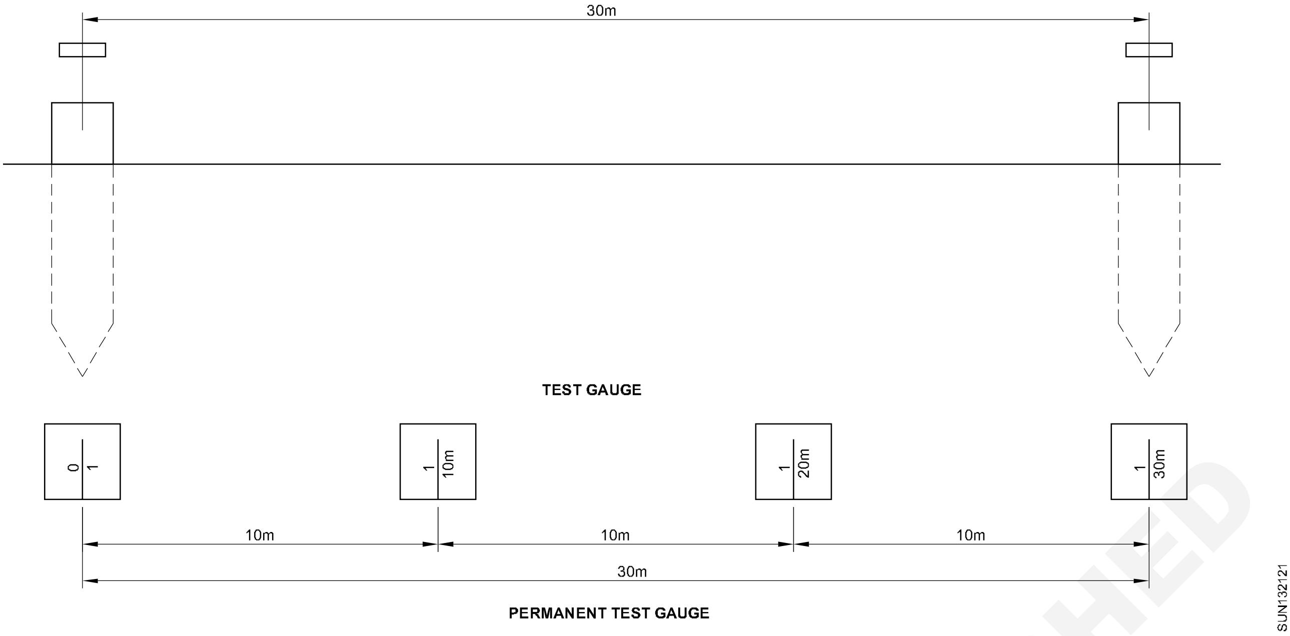
Following are the methods of testing a chain. (Fig 1)

– By comparing it with a chain standard or with a test gauge

– By comparing the chain with the levelling staff laid down successively.

– By comparing the chain with the steel tape reserved specially for this purpose.

Fig 1




## Errors in chain

Errors in chain are,

1 **Instrumental error:** They occur due to faulty adjustments of devices such as chain may be too long or too short etc.

2 **Natural errors:** They arise due to variation of temperature

3 **Personal errors:** They are due to chain not being straight

## Mistakes in Chaining

Mistakes are generally done by inexperienced chainman. These can be avoided by careful working. Following are the common mistakes made in the field.

i) **Miscounting the chain length:** This is the most serious mistake and occurs due to wrong counting or due to loss of arrow

ii) **Displacement of arrows:** If an arrow is displaced, it may not be replaced correctly. To avoid this mistakes, the end of the chain length should be marked both by scratching a cross on the ground and fixing an arrow.

iii) **Misreading:** It happens due to reading from the wrong end of the chain. It can be avoided by carefully noticing the position of the central tag.

## Limits of error in chain

As per Indian standard specifications every metre length of chain should be accurate to within ± 2mm when measured with tension of 8 kg and checked against a certified steel tape which has been standardised at $20^0$C

The overall length of chain should be within the following limits.

20m chain : ± 5mm

30m chain : ± 8mm

## Adjusting the chain

I If the chain is found to increase in length than the standard length, it may be adjusted

i) By closing up the joints of the opened out rings.

ii) By Hammering back to the shape, of the flattened out rings.

iii) By replacing some of the larger rings by smaller rings.

iv) By removing some of the rings.

v) By adjusting links at the handle.

II If the chain is found to decrease in length than the standard length, it may be corrected.

i) by straightening the bent up links.

ii) by replacing some of the smaller rings by larger ones.

iii) by inserting the new rings as required

iv) by adjusting the links at the handle

# Ranging

**Objectives:** At the end of this lesson you shall be able to
- **state ranging**
- **state the necessity of ranging**
- **state the types of ranging**
- **interpret the signals surveyor and the corresponding actions by assistance.**

## Ranging

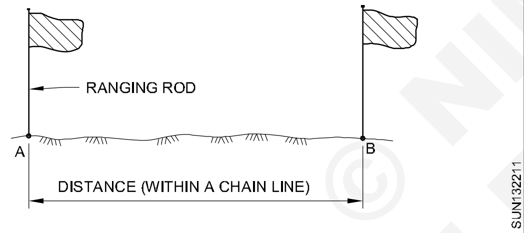
The process of establishing intermediate points in line with the terminal points before chaining is known as ranging. This is necessary when the distance is longer than one chain length.

## Necessity of ranging

To measure the length of a survey line also called a chain line, it is necessary that the chain should be laid out on the ground in a straight line between the end stations.

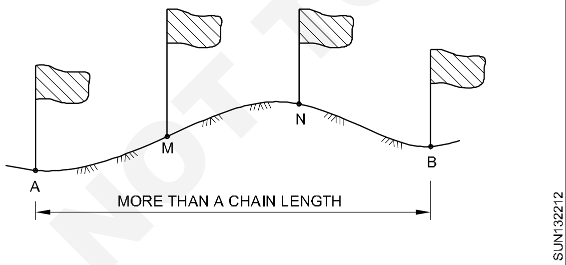
If the line AB is with in a chain length or the end stations are clearly visible, it is easy to put the chain in a true alignment as show in Fig 1.

Fig 1




But if the line AB is more than one chain length or the end stations A and B are not clearly visible, it is necessary to place intermediate ranging rods at M and N to maintain a straight line between the stations as shown in Fig 2.

Fig 2




## Types of ranging

There are two types of ranging. They are

- Direct ranging
- Indirect ranging

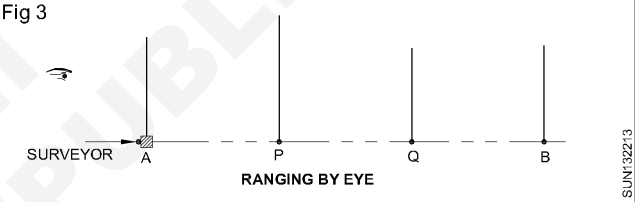
## Direct ranging

When intermediate ranging rods are placed along the chain (in between the visible end) line by direct observation from either end station is known as direct ranging.

Direct ranging may be done either by eye judgement or by using line ranger but in important works theodolite is preferably used.

Fig 3 shows A and B are the ends of a survey line and P and Q are the intermediate stations.

Fig 3




## Indirect ranging (or) Reciprocal ranging

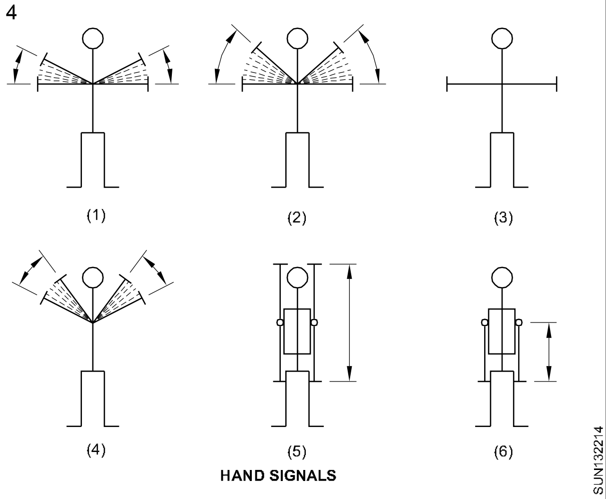
When the ends of the line are not inter visible due to high ground or a hill or a valley intervening, and also when the ends of a line are not distinctly visible from one another due to the distance being too great.

In this case, to fix the intermediate points indirect ranging is adopted.

## Hand signals for ranging (Fig.4)

The following hand signal are used by a surveyor to direct the assistant to move to the desired position.

Fig 4



| Sl. No. | Signal by the surveyor | Action by the Assistant |
|---|---|---|
| 1 | Rapid sweep with right or left hand | Move considerably to the right or left. |
| 2 | Slow sweep with right or left hand | Move slowly to the right or left |
| 3 | Right or left arm extended | Move continuously to the right or left |
| 4 | Right or left arm up and moved to the right or left | Plumb the rod to the right or left |
| 5 | Both hands above head and then brought down | The position of the rod is correct |
| 6 | Both arms extended forward horizontally and then brought down. | Fix the rod |

# Offsets and offsetting

**Objectives:** At the end of this lesson you shall be able to
- **state the meaning of offset and offsetting**
- **state the classification of offsets, its limits and its definition**
- **state the methods of taking offsets for various site conditions.**

### Offset

The lateral distance measured from the chainline to the object is called offset.

### Offsetting

The process of measuring lateral distances from the chainline to the objects which are to be plotted is called as offsetting.

It is done to locate the objects with reference to the chainline.

These are measured on either side of a chainline.

Classification of offsets

**Based on length of chain line**

- Short offset
- Long offset

**Based on direction of chain line**

- Perpendicular offset
- Oblique offset

### Limits of Offsets

The length of offset depends upon the degree of accuracy required, scale used, method of setting out the perpendicular and nature of the ground. Hence the length of perpendicular offset should be within 15m

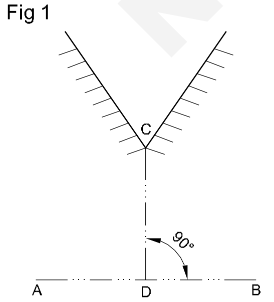
Short offset - Less than 15m

Long offset - More than 15m

### Perpendicular offset

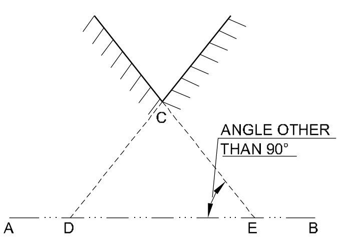
It is also known as rectangular offset or right offset. The distance measured at right angles to the chain line from the objects is known as perpendicular offset. (Fig 1)

Fig 1




PERPENDICULAR OFFSET

Fig 2




OBLIQUE OFFSET

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### Oblique offset

Offsets which are other than right angles to the chainline are known as oblique offset such as CD and CE in Fig 2.

This is taken when

- The object is at a long distance
- accuracy is required.

### Taking offsets

- The operation of taking and recording the distance on either side of a chainline is known as taking offsets.
- The measurement on the chain line is recorded as 'Chainage'
- Long offsets are measured with steel tape and short offsets are measured with metallic tape.
- When the offsets are short, perpendicular offset is laid by holding the zero end of the tape at the object and swing the tape over the chain to find the chainage.
- The minimum distance will be the perpendicular offset.
- When greater accuracy is required or the offsets are long, the right angles should be laid out with cross staff or optical square.

### Methods of Taking offsets

- An offset should be taken wherever the outline of an object changes.
- In case of straight wall or boundary, an offset should taken at each end of the corner. (Fig 3)
- In case of an irregular boundary, sufficient number of offsets at suitable interval should be taken. (Fig 4)

Fig 3

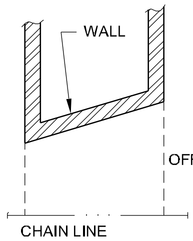
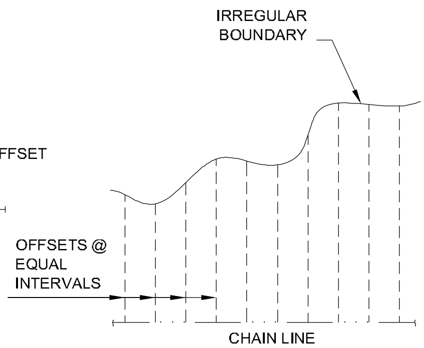



Fig 4




METHODS OF TAKING OFFSETS

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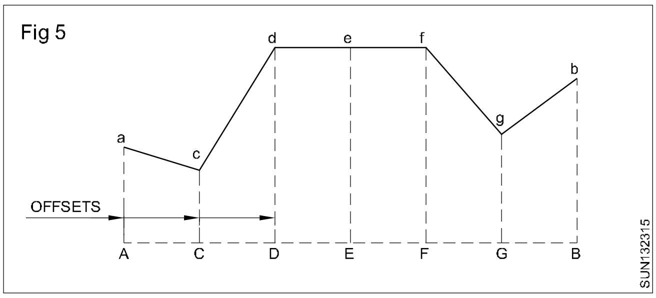
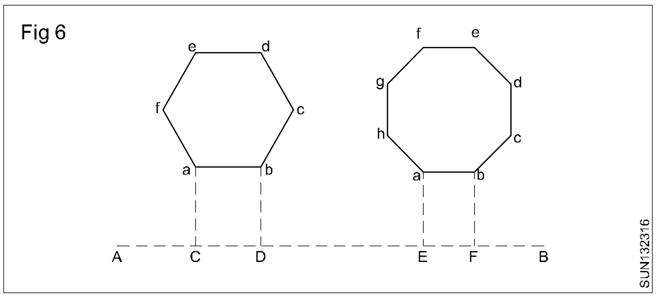
– Whenever the outline of the object changes its direction an offset, must be taken at each change of direction (Fig 5)

Fig 5



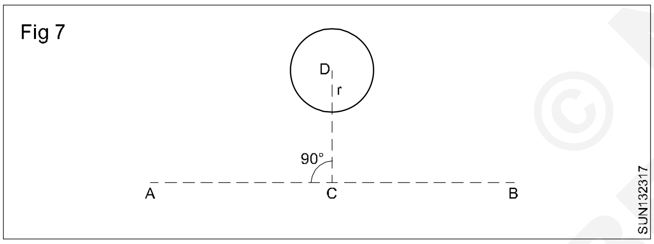

– In case of polygonal objects such as pentagon, Hexagon, Octagon etc, offsets should be taken at the ends of the side nearer to the chainline and the length of the sides (Fig 6)

Fig 6



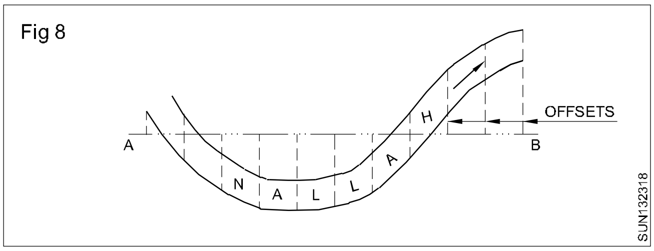

– In case of circular shapes, an offset should be taken to its centre and its radius should be measured. (Fig 7)

Fig 7



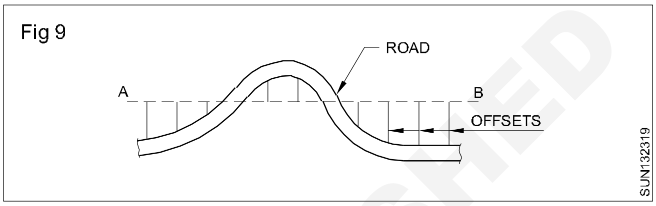

– In case of a nallah, offsets should be taken to both the sides of its width. (Fig 8)

Fig 8



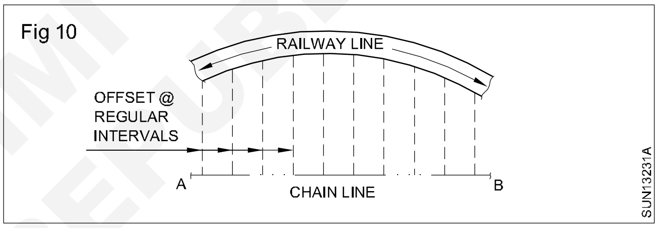

– In case of roads or foot paths with constant width offsets should be taken at the beginning, middle and the end of the curve and at few points in between (Fig 9) width should also be measured.

Fig 9




– In case of fair curve such as railway line, offset should be taken at a regular interval and width should be measured. (Fig 10)

Fig 10






## Field book

**Objectives:** At the end of this lesson you shall be able to
- **name the two types of field book**
- **explain about booking of field book**
- **explain about inking and colouring and using of conventional signs and symbols.**

### Field book

The field measurements , sketches, notes are recorded for future reference in a notebook called field book.

It is a rectangular notebook of size 20cm x 12cm and open length wise

There are two kinds of field book.

i) Single line field book

ii) Double line field book

### Single line field book

Single line field book is used for large scale survey most detailed dimension work.

A red line is ruled down at the middle of each page.

This single line represents the survey line or chain line

The chainages are entered on the chain line.

Offsets are entered in the order they appear at the chain line.

Objects are sketched and offsetting distance are entered as shown in Fig 1.

### Double line field book:

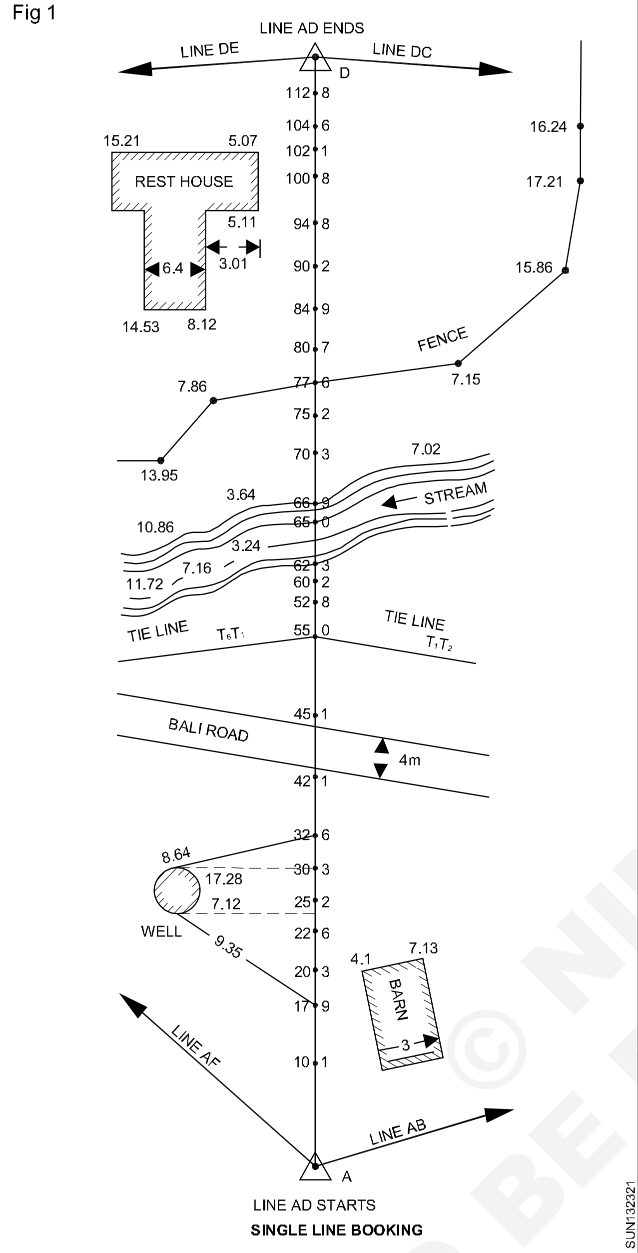
Double line field book is used for all ordinary works.

Two blue lines or red lines are ruled down in the middle of each page.

The space between these two red or blue lines represents the chain line.

The chainages are entered in between these two lines.

Fig 1



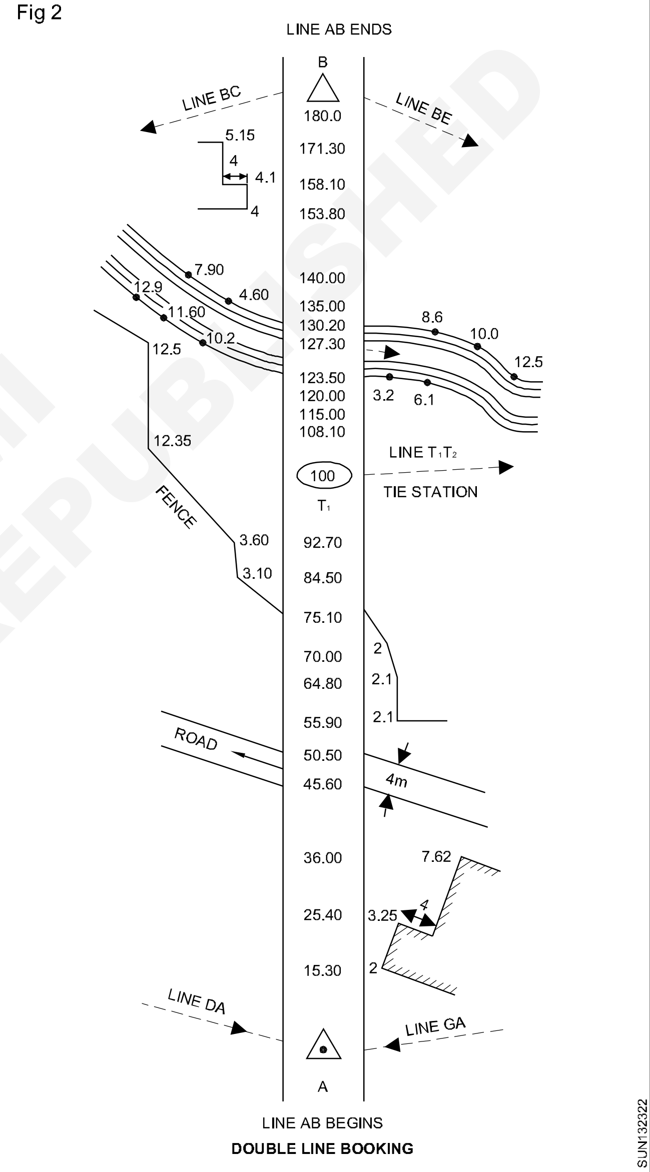

Objects are sketched and offsetting distances are entered as shown in Fig 2

## Booking Field notes

Following informations are recorded at the beginning of survey

- Date of commencement and completion of survey and names of surveyors.
- Symbol denoting the station point
- Details of survey lines.
- Location sketches of survey stations
- Name of the line (Say AB,BC)
- Booking is commenced at the bottom of the page and worked upwards.
- Each chainline or tie line should be recorded in a separate page.
- The recorder should move in the forward direction of chaining.
- All measurements should be recorded immediately
- Wrong entries should be scored out and correct measurements should be written over the wrong measurements.
- If the entire page is discarded it should be crossed and marked as CANCELLED
- The offsetted objects are sketched with conventional signs (Fig 1 & 2) towards left or right of the central column.

Fig 2




- The sketches should be drawn proportionally
- Figures denoting the dimensions of the details of the objects should be included between the arrow heads.
- Numerals should be neatly and legibly written.
- Over writing should not be done.
- Offsets are written close to the points offsetted and exactly opposite to and in line with the chainages.

– To avoid confusion sufficient space should allow between rows of booking.

– When objects such as fence, road, wall etc crosses the chain line, the chainage of the point of intersection should also entered and direction should be noted.

– A symbol Δ is used to denote a main station.

– The zero chainage at the commencement and the closing chainage at the end of a line should written inside the Δ

– The name of the station should written close to the Δ.

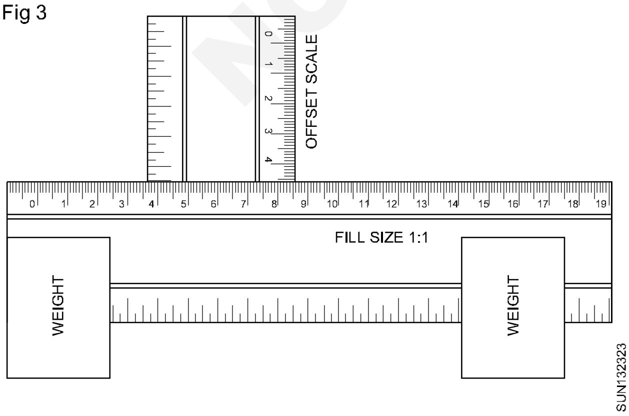
– Tie or subsidiary stations should indicate by circles or ovals round the chainages

**Plotting of a chain survey**

- Plotting work is started after the field work is over.
- The survey is plotted on the drawing sheet with a suitable scale.
- It should be plotted always north direction, so then the top of the drawing sheet represents north.
- The plotting should be always drown on the centre of the sheet taking sufficient spaces for margin, title and scale.
- The base line is firstly drawn in its proper position.
- Intermediate stations are marked on the base line and complete the frame work of the triangles.
- The triangles are checked by check lines.
- For plotting offsets, mark the chainages of the points along the chain and from which the perpendicular offsets are marked by using an offset scale.
- The plotting of offsets should be continued according to the field book is maintained in the field book.
- The main stations and substations, objects, chain line are shown in accordance with the conventional signs.
- The heading should be written on the top of the drawing sheet.
- The map should not have any dimensions.

**Offset scale (Fig 3):** Using of offset scale for plotting perpendicular offset

Fig 3




- Put the long scale along the chain line, with its zero mark is exactly at the starting point of the line.
- The offset scale is placed at right angles to the long scale and moved to the required chainages. Then the offset lengths are marked with the help of the pricker.

**Inking maps or plans**

After completing and checking the plan, it is inked in. It is done to work from top of the plan downwards or from left or right. The inked in lines should be fair. Curved lines should be inked first with the help of French curves after that straight lines should be inked.

**Colouring**

The following points should be considered in mind while colouring.

– Before commencing colouring clean the drawing throughly

– Mix all colours in light and not too dark.

– Always mix more quantity of colour if one colour is required for the whole of the work.

– While colouring a drawing, the drawing board should be in a flat position to spread the colour evenly.

The following colours are used for the features shown

| Features | Colours |
|---|---|
| Road metalled | Burnt Sienna |
| Road Unmetalled | Burnt amber |
| Compound wall | Indigo |
| Buildings | Crimson lake |
| Water | Prussian blue |
| Barren land | Burnt amber |
| Bench mark | Crimson lake |
| Truss | H green |
| Cultivated land | H green |

**North point**

The north point must be shown on a plan in any convenient blank space on the paper preferably at the top pointing upwards

**Scale**

Scale should be drawn under the title or just inside the border at the bottom of the drawing.

**Conventional signs & Symbols**

The earth surface contains varieties of natural and artificial features. If it is to be shown graphically, it will not be possible without its description. To overcome this difficulty standard symbols have been adopted for each type of details.

The symbols which are drawn to natural or artificial details on a map is known as conventional signs.

Various signs used in Surveying.

## Obstacles in chain surveying

**Objectives:** At the end of this lesson you shall be able to
- **define obstacles**
- **state the three types of obstacles**
- **calculate the obstructed distance.**

### Definition

During chaining, sometimes rivers, ponds, buildings, hills, thick jungles may prevent the chainman to take the measurements directly. These obstructions are known as obstacles.`

### Type of obstacles

1 Obstacles to ranging

2 Obstacles to chaining

3 Obstacles to both chaining & Ranging.

**Obstacles to ranging:** Two cases

Case (i)

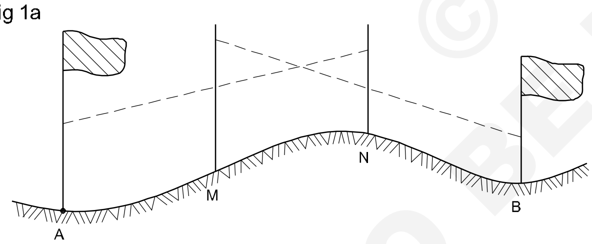
Both ends of the line may be visible from intermediate points on the chain line.

E.g. Hill, Valley (Fig 1a) AB = AM + MN + NB

Fig 1b XY = XE + EB + BY

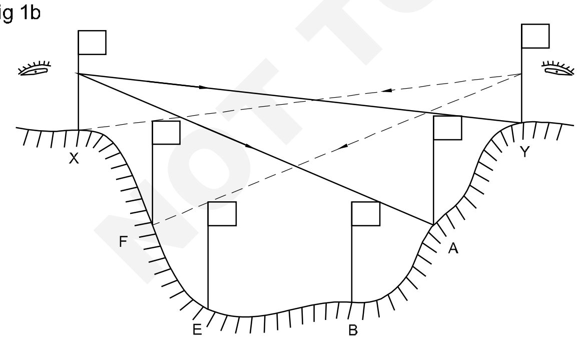
Horizontal distances are calculated by stepping method.

Fig 1a




RANGING ACROSS A HILL

Fig 1b



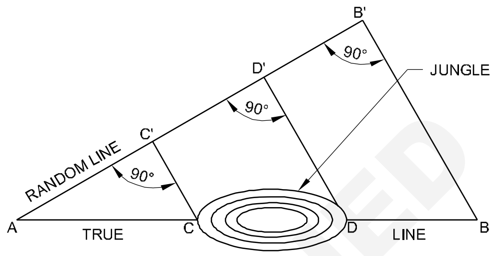

RANGING ACROSS A VALLEY

Case (ii)

Both ends of the line may not be visible from intermediate points on the chain line. (Fig 1b)

E.g. Thick Jungle (Fig 2) AB = $\sqrt{(AB')^2 + (BB')^2}$

Fig 2




RANGING ACROSS A VALLEY

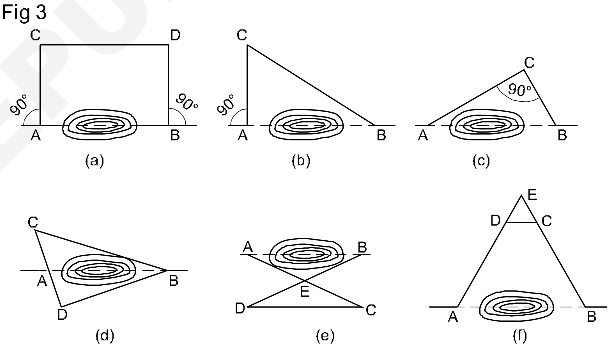
### Obstacles to chaining

**Case (i)**

When it is possible to chain round the obstacle.

E.g. Pond, hedge etc. (Fig 3)

Fig 3




OBSTACLES TO CHAINING

Following are the cases applicable in obstacles to chaining. In all the cases AB is the required chain line but not able to run over the obstacles and is to be calculated.

**As in Fig 3a,**

AC and BD are perpendiculars to AB, and AC = BD

Then obstructed distance AB = CD

**As in Fig 3b,**

AC is perpendicular to AB.

Then with known distance of AC and BC obstructed distance AB = $\sqrt{BC^2 - AC^2}$

**As in Fig 3c**

Lines AC and BC arc meet at an angle of $90^0$.

Then with the known distances of AC and BC, obstructed distance, AB = $\sqrt{AC^2 + BC^2}$

**As in Fig 3d**

With the known distances of BC, CD and DB, obstructed distance,

AB =

**As in Fig 3e**

$\Delta^s$ EAB and EDC are equal in all respects, then obstructed distance AB = DC

**As in Fig 3f**

$\Delta^s$ AEB and DEC are similar, then $\frac{AB}{DC} = \frac{AE}{DE}$

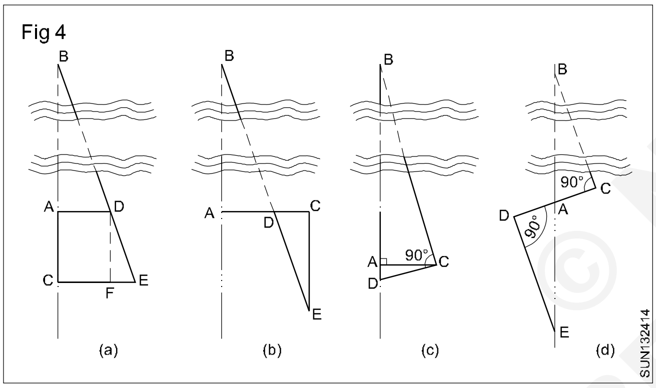
Thus with the known distance DC, AE and DE, AB is calculated.

**Case (ii)**

When it is not possible to chain round the obstacles.

E.g. River (Fig 4)

**As in Fig 4a**




AD and CE are perpendiculars on AC.

B, D and E are in a straight line.

FD is perpendicular to CE at F.

$\Delta^s$ ABD and FDE are similar

Then $\frac{AB}{AD} = \frac{FD}{FE}$

Hence FD = AC and FE = CE - AD (CF = AD)

Thus obstructed distance AB = $\frac{AC \times AD}{CE - AD}$

**As in Fig 4b**

AC is perpendicular to AB.

AD = DC.

Then ABD and DEC are similar.

Thus obstructed distance AB = CE.

**As in Fig 4c**

AC is perpendicular to AB.

BAC and BCD are right angled triangle.

Now ABC and DAC are similar.

Then $\frac{AB}{AC} = \frac{AC}{AD}$

Thus AB = $\frac{AC}{AD}$ x AC

Obstructed distance AB = $\frac{AC^2}{AD}$

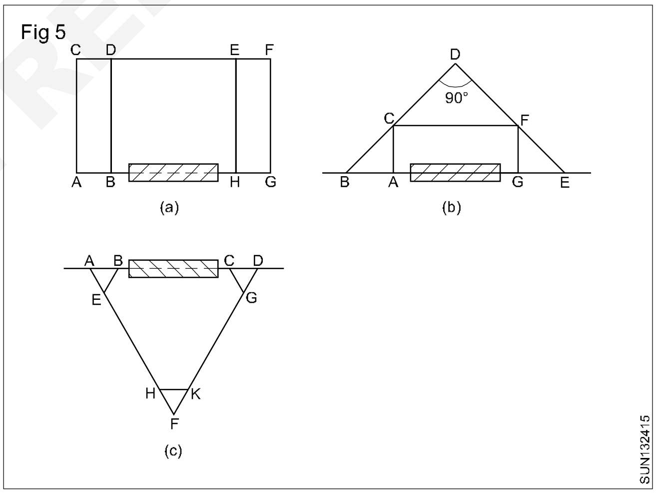
As in Fig 4d

ACB and ADE are right angled triangles, AC = AD

Then obstructed distance AB = AE

**Obstacles to both chaining and Ranging**

E.g. Buildings. (Fig 5)



## Chaining on sloping ground

**Objectives:** At the end of this lesson you shall be able to
- **explain the methods of chaining on sloping ground**
- **state necessity of calculating horizontal distances.**

**Methods of chaining on sloping ground**

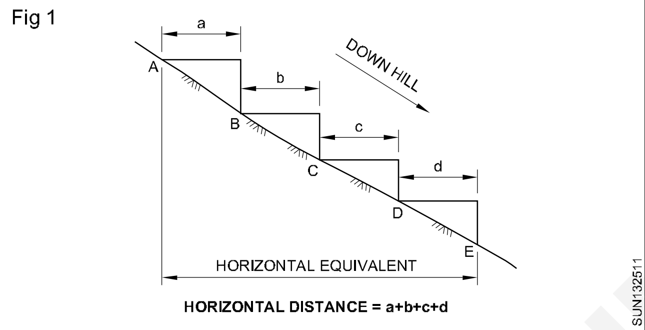
– Direct method

– Indirect method

**Direct method**

**Stepping method** (Fig 1): In this method the horizontal distance on sloping ground is directly measured.

Fig 1




**Indirect method** (Fig 2)

In this method the actual sloping ground is measured and the angle of slope is also measured by an angle measuring instruments.

Then the horizontal distance of the sloping ground is calculated by using the given formula.

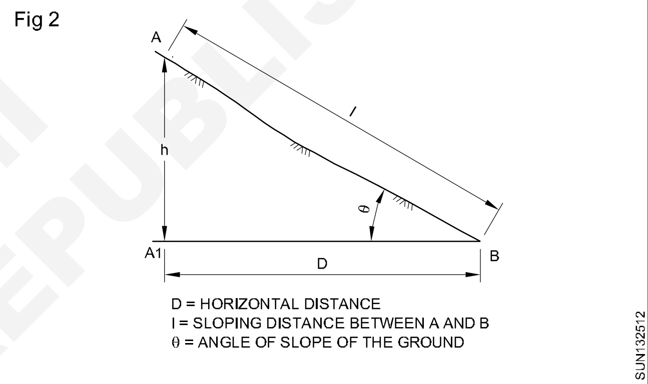
Horizontal distance, D = $A_1B$= l Cos$\theta$.

**Necessity of calculating horizontal distance:**

Actually the distances measured on a sloping ground are inclined distance. This will be more than the horizontal distance for plotting purpose only horizontal distance (D) is taken into account.

Hence all the sloping distances are converted into a horizontal equivalent.

Fig 2

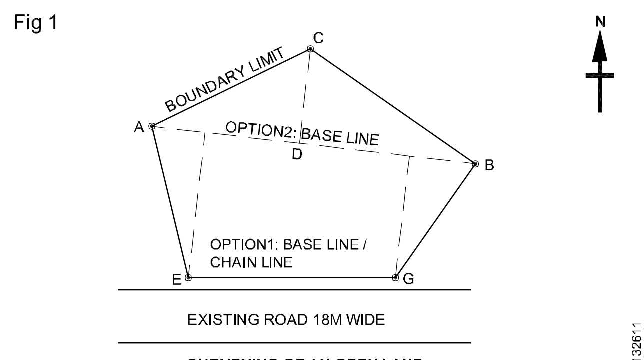


## Chain survey to an open land for layout plots

**Objectives:** At the end of this lesson you shall be able to
- **explain about preparation of a map, layout planning and its implementation.**

Preparation of map of the open land (Fig 1)

Fig 1

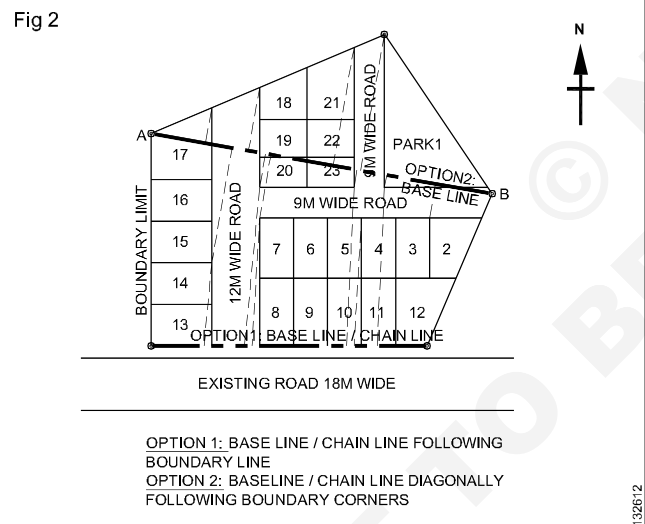



SURVEYING OF AN OPEN LAND

It is necessary to prepare a map for layout plan and implementation.

Layout planning (Fig 2)

Fig 2




PROPOSED LAYOUT PLAN.

After preparing the map of the land the area is sub divided into plots with access roads and for all other civic amenities without wasting of land. The layout plan prepared according to the purpose of residential or industrial establishments.

**Reading of the layout plan and implementation**

From the prepared layout plan the surveyor to mark all the details directly on the ground as per the layout plan.

As for as possible the chain survey to be done in triangulation method. Equilateral triangle is one easy to form in the field if obstacles are not available.

In an equilateral triangle having the angles and sides are equal.

(i.e) side AC = CD = AD

Take an example

Side AC = 51m

Side CD = 51m

Side AD = 51m

The sum of interior angles of a triangle is equal to $180^o$ in ACD

$$\angle A = \angle C = \angle D$$

## Calculation of area

**Objectives:** At the end of this lesson you shall be able to
- **calculate the areas of an irregular field**
- **apply geometrical formulae for calculating the area**
- **describe the construction and use of planimeter.**

### Calculation of the area of an irregular field

In this survey the area of plot may be determined by the direct use of field notes.

In this method of survey a chain line known as base line to be laid through the centre of the area of the field.

The offset are taken to the boundary points in the order of their chinages on both the sides of the base line.

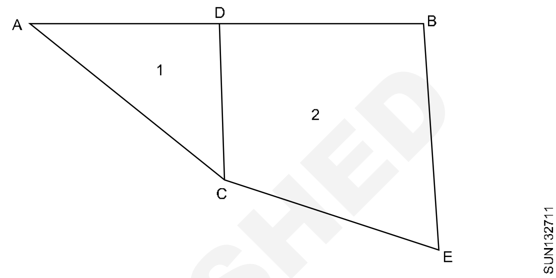
The chainages and offsets are entered in the field book.

With reference to the field book the boundary points are plotted and the area to be divided into number of triangles and trapezium according to the shape.

### Application of geometrical formulae for calculating the area

Now apply the geometrical formulae for calculating the according to the shape of the figures. (Fig 1)

Fig 1




1 Area of triangle

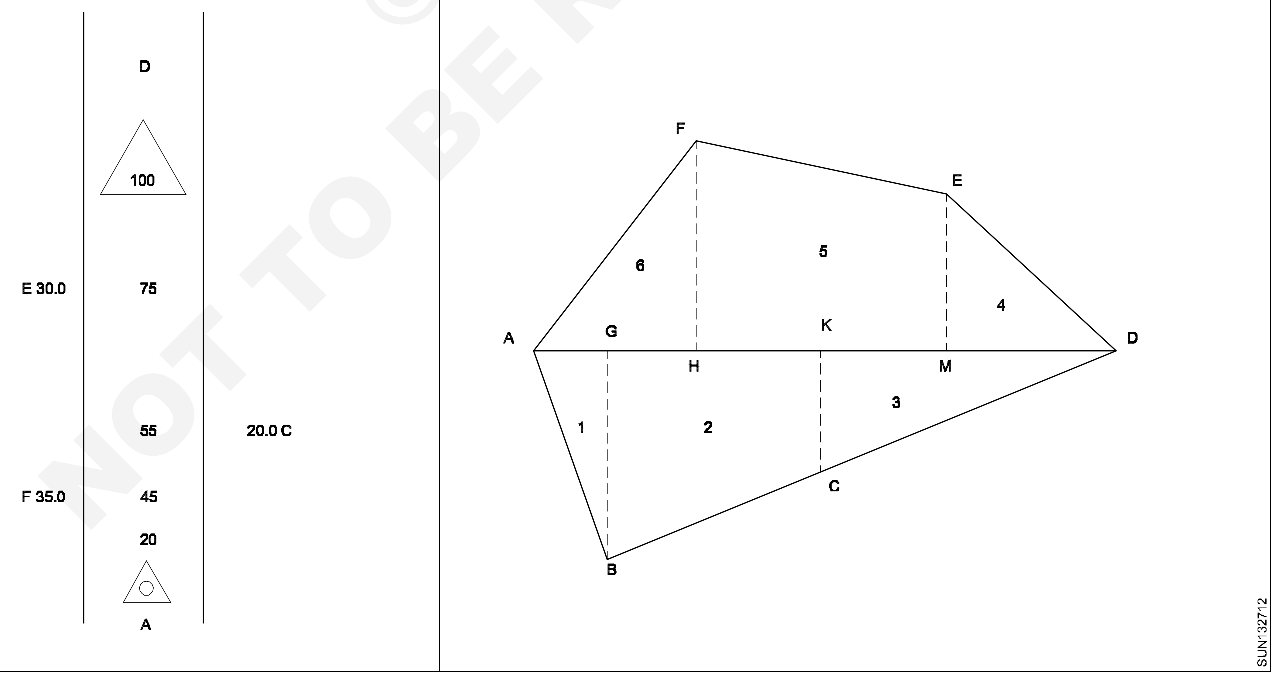
½ x base x height

2 Area of trapezium

base (a+b)/2 x height

Plot the following details of a field and calculate its area all measurements are in metres (Fig 2)

Fig 2



Serial No. 1 In $\Delta$ABG

Chainage in metres 0 and 20m.

Offsets in metres 0 and 36m.

In $\Delta$ ABG

Area = ½ x base x height

=1/2 x 20 x 36

=360 sq.m

**Area of trapezium GBCK**

Chainage in metres = 2m and 55m = 35m

Offsets in metres 36m and 20m = 28m

=35 x 28 = 980 sq.m

**Sl. No. 3**

Area of triangle KCD

=45m x 10m = 450 Sq.m

**Sl. No. 4**

Area of triangle DME = 25 x 15 = 375 sq.m

**Sl. No. 5**

Area of Trapezium = 30 x 32.50m= 975.00 sq.m

**Sl. No. 6**

Area of triangle AHF = 45 x 17.50 = 787.50 sq.m

| **S. No.** | **Figure** | **Chainage in metres** | **Base in Metres** | **Offsets in metres** | **Mean offsets in metres** | **Area in square Metres** | | **Remarks** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | +ve | -ve | |
| 1 | 2 | 3 4 | | 5 | 6 7 | 8 | 9 | |
| 1 | $\Delta$ABG | 0 and 20 | 20 | 0 and 36 | 18 | 360.00 | – | |
| 2 | Trapezium GBCK | 20 and 55 | 35 | 36 and 20 | 28 | 980.00 | -- | |
| 3 | $\Delta$KCD | 55 and 100 | 45 | 0 and 20 | 10 | 450.00 | -- | |
| 4 | $\Delta$DME | 100 and 75 | 25 | 0 and 30 | 15 | 375.00 | -- | |
| 5 | Trapezium | 75 and 45 | 30 | 30 and 35 | 32.50 | 975.00 | -- | |
| 6 | $\Delta$AHF | 45 and 0 | 45 | 35 and 0 | 17.50 | 787.50 | -- | |
| | | | | | Total | 3927.50 | | |



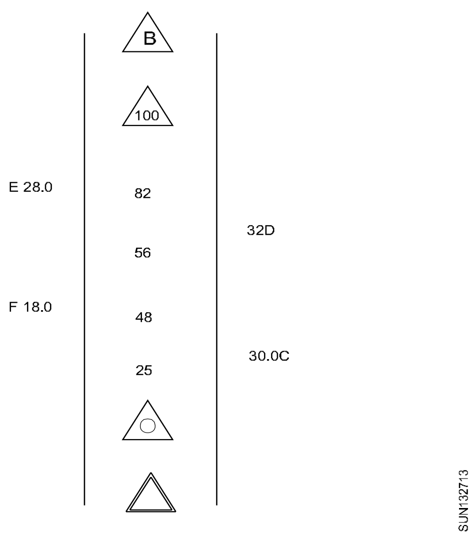
**Exercise**

The same exercise may be used by planimeter and find the area.

**Exercise 1, (2)**

The following readings were taken in the field. Plot and calculate its area. All measurements in metres. (Fig 3)

Fig 3



## 2 Instrumental method

Planimeter

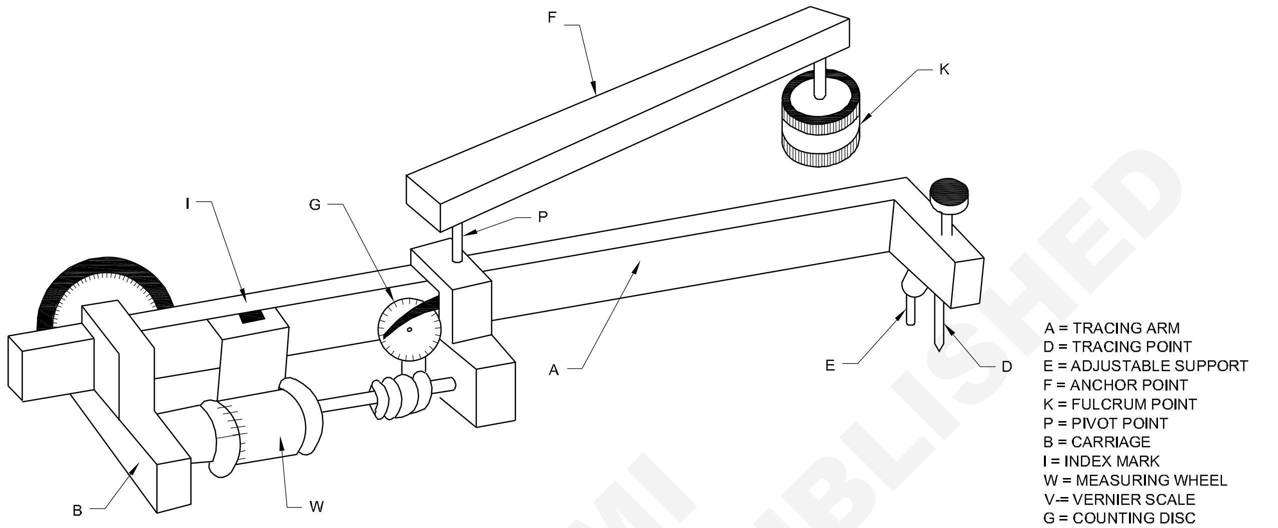
It is a mechanical device which is used for measuring of the area of any irregular shape of the figure. It gives best results more than that can be achieved by any other method except by direct calculation from the field notes.

**Angular polar planimeter**

**Constructional details of a planimeter (Fig 4)**

- It consists of two arms. The arm 'A' is called as Tracing arm. Its length can be adjusted and graduated.
- It carries a tracing point 'D' which can be moved along the boundary of the line of the area.
- An adjustable support 'E' which keeps the tracing point just clear of the surface.
- The other arm 'F' is called as the pole arm (or) anchor arm.

Fig 4




PLANIMETER

- It is having a needle point with a weight 'K' at one end.
- The weight forms the centre of rotation.
- The other end of the pole arm can be pivoted at a point 'P' by a ball and socket arrangement.
- A carriage point 'B' which can be set at various points of the tracing arm with respect to the vernier of the index mark I.
- The carriage point having a measuring wheel 'W' and a vernier 'V'.
- The wheel is divided into 100 divisions and the vernier is divided into 10 divisions.
- The wheel and the vernier measure readings upto three places (i.e) 0.145, 0.194 etc.
- The wheel is geared to a counting disc which is divided into 10 divisions. For ten complete revolutions of the wheel, the disc shows a reading of one divisions. Therefore the planimeter shows a reading of four digits (i.e. 1.145, 1.194).

  The wheel shows - tenth and hundredth

  Vernier shows - Thousandth

The planimeter rests on the tracing point, anchor point and the measuring wheel.

**Example 1**

The following readings were recorded by a planimeter with the anchor point inside the figure. I.R = 9.377, F.R = 3.336, M = 100 $cm^2$ and C = 23.521.

Calculate the area of the figure when it is observed that the zero mark of the dial passed the index mark once in the clockwise direction.

**Given data**

I.R = 9.377

F.R = 3.336

N = -1 (For anticlose wise direction)

M = 100 $cm^2$

C = 23.521

Area = M (F.R - I.R ± 10N + C)

A = 100 (3.336 - 9.377 - 10 x 1 + 23.521)

= -6.041 - 10 + 23.521

= -16.041 + 23.521

= 7.480 x 100

= 748 $cm^2$

**Example 2**

The following particulars were noted while measuring the area of a figure with a planimeter.

a I.R and F.R were 8.652 and 6.798 respectively.

b The tracing arm was set to the natural scale.

c The zero of the dial passed the index mark once in the anticlockwise direction.

d Constant C = 20.

e Scale of the map is 1cm = 10m.

f The anchor point was inside the figure.

Calculate the area of the figure.

**Given data**

I.R = 8.652

F.R = 6.798

Natural scale means M = 100 $cm^2$

C = 20

N = -1

Scale 1cm = 10m

Area of the figure A = M (F.R - I.R - 10 x N + C)

= 100 (6.798 - 8.652 - 10 x 1 + 20)

= 814.6 $cm^2$

Since the scale is 1 cm = 10m

1 $cm^2$ = 10$m^2$

Required Area = 814.6 x 100 = 81460$m^2$

**Example 3**

The area of an irregular figure was measured with a planimeter having the anchor point outside the figure. The initial and final readings were 4.855 and 8.754 respectively. The tracing arm was set to the natural scale. The scale of the map was 1cm = 5m. Find the area of the figure.

**Given data**

I.R = 4.855

F.R = 8.754

M = 100 $cm^2$ (Natural scale)

N = 0 (There is no comment about the crossing of the index mark)

C = 0 (anchor point outside)

Scale = 1cm = 5m

Area = M (F.R - I.R)

= 100 (8.754 - 4.855)

= 389.9 $cm^2$

Scale of the figure 1 cm = 5m

1 $cm^2$ = 25$m^2$

Required Area = 389.9 x 25 = 9747.5$m^2$

**Exercise**

Calculate the area of the figure corresponding to the following data recorded by planimeter.

a I.R = 2.436

b F.R = 7.745

c M = 100 $cm^2$

d C = 20.00

e The figure traversed clockwise with the anchor point inside and the zero of the dial passed the index mark once in the reverse direction.

(Ans.1530.9 $cm^2$)

# Preparing Site Plan

**Objectives:** At the end of this lesson you shall be able to
- **define the triangulation and traverse in survey**
- **state closed and open traversed survey**
- **state the three types of survey lines in triangulation**
- **explain about field work.**

### General Information

As a surveyor, you will not able to plot the Fig 1a without anyone of the angular measurements.

You can able to plot the same figure without any angular measurements, if the length AC and BD is given. (Fig 1b)

Fig 1a is converted into number of triangles as in Fig 1b.

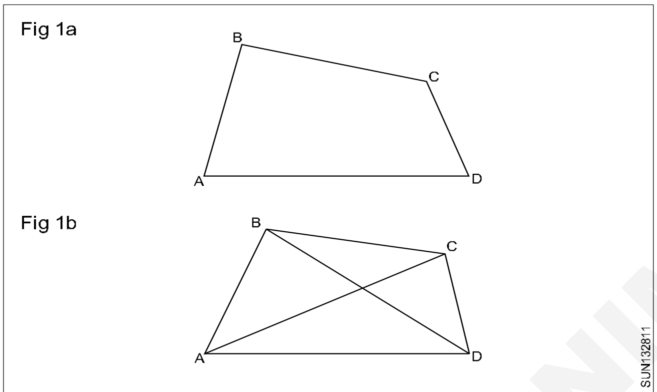


Fig 1a
Fig 1b

A triangle is the simplest plane figure, which can be drawn without any angular measurements.

Hence the area to be surveyed is divided into a network of triangles.

### Triangulation

The method of dividing the whole area to be surveyed into network of triangles and the sides of all the triangles are measured directly in the field and no angular measurements are taken is known as Triangulation survey.

### Traverse

A series of connected survey lines of known lengths and directions is called as traverse. The survey lines are measured with chain or tape and directions are determined with angular instruments. It is of two types. They are closed traverse and open traverse.

### Frame work

The lines or the triangles covering the whole area to be surveyed is called frame of work such as ABCD in Fig. (1a,b)

According to the nature and shape of the area of the triangles are to be arranged.

When forming triangles in a chain survey, the angle between the triangles should be selected more than 30° and less then 120°. This process of forming triangles are called as well conditioned triangle.

The angles formed in a chain survey should be an equilateral one which is best suited for plotted work.

**Closed traverse** (Fig 2)**:** When the finishing points of the survey coincides with the starting point of the survey is known as a closed traverse.

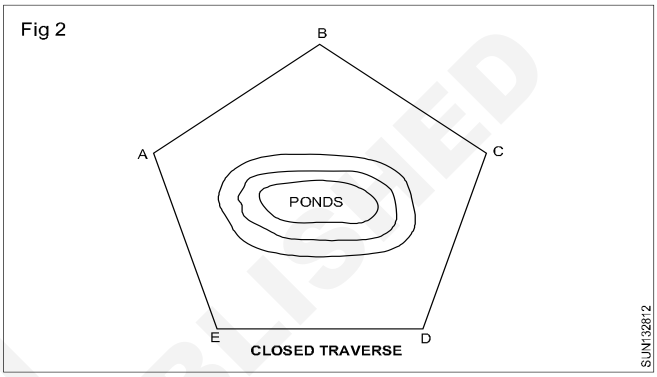


Fig 2

It is suitable for the survey of boundaries of forests, ponds, estate, lakes etc.

**Open traverse** (Fig 3): It consists of series of survey lines extending in the same direction and not returning to the starting point.

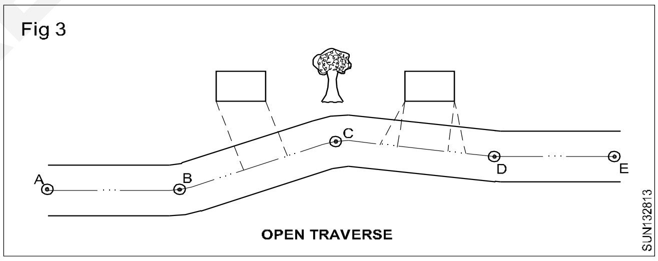


Fig 3

It is suitable for the survey of road, railway, river, coast line etc.

### State the three types of survey lines in triangulation

To conduct a Triangulation survey stations are to be established.

- The beginning and end points of a chain line is called as survey stations. Stations are denotes as .
- Stations are divided into main stations and Tie station or subsidiary station.
- The stations connecting boundaries of the area are called as main stations (in Fig 4, A,B,C,D)
- The stations other than main stations are called as Tie stations.

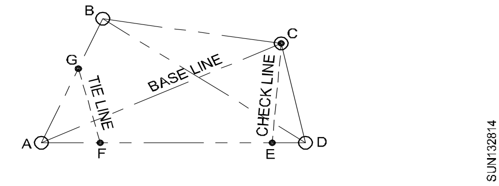
### Baseline

The longer line of the chain line is considered as baseline is AC (in Fig 4) From this line the chainages and offsets are taken.

The accuracy of the whole survey is mainly based on the accuracy of this line.

Baseline should be decided in such a way that it should divide the whole area approximately equal on both sides of chain line.

Fig 4




**Check line/Proof line**

A line joining the apex of a triangle 'C' and a fixed point on the opposite side 'E' (In Fig 4) CE is the check line.

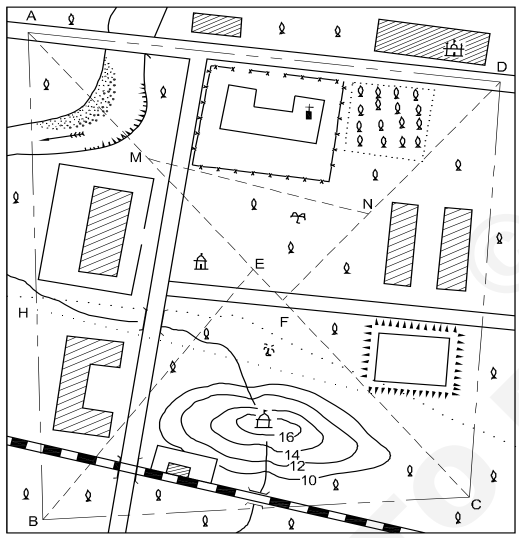
It is used to check the accuracy of the frame work

**Tie line:** A line joining some fixed points on any two lines in a main survey line is known as tie line. (FG in Fig 4)

It is used to check the accuracy of framework to locate the interior details which are faraway from main lines.

Fig 5 shows a model layout of chain survey.

Fig 5




MODEL LAYOUT OF A CHAIN SURVEY

**Field work**

It consists of

1 Reconnaissance

2 Marking and fixing stations

3 Reference sketches

4 Running survey lines

**Reconnaissance**

The preliminary inspection of the whole area of the site to be surveyed is known as reconnaissance.

It is always essential to fix survey stations for running survey lines and taking details.

Hence the surveyor should walk over the whole area to examine the ground and decide about for laying survey lines.

A key plan also being prepared.

**Marking and fixing stations**

After preparing a key plan the survey stations are fixed by driving a wooden pegs or nails.

Wooden pegs are used in soft ground and for roads or hard surface nails may be used for fixing on the ground.

**Reference sketches**

Each and every survey stations are referred with some permanent points.

These permanent points to the survey stations are located by measurement and made with reference sketches.

These are very useful to refix a survey station when it is displaced or lost.

**Running survey lines**

Survey lines are then laid in between the survey stations and details should be taken by offsetting method.

**Chain angles**

In a chain traversing the entire work is done only by a chain or tape without having angular instrument is known as chain angle method. It is to be done when the area cannot be divided into triangles such as river, nalla, standing crop etc. (Fig 6 and 7)

Fig 6

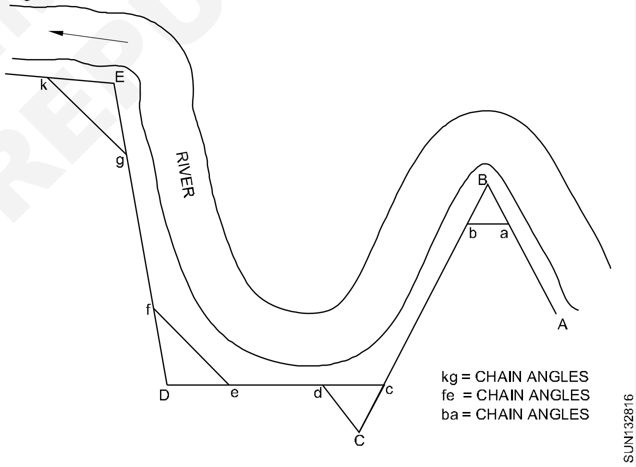
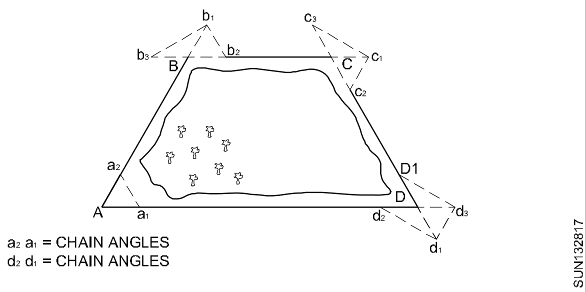



Fig 7

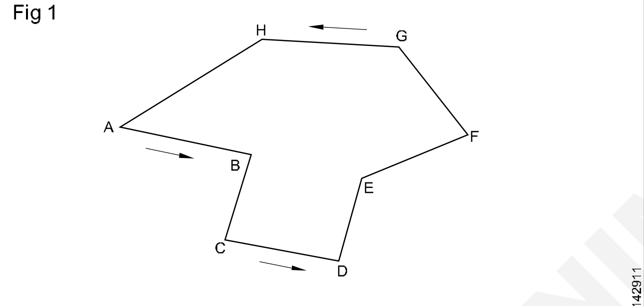


# Identification and Parts of instruments in compass survey

**Objectives:** At the end of this lesson you shall be able to
- **state about traversing**
- **state types of compass**
- **name the prismatic compass and construction**
- **construction of survey's compass.**

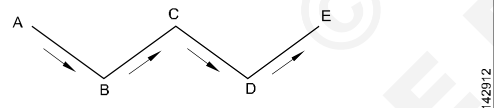
**Traversing:** Traversing is that type of survey in which a number of connected survey lines form the frame work and the directions and lengths of the survey line are measured with the help of an angle measuring instrument and a tape respectively. When the lines form a circuit which ends at the starting point is called closed traverse. Fig 1 If the circuit end else where it is said to be an open transverse. Fig 2.

Fig 1




CLOSED TRAVERSE

Fig 2




OPEN TRAVERSE

**Compass:** A compass is a small instrument which consists essentially of a magnetic needle, a graduated circle and a line of sight. When the line of sight is directed towards a line, the magnetic needle points towards magnetic meridian and the angle which the line makes with the magnetic meridian is read at the graduated circle.

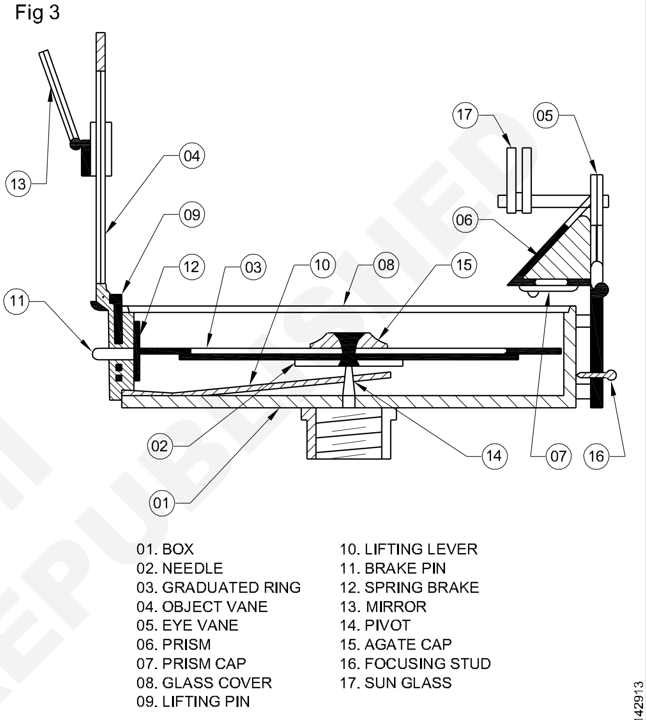
The compass cannot measure the angle directly. If it is desired to find out the angle between the two lines, firstly their angles with the magnetic meridian are determined separately and the difference of the two values is found which is equal to the angle between the lines.

**Types of compass:** The two forms of the compass commonly used are.

1 The prismatic compass
2 The surveyors compass
3 Trough compass
4 Compass and level

**The prismatic compass:** It is the most convenient portable magnetic compass, which can either be used as a hand instrument or can be fitted on a tripod. The main parts of prismatic compass are shown in Fig 3.

Fig 3




THE PRISMATIC COMPASS

**Construction (Fig 3)**

- The prismatic compass consists of cylindrical metal box (1) of 8 cm to 12 cm diameter in the centre of which is a pivot (2) carrying a magnetic needle (3) which is already attached to the graduated aluminium ring (4) with the help of an agate cap (5).
- The ring is graduated to half a degree and is read by a reflecting prism (6) which is protected from dust, moisture etc. by the prism cap (7).
- Diametrically opposite to the prism is the object vane (8) hinged to the box side and carrying a horse hair (9) with which an object is bisected.
- The eye is applied at the eye hole below the sighting slit (10).
- The graduations on the ring can be observed directly by the eye after they are reflected from the diagonal of the prism.
- The graduations can be made clearly visible by adjusting the prism to the eye sight by the focussing screw (11)

- Both the horizontal and vertical side faces of the prism are made convex to give magnified readings.
- To prevent undue wear of the pivot point the object vane is brought down on the face of the glass cover (12) which presses against a lifting pin (13)
- The needle is then automatically lifted off the pivot by the lifting lever (14).
- To damp the oscillations of the needle, before taking a reading and bring it to rest quickly the light spring brake (15) attached to the inside of the box is brought in contact with the edge of the ring by gently pressing inward the brake pin (16).
- If the bearings of very high (or) very low objects are taken the reflecting mirror (17) which slides on the object vane is tilted and image is bisected by the horse hair.
- A pair of sun glasses (18) shall have to be inter proposed between the slit and coloured vane when the sun or luminous of objects is to be bisected.
- A metal cover fits over the glass cover as well as the object vane when the compass is not in use.

Fig 4a

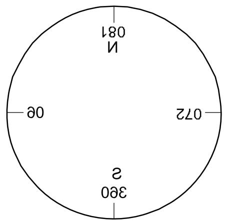
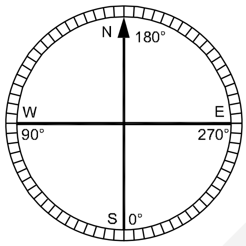



Fig 4b

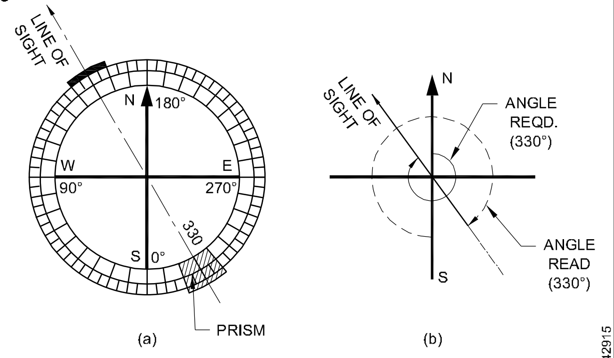



SYSTEM OF GRADUATION IN PRISMATIC COMPASS

SUN142914

- In the prismatic compass (Fig 4a) graduations are marked on the ring in a clockwise direction with 0 or 360 at south end of the needle.
- So that 90 is marked at the west 180 at the north and 270 at the east.
- The figures are written upside down as in Fig (4b)
- The greatest advantages of prismatic compass is that both sighting the object as well as reading circle can be done simultaneously without changing the position of the eye.

Fig 5




OBSERVATION AND READING IN PRISMATIC COMPASS

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The bearing shows $330^0$ at the observers end under the prism (i.e at the south end). (Fig 5)

**Surveyors compass:** It is similar to prismatic compass except with a following few modification. (Fig 6).

– The graduated ring is directly attached to the circular box and not with the magnetic needle.

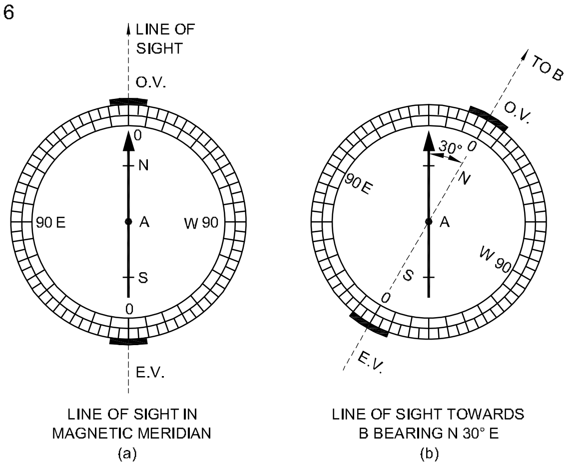
– The magnetic needle floats freely over the pivot.

– No prism is attached to the eye vane and it is having a narrow vertical slit.

– Readings are taken directly with naked eye against the north end of the needle.

– The ring is graduated in quadrated system of having $0^0$ at north and south ends, $90^0$ at East and west ends. Fig 6a shows the line of sight passes through the meridian. Fig 6b shows when the line of sight towards 'B' and the bearing is N $30^0$E.

Fig 6




SYSTEM OF GRADUATION IN SURVEYOR'S COMPASS

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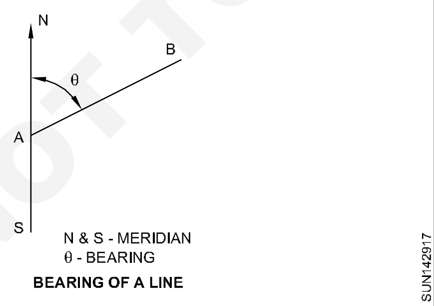
**Comparison between prismatic compass and surveyors compass**

| No. | Item | Prismatic compass | Surveyor's compass |
|---|---|---|---|
| 1 | Magnetic needle | The needle is broad type and needle does not act as index. | The needle is of edge bar type of needle and acts as the index also. |
| 2 | Graduated ring | The graduated ring is attached with the needle. The ring does not rotate along with the line of sight. | The graduated ring is attached to the box and not to the needle. The ring rotates along with the line of sight. |
| | | The graduations are in Whole circle bearing system, having $0^0$ at south end $90^0$ at west, $180^0$ at North and $270^0$ at East. | The graduations are in Quadrantile bearing system having $0^0$ at North and South, $90^0$ at East and West. East and west are interchanged |
| | | The graduations engraved are inverted | The graduations engraved are erect. |
| 3 | Sighting vane | The object vane consists of metal vane with a vertical hair | The object vane consists of a metal vane with a vertical hair. |
| | | The eye vane consists of a small metal vane with a slit | The eye vane consists of a metal vane with a fine slit. |
| 4 | Reading | The reading is taken with the help of a prism provided with the eye vane. | The reading is taken by directly seeing through the top of the glass. |
| | | Sighting and reading can be done simultaneously from one position of the observer. | Sighting and reading cannot be done simultaneously from one position of the observer. |
| 5 | Tripod | It is used with or without Tripod | It cannot be used without a Tripod. |

**Bearing of a line:** It is the horizontal angle which a line make with some reference direction also known as meridian. The reference direction may be any of the following. (Fig 7)

– True meridian.
– Magnetic meridian.
– An assumed meridian.

Fig 7




**True meridian:** True meridian of a place is a direction indicated by an imaginary circle passing round the earth through that place and the two north and south poles.

**True bearing:** The horizontal angle between a line and the true meridian is called true bearings of the line. It is also called as azimuth.

**Magnetic meridian:** The direction indicated by a freely suspended and properly balanced magnetic needle unaffected by local attractive forces is called the magnetic meridian.

**Magnetic bearings:** The horizontal angle which a line makes wiht this meridian is called magnetic bearings or simply bearings of the line.

**An assumed or Arbitary meridian:** Arbitrary meridian is any convenient direction towards a permanent and prominent mark or signal such as a church spire or top of a chimney. Such meridians are used to determine the relative positions of lines in a small area.

**Arbitary Bearings:** Arbitary bearings of a line is the horizontal angle which it makes with any arbitary meridian passing through the one of the extremities or the horizontal angle between a line and this arbitary meridian is called arbitary bearing of the line.

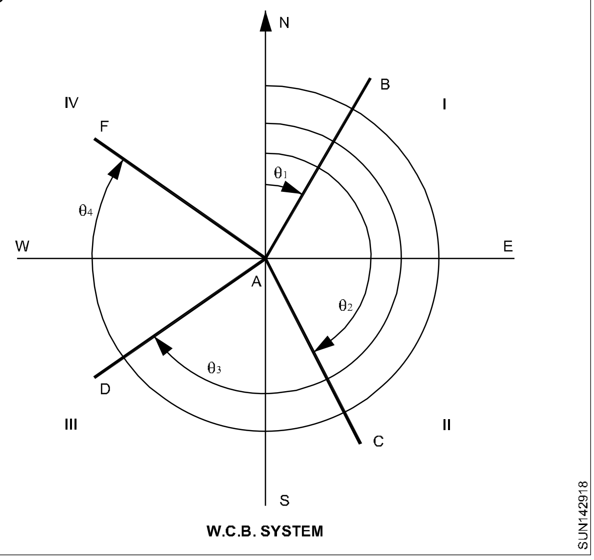
**Designation of Bearings:** The bearings are expressed the following two ways,

– Whole circle bearings.
– Quadrantal bearings.

**Whole circle bearing (W.C.B):** In this system, the bearings of a line, is measured from the magnetic north in clockwise direction. The value of the bearing thus varies from $0^0$ to $360^0$. The prismatic compass measures the bearings of lines in the whole circle system.

Referring Fig 8 the W.C.B of AB is $\theta_1$; of AC is $\theta_2$; of AD is $\theta_3$ and of AF is $\theta_4$.

Fig 8



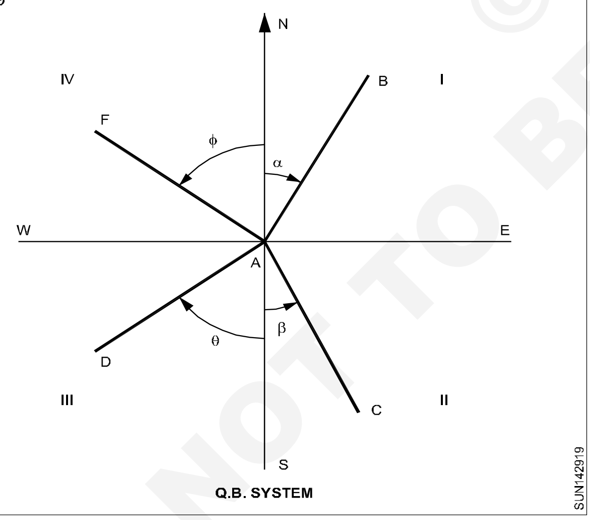
W.C.B. SYSTEM

**The Quadrantal bearings:** In this system, the bearings of a line is measured east ward or westward from north or south which ever is nearer. Thus both North and South are used as reference meridians and the directions can be either clockwise or anticlockwise depending upon the position of the line. These bearings are observed by surveyors compass.

Referring Fig 9 the QB of the line AB is $\propto$ and it is written as N $\propto$ E

The bearing of Line AC is $\beta$ and it is written as S $\beta$ E.

Fig 9



Q.B. SYSTEM

Similarly the bearing of Line AD and AF are written as S $\theta$ W and N $\phi$ W

**Conversion of Bearings from one system to other system**

**Reduced bearing:**

When the whole circle bearings exceeds $90^0$, then it is to be converted or reduced to quadrantal bearing system which has the same numerical values of the trigonometrical function is known as reduced bearing (R.B).

(i) Referring Fig 8, W.C.B system, the conversion of W.C.B into R.B can be expressed in the following table.

Table 1

| Line | W.C.B between | Rule for R.B | Quadrant |
|---|---|---|---|
| AB | $0^0$ and $90^0$ | R.B = W.C.B | NE |
| AC | $90^0$ and $180^0$ | R.B = $180^0$ - W.C.B | SE |
| AD | $180^0$ and $270^0$ | R.B = W.C.B - $180^0$ | SW |
| AF | $270^0$ and $360^0$ | RB = $360^0$ - W.C.B | NW |

(ii) Referring Fig 9 the conversion of R.B into W.C.B can be expressed in the following table.

Table 2

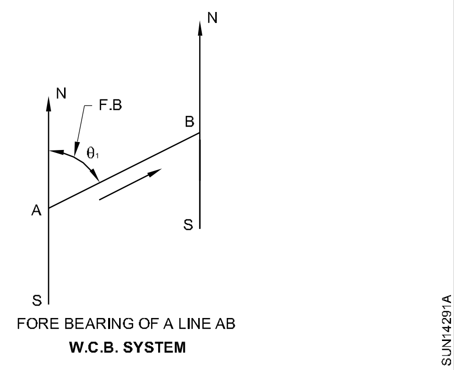
| Line | R.B | Rule for W.C.B | W.C.B between |
|---|---|---|---|
| AB | N $\alpha$ E | W.C.B = R.B | $0^0$ and $90^0$ |
| AC | S $\beta$ E | W.C.B = $180^0$ - R.B | $90^0$ and $180^0$ |
| AD | S $\theta$ W | W.C.B = $180^0$ + R.B | $180^0$ and $270^0$ |
| AF | N $\phi$ W | W.C.B = $360^0$ - R.B | $270^0$ and $360^0$ |

**Fore Bearings and Back Bearings:** Every line has two bearings, observed one at each end of the line. The bearing of a line taken in the progress of the survey or in the forward direction is the fore or forward bearing (F.B) of the line. While its bearing taken in the reverse or opposite direction is known as reverse or back bearing (B.B).

**Whole circle bearing system**

Fig 10 shows, the bearing of line AB expressed in the direction A to B is the F.B of AB

Fig 10



FORE BEARING OF A LINE AB

W.C.B. SYSTEM

The bearing of line AB when recorded in the opposite direction from B to A is B.B of AB (or) F.B of BA. (Fig 11)

In the whole circle system, the fore and back bearings of a line differ exactly by $180^0$.

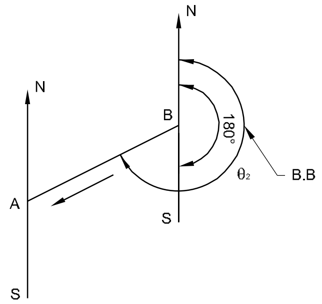
$\therefore$ B.B of a line = F.B $\pm$ $180^0$ [Equation 1]

| |
|---|
| **Use plus sign if the given F.B is less than $180^0$ and minus sign if it exceeds $180^0$.** |

**Quadrantal bearing system**

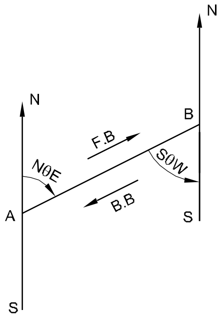
In the quadrantal system F.B and B.B are numerically equal but with opposite cardinal points. B.B of a line may, therefore be obtained by simply substituting N for S or S for N; and E for W or W for E in its fore bearings. (Fig 12)

Fig 11




BACK BEARING OF A LINE AB
**W.C.B. SYSTEM**

Fig 12




FORE BEARING OF AB = N θE
BACK BEARING OF AB = S θW
**QUADRANTIAL BEARING SYSTEM**

**Supposing F.B of a line is N $30^0$E then its B.B is equal to S $30^0$W**

**Example**

**Problems on conversion of bearing**

a) Convert the following W.C.B to quadrantal bearings.

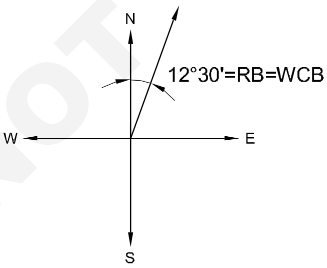
i) $12^0$ 30' ii) $160^0$ 30' iii) $210^0$ 30' iv) $285^0$ 30'

**Solution:**

**Applying the rules given in the table 1**

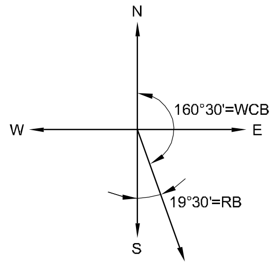
i) W.C.B = $12^0$30'
W.C.B = $12^0$ 30' which is less than $90^0$
∴ R.B = N $12^0$ 30' E (Fig 1)

Fig 13



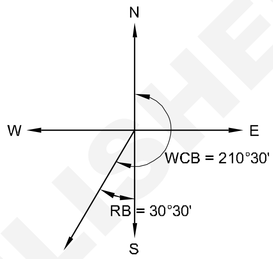

ii) W.C.B = $160^0$ 30'
The W.C.B is within $90^0$ to $180^0$
∴ RB = $180^0$ - W.C.B
= $180^0$ - $160^0$ 30'
= S $19^0$ 30' E (Fig 2)

Fig 14



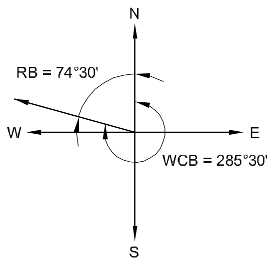

iii) W.C.B = $210^0$ 30'
The W.C.B is within $180^0$ to $270^0$
∴ RB = W.C.B - $180^0$
= $210^0$ 30' - 180'
= S $30^0$ 30' W (Fig 3)

Fig 15




iv) W.C.B = $285^0$ 30'
The W.C.B is with in $270^0$ to $360^0$
∴ R.B = $360^0$ - W.C.B
= $360^0$ - $285^0$30'
= N $74^0$ 30' W (Fig 4)

Fig 16




b) Convert the following quadranted bearings to whole circle bearings.

i) N $30^0$ 30' E ii) S $70^0$ 30' E iii) S $36^0$ 30'W

iv) N $85^0$30'W

**Solution:**

**Applying the rules given in Table 2**

i) Q.B = N $30^0$ 30'E

W.C.B = R.B = $30^0$ 30' (Fig 1)

ii) Q.B = S $70^0$ 30'E
W.C.B = $180^0$ - R.B
= $180^0$ - $70^0$ 30'
= $109^0$ 30' (Fig 2)

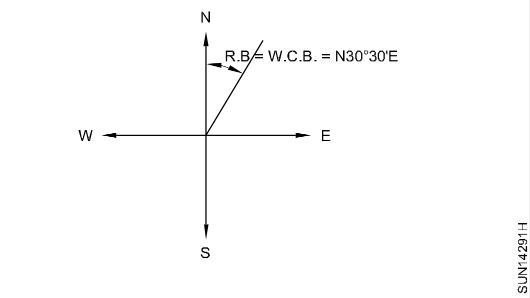



Fig 17

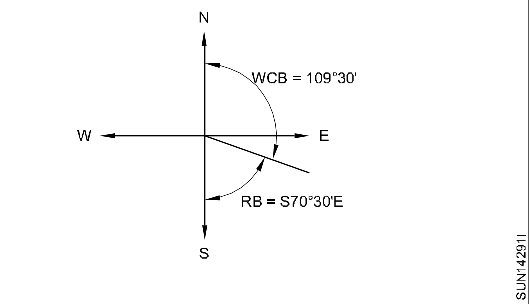



Fig 18

iii) Q.B = S $36^0$ 30'W

W.C.B = $180^0$ + Q.B

= $180^0$ + $36^0$ 30'

= $216^0$ 30' (Fig 3)

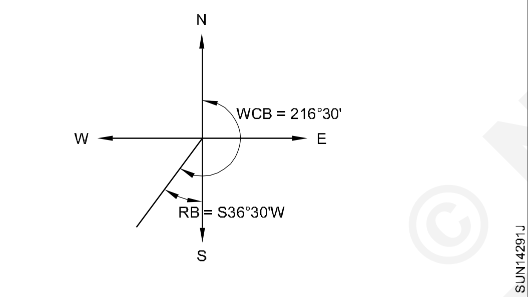



Fig 19

iv) Q.B = N $85^0$ 30'W

W.C.B = $360^0$ - $85^0$ 30'

= $274^0$ 30' (Fig 4)

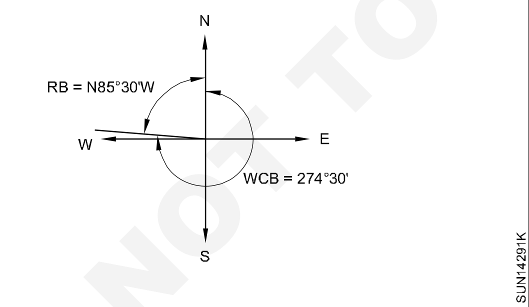



Fig 20

**Exercise**

1 Convert the following W.C.B to R.B

a) $87^0$ 30'

b) $120^0$ 30'

c) $210^0$ 00'

d) $266^0$ 30'

e) $310^0$ 30'

f) $359^0$ 30'

2 Convert the following R.B to W.C.B

a) N $46^0$ 30' E

b) S $20^0$ 30' E

c) S $10^0$ 30' W

d) N $50^0$ 30' W

**Example**

Find back bearings of the following observed fore bearings of lines AB $63^0$ 30'; BC $112^0$ 30'; CD $203^0$ 30'; DE $320^0$ 30'

**Solution**

From the equation (1)

B.B = F.B $\pm$ $180^0$

| **Using + sign when F.B is less than $180^0$ and - sign more than $180^0$** |
|---|

i) F.B of AB = $63^0$ 30' (Fig 1)

$\therefore$ B.B of AB = F.B of AB + $180^0$

= F.B of AB + $180^0$

= $63^0$ 30' + 180

= $243^0$ 30'

B.B of AB = $243^0$ 30'

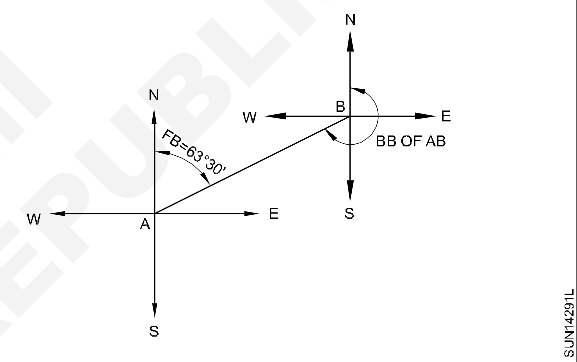



Fig 21

ii) F.B of BC = $112^0$ 30' (Fig 2)

B.B of BC = F.B of BC + $180^0$

= $112^0$ 30' + 180

= $292^0$ 30'

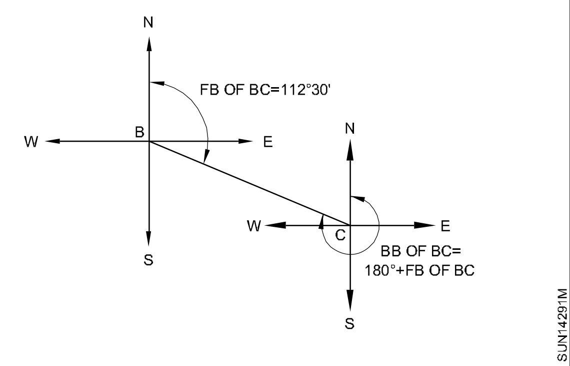



Fig 22

iii) F.B of CD = $203^0$ 30' (Fig 3)

B.B of CD = F.B of CD - $180^0$

= $203^0$ 30' - 180

= $23^0$ 30'

iv) F.B of DE = $320^0$ 30' (Fig 4)

B.B of DE = F.B of DE - $180^0$

= $320^0$ 30' - 180

B.B of DE = $140^0$ 30'

Fig 23

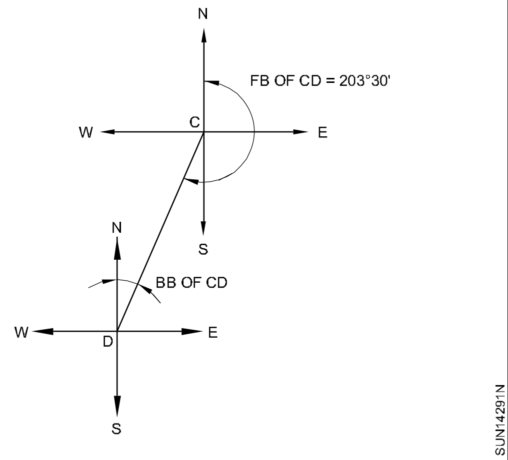
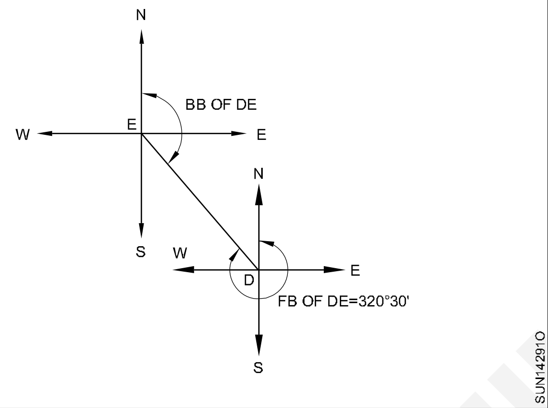



Fig 24




**Example :**

The fore bearing of the lines are as follows.
AB : N32$^0$ 30' E
BC : S 43$^0$ 30' E
CD : S 26$^0$ 30'W

DE : N 65$^0$ 35'W

Find their back bearings

**Solution:**

When bearings are expressed on the quadrantal systems, the back bearings of a line is numerically equal to its fore bearings but with opposite letters. Therefore

i) F.B of AB = N 32$^0$ 30' E (Fig 1)
$\therefore$ B.B of AB = S 32$^0$ 30' W

Fig 25

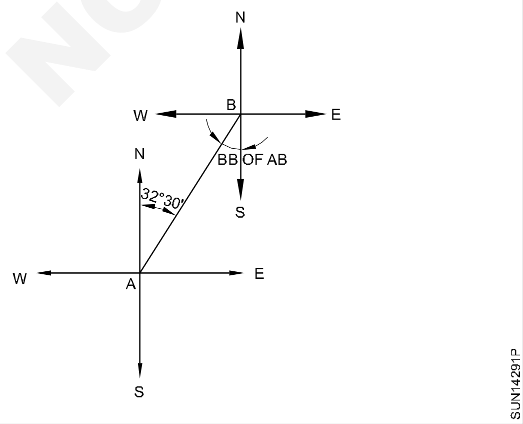
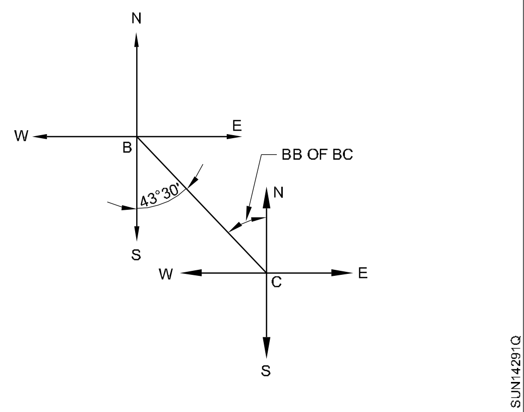
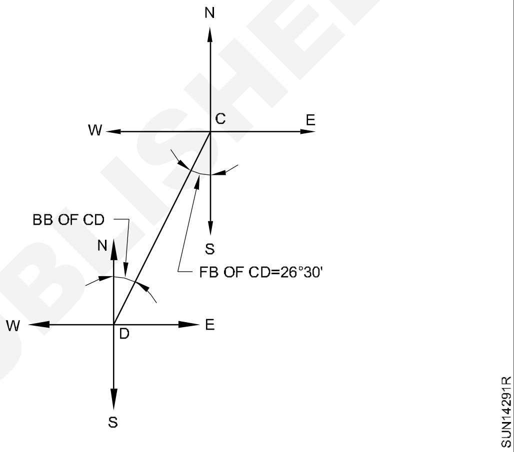



Fig 26



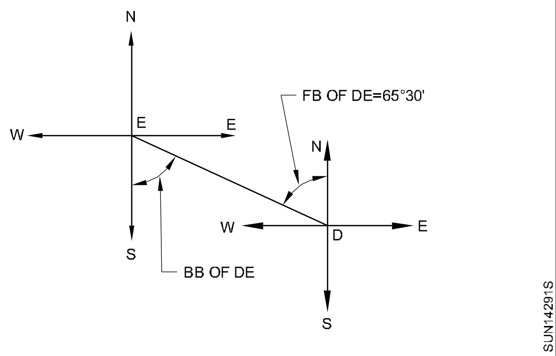

ii) F.B of BC = S 43$^0$ 30'E (Fig 2)
B.B of BC = N 43$^0$ 30'W

Fig 27




iii) F.B of CD = S 26$^0$ 30'W (Fig 3)
B.B of CD = N 26$^0$ 30' E

Fig 28




iv) F.B of DE = N 65$^0$ 30'W (Fig 4)
$\therefore$ B.B of DE = S 65$^0$ 30' E

**Exercise**

1 The following are the observed Fore bearing of the lines : AB = 88$^0$ 30' ; BC = 142$^0$ 30' ; CD = 209$^0$ 00' ; DE = 324$^0$ 30' Find their back bearing.

2 The fore bearings of the lines are as follows:

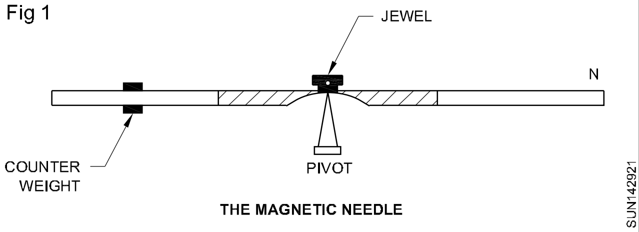
AB = N 26$^0$ 30' E; BC = S 78$^0$ 30' E; CD = S 69$^0$ 0'W; DE = N32$^0$ 30'W, Find their back bearings.

# Magnetic declination

**Objectives:** At the end of this lesson you shall be able to
- **define the dip of the magnetic needle**
- **state the magnetic declination and variations**
- **calculate true bearings**
- **state local attraction and its elimination**
- **explain about errors and its limits**
- **state the testing the prismatic compass.**

**Dip of the Magnetic Needle:** Before Magnetisation, the needle remains in the horizontal position if it is properly balanced, but after being magnetised, it cannot remain in the same position due to the magnetic influence of the earth. One end of the needle deflects downward towards the magnetic pole. In northern hemisphere the north end of the needle is deflected downward, and in the southern hemisphere the south end points downward. This inclination of the needle with the horizontal is known as the dip of the needle. (Fig 1)

Fig 1




THE MAGNETIC NEEDLE

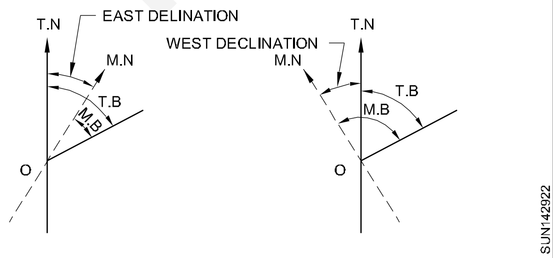
The amount of the dip is not uniform, but it varies in different parts of the earth. It varies from $0^0$ to $90^0$ (zero at equator and $90^0$ at the poles)

> **To keep the needle in the horizontal position, it is balanced by placing a brass sliding weight or rider at a suitable point over the higher end of the needle.**

**Magnetic declination:** In certain places, the magnetic meridian at a place does not coincide with the true meridian at that place. The horizontal angle which the magnetic meridian makes with the true meridian is known as magnetic declination or declination.

When the needle is deflected towards east of the true meridian it is called east declination and west declination when it is deflected towards west of the true meridian. (Fig.2)

Fig 2




The magnetic meridian differs from time to time on the earth's surface.

**Calculation of True bearings:**

**Rule 1**

True bearing of a line = Magnetic bearing of the line ± declination.

> **Use + sign when the declination is east**
> **Use - sign when the declination is west**

**Rule 2**

Magnetic bearing of a line = True bearing of the line ± declination

> **Use + sign when the declination is west**
> **Use - sign when the declination is east**

**Variations in Declination:** The declination is not constant for any places, but it changes from time to time and place to place.

The variations may be regular or irregular.

1 **Regular variations:** This variations may itself be analysed into several components of different periods and amplitudes. They are (i) Secular (ii) annual and (iii) diurnal or daily

   - **Secular variation:** The magnetic meridian swings like a pendulum. It swings in one direction for a long period and gradually comes to rest and then swings in the opposite direction.
   - **Annual variation:** It has a period of one year and therefore it is known as annual variations. The amount of variation is in difficult places 0 to ±12 minutes, but it is not remain constant at any place.
   - **Diurnal or daily variation:** It is an oscillation of the needle from its mean position during the day. The amount of this variation varies from 1 minute to about 12 minutes at different places.

2 **Irregular variations:** These are occured by magnetic storms such as earth quakes or volcanic erruptions and their amount may be even $1^0$ or $2^0$ at a time. It may occured at anytime. It cannot be prediteted.

**Calculate true bearing problems on magnetic declination:**

**Example 1**

The magnetic bearing of line is $197^0$. Find its true bearing, if the magnetic declination is $3^0$ W

**Solution** (Fig 3)

Using Rule 1

True bearing of the line = Magnetic bearing of the line ± declination.

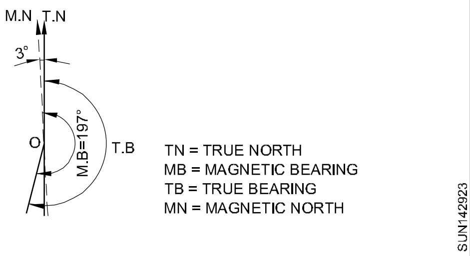
Use - sign because the declination is west.

True bearing of the line = Magnetic bearing of the line - declination.

$= 197^0 - 3^0$

$= 194^0$

Fig 3




**Example 2**

If the magnetic bearing of the line is N $37^0$ W and the magnetic declination is $2^0$ E Find the true bearing.

**Solution** (Fig 4)

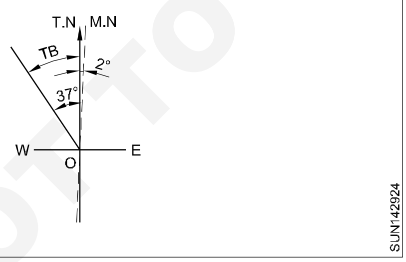
From Rule I

True bearing of a line = Magnetic bearing of line ± declination

$= N(37^0 - 2^0)$ W

$= N\ 35^0$ W

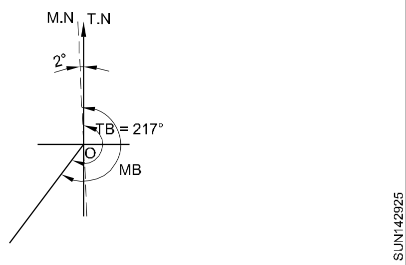
Fig 4




**Example 3**

True bearing of a line is $217^0$ and magnetic declination is $2^0$ w. Find the magnetic bearing.

Fig 5




**Solution** (Fig 5)

In Fig 5 Magnetic bearing of the line = True bearing of line + declination.

$= 217^0 + 2^0$

$= 219^0$

Use + sign declination in west.

**Example 4**

The magnetic and true bearing of a line are $327^0$ 14' and $324^0$ 37' respectively. Find the value of the magnetic declination at the place of observations.

If the annual change is 3' West what would be the magnetic and True bearing of the line four years since the date of the above measurement.

**Solution** (Fig 6)

Magnetic bearing of the line = $327^0$ 14'

True bearing of the line = $324^0$ 37'

$\therefore$ Declination = $327^0$ 14' - $324^0$ 37' = $2^0$37'

From Fig 6,

declination is west, ie $2^0$ 37'

Annual variation = 3' west

Variation in 4 years = 4 x 3' = 12' W

Total declination after 4 years = $2^0$ 37' + 12'

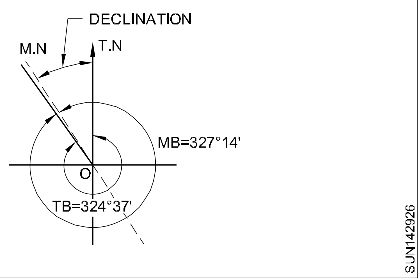
= $2^0$ 49' W

True bearing of a line after 4 years = $324^0$ 37' (Same as above)

magnetic bearing after 4 years = $324^0$ 37' + $2^0$ 49'

= $327^0$ 26'

Fig 6




**Example 5**

A line was drawn as its magnetic bearing $212^0$ on an old map when the magnetic declination was $4^0$W. To what bearing should if be set now if the present declination is $10^0$E

**Solution** (Fig 7)

When the declination was $4^0$W.

True bearing of the line = Magnetic bearing of the line - declination

$= 212^0 - 4^0$

$= 208^0$

When declination is $10^0$ East,

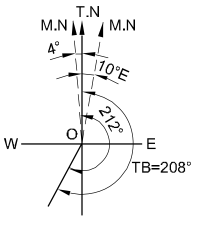
Magnetic bearing of the line = True bearing of the line - declination.

$= 208^0 - 10^0$

$= 198^0$

$\therefore$ To set the line now to the bearing of $198^0$

Fig 7




### Example 6

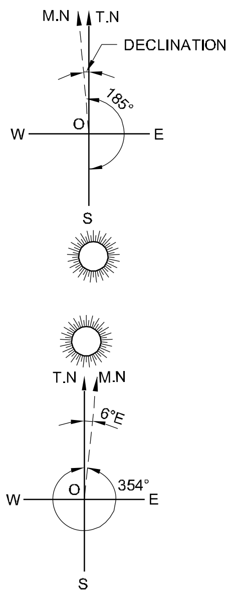
Find the magnetic declination if the magnetic bearing of the sun at noon is

1 $185^0$
2 $354^0$

**Solution** (Fig 8)

Fig 8(i)

Fig 8(ii)




i Magnetic Bearing of the line - $185^0$ (Fig 8(i))

At noon the sun is exactly on the True meridian. Since the magnetic bearing of the sun is $185^0$ it is at south pole

Magnetic declination = $185^0$ - $180^0$ = $5^0$ W.

ii Magnetic bearing of the line is $354^0$ (Fig. 8(ii))
The magnetic bearing of the True north is $354^0$
Magnetic declination = $360^0$ - $354^0$
= $6^0$ to the east of the true meridian.
Magnetic declination = $6^0$ E

### Exercise

1 The magnetic bearing of a line AB is $125^0$. Find its true bearing if the magnetic declination at A is (a) $9^0$ 0'W (b) $5^0$ 30'E

2 The true bearing of a line CD is $138^0$ 30' Find its magnetic bearing if the magnetic declination at c is (a) $5^0$ 30'W (b) $3^0$ 15'E

3 A line has a true bearing of $255^0$ . The declination is $3^0$ 30' E. Calculate the magnetic bearing on whole circle and reduced bearing systems.

4 Find the magnetic declination if magnetic bearings of the sun at noon, are, a) $182^0$ 00' b) $178^0$ 30' c) $359^0$ 0'

5 The true bearing of a line is N $30^0$ 30'E compute the magnetic bearing of the line if the magnetic declination is a) $4^0$ 15'E and b) $5^0$ 30'W.

**Local attraction:** A magnetic meridian of a place is established by the magnetic needle which is not attracted by other attractive forces. Always the magnetic needle pointing to the magnetic north.

If the compass is placed under the external attractive forces, like magnetic rock, iron ore, and also by steel structures, rails, electric cables, conveying electric current iron pipes. Iron lamp post etc. may affect the magnetic needle of the compass. Due to these external attractive forces, we can't able to find the normal position of the magnetic meridian. Such a disturbing force is known as local attraction.

**Detection of Local attraction:** The local attraction at a particular place can be detected by observing the fore and back bearings of each line and finding its difference. If it differs exactly by $180^0$ there is no local attraction at both stations, provided instrumental and observational errors are eliminated. But if the difference is not equal to $180^0$ then local attraction exists there either one or both stations.

### Elimination of Local attraction

If there is local attraction at a station all the bearings measured at that place will be incorrect. The amount of error will be equal in all the bearings. There are two methods for eliminating the effects of local attraction.

### First method

The amount and direction of error due to local attraction at each of the affected station is to be calculated.

If the observed bearings are in the **whole circle system**, then the correction applied by using the following rule after finding the nature of error.

**Rule:** If at a station, observed bearing of a line is more than that of its correct one, the error at this station is +ve and the correction is -ve and if the error is -ve at this station, the correction is +ve.

If the observed bearings are in the quadrantal system the corrections must be applied in proper direction.

In I and III quadrants the numerical value of bearings increased in clockwise direction and II and IV quadrants they increase in anticlocked wise direction. Hence +ve corrections are applied for clockwise and -ve corrections applied for anticlockwise directions.

### Example 1

The following bearing was observed in running a closed transverse

| Line | FB | BB |
|---|---|---|
| AB | $75^0$ 00' | $254^0$ 30' |
| BC | $115^0$ 30' | $296^0$ 30' |
| CD | $165^0$ 30' | $345^0$ 30' |
| DE | $225^0$ 00' | $44^0$ 00' |
| EA | $304^0$ 30' | $125^0$ 00' |

Find the error due to local attraction. Determine the correct bearings.

**Solution**

| **Line** | **FB** | **BB** | **Error** |
|---|---|---|---|
| AB | $75^0$ 00’ | $254^0$ 30’ | $0^0$ 30’ |
| BC | $115^0$ 30’ | $296^0$ 30’ | $1^0$ 00’ |
| CD | $165^0$ 30’ | $345^0$ 30’ | NIL |
| DE | $225^0$ 00’ | $44^0$ 00’ | $1^0$ 00’ |
| EA | $304^0$ 30’ | $125^0$ 00’ | $0^0$ 30’ |

From the above calculation we came to know that the stations C and D are free from local attraction and all other stations are having local attractions. Hence the observed bearings at the stations C and D are correct.

Commencing from the fore bearing of ‘DE’ all other incorrect bearings can be calculated as follows.

Observed F.B of DE = $225^0$ 00’
Deduct = $180^0$ 00’
-------------
Corrected B.B of DE $45^0$ 00’
Observed B.B of DE = $44^0$ 00’
-------------
Error at station E (-) $1^0$ 00’

Observed FB of EA = $304^0$30’
Correction at station E = (+) $1^0$ 00’
-------------
Corrected FB of EA = $305^0$ 30’
Deduct $180^0$ 00’
-------------
Correct B.B of EA = $125^0$ 30’
Observed B.B of EA = $125^0$ 00’
-------------
Error at station A (-) $0^0$ 30’
-------------
Observed F.B of AB = $75^0$ 00’
Correction at station A (+) $0^0$ 30’
-------------
Corrected FB of AB = $75^0$ 30’
Add $180^0$ 00’
-------------
Corrected BB of AB = $255^0$ 30’
Observed BB of AB $254^0$ 30’
-------------
Error at station ‘B’ (-) $1^0$ 00’
-------------
Observed F.B of BC = $115^0$ 30’
Correction at station ‘B’ = (+) $1^0$ 00’
-------------
Corrected FB of BC = $116^0$ 30’
Add $180^0$ 00’
-------------
Corrected B.B of BC $296^0$ 30’
-------------
Observed B.B of BC’ = 296.30

Hence OK

| Line | F.B | B.B | Correction | Corrected | |
|---|---|---|---|---|---|
| | | | | FB | BB |
| AB | $75^0$ 00’ | $254^0$ 30’ | (+) $0^0$ 30’ at ‘A’ | $75^0$ 30’ | $255^0$ 30’ |
| BC | $115^0$ 30’ | $296^0$ 30’ | (+) $1^0$ 00’ at ‘B’ | $116^0$ 30’ | $296^0$ 30’ |
| CD | $165^0$ 30’ | $345^0$ 30’ | Nil at ‘C’ | $165^0$ 30’ | $345^0$ 30’ |
| DE | $225^0$ 00’ | $44^0$ 00’ | Nil at ‘D’ | $225^0$ 00’ | $45^0$ 00’ |
| EA | $304^0$ 30’ | $125^0$ 00’ | (+) $1^0$ 00’ at ‘E’ | $305^0$ 30’ | $125^0$ 30’ |

**Example 2**

The following bearings were taken in traversing with a compass in a place where local attraction was suspected.

| Line | F.B | B.B |
|---|---|---|
| AB | N $46^0$ 00’E | S $46^0$ 00’W |
| BC | S $60^0$ 30’E | N $61^0$ 30’W |
| CD | S $10^0$ 30’E | N $9^0$ 00’W |
| DA | N $79^0$ 00’W | S $79^0$ 30’E |

At what station do you suspect local attraction? Determine the correct bearings of each line.

**Solution**

If the numerical value of Fore and back bearings of a line is same there is no local attraction. Examining the above problem the station A and B are free from local attraction. The stations C and D are having local attraction and to be corrected.

Fore and Back bearings of AB are correct
Fore bearing of BC = S $60^0$ 30’E
Corrected B.B of BC = N $60^0$ 30’ W
Observed B.B of BC = N $61^0$ 30’ W
Difference = (+) $1^0$ 00’ error at ‘c’

Observed F.B of CD = S $10^0$ 30’E
Correction at C’ = (-) $1^0$ 00’
------------------
Corrected FB of CD = S $9^0$ 30’E
Corrected B.B of CD = N $9^0$ 30’W
Observed B.B of CD = N $9^0$ 00’ W
------------------
Difference (-) $0^0$ 30’ error at D
------------------
Observed F.B of DA = N $79^0$ 00’W
Correction at D = (+) $0^0$ 30’
------------------

Corrected F.B of DA = N $79^0$ 30'W
Corrected B.B of DA = S $79^0$ 30'E
------------------
Observed BB of DA = S$79^0$ 30' E
------------------

Hence error at A is N

| Line | Corrected | | Remarks | Observed | | Correction |
|---|---|---|---|---|---|---|
| | F.B | B.B | | FB | BB | |
| AB | N $46^0$ 00'E | S $46^0$ 00'W | NIL at 'A' | N $46^0$ 00' E | S $46^0$ 00' W | |
| BC | S $60^0$ 30'E | N $61^0$ 30'W | NIL at 'B' | S $60^0$ 30' E | N $60^0$ 30' W | |
| CD | S $10^0$ 30'E | N $9^0$ 00'W | -$1^0$ 00' at C | S $9^0$ 30' E | N $9^0$ 30' W | |
| DA | N $79^0$ 00'W | S $79^0$ 30'E | + $0^0$ 30' at D | N $79^0$ 30' W | S $79^0$ 30' E | |

**Example 3**

The following bearings were recorded for a closed compass transverse

| Line | F.B | B.B |
|---|---|---|
| AB | $74^0$ 30' | $256^0$ 00' |
| BC | $107^0$ 00' | $286^0$ 30' |
| CD | $224^0$ 30' | $44^0$ 30' |
| DA | $308^0$ 00' | $127^0$ 00' |

Which stations are affected by local attraction. Determine the correct bearings. Find the true bearings if the declination was $2^0$ 00' west

**Solution**

Fore and Back bearings of the line CD differ exactly by $180^0$, therefore stations C and D are free from local attraction. Consequently bearings taken at these stations are correct.

Fore and back bearings of CD are correct
F.B of DA = $308^0$ 00'
Subtract = $180^0$ 00'
-------------
Corrected B.B of DA = $128^0$ 00'
Observed B.B of DA = $127^0$ 00'
-------------
Difference (-) $1^0$ 00' error at A
-------------

Observed F.B of AB = $74^0$ 30'
Correction = (+) $1^0$ 00'
-------------
Corrected F.B of AB = $75^0$ 30'
Add = $180^0$ 00'
-------------
Corrected B.B of AB $255^0$ 30'
Observed B.B of AB $256^0$ 00'
----------------
Difference (+) $0^0$ 30' error at 'B'
----------------

Observe F.B of BC = $107^0$ 00'
Correction at B = (-)$0^0$ 30'
-------------
Corrected F.B of BC = $106^0$ 30'
Add = $180^0$ 00'
-------------
Corrected B.B of BC = $286^0$ 30'
Observed B.B of BC = $286^0$ 30'
Hence O.K

Which agrees to the given B.B of BC observed at the station C which is free from local attraction. Having corrected the bearings of the lines, their true bearings may be determined by subtracting $2^0$ 00' from the corrected bearings of the lines, since the magnetic declination is west. The results may be tabulated as follows.

| Line | Observer | | Correction | Corrected | | Decli nation | True | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | F.B | B.B | | F.B | B.B | | F.B | B.B | |
| AB | $74^0$ 30' | $256^0$ 00' | (+) $1^0$ at A | $75^0$ 30' | $255^0$ 30' | Declination being 2°00'W T,B of line = MB -2° | $73^0$ 30' | $253^0$ 30' | Stations C and D are free from local attraction. |
| BC | $107^0$ 00' | $286^0$ 30' | (-) $0^0$ 30' at B | $106^0$ 30' | $286^0$ 30' | | $104^0$ 30' | $284^0$ 30' | |
| CD | $224^0$ 30' | $44^0$ 30' | $0^0$ at C | $224^0$ 30' | $44^0$ 30' | | $222^0$ 30' | $42^0$ 30' | |
| DA | $308^0$ 00' | $127^0$ 00' | $0^0$ at D | $308^0$ 00' | $128^0$ 00' | | $306^0$ 00' | $126^0$ 00' | |

**Second method**

In this method the included angles for all stations are computed from the observed bearings and check it with the sum of theoritical angles and correct the angles. Then commencing from the unaffected line and using these included angles the correct bearings of the successive lines are computed.

**Example 4**

The observed bearings of the lines AB, BC, CD and DA are as follows, Find which station is free from local attraction and workout the correct bearings.

| Line | F.B | B.B |
|---|---|---|
| AB | $46^0$ 00’ | $226^0$ 00’ |
| BC | $119^0$ 30’ | $299^0$ 00’ |
| CD | $170^0$ 00’ | $351^0$ 00’ |
| DA | $280^0$ 00’ | $99^0$ 30’ |

**Solution**

On examining the values of the observed bearings of the lines, it will be seen that fore and back bearings of the line AB only differ by $180^0$. Stations A and B are therefore both free from local attraction and the observed fore and back bearings of AB are correct. Now the true included angles between the lines are computed from the observed bearings of the lines.

From the Fig 9

$\angle A = 99^0 30' - 46^0 00 = 53^0 30'$

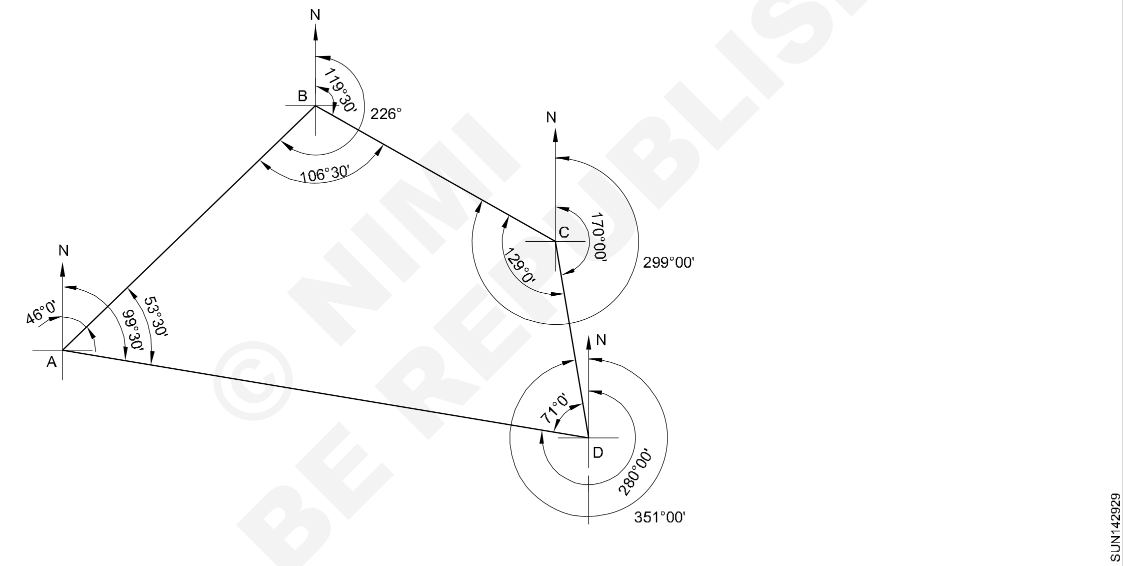
$\angle B = 226^0 00' - 119^0 30' = 106^0 30'$

$\angle C = 299^0 00' - 170^0 00' = 129^0 00'$

$\angle D = 351^0 00 - 280^0 00 = 71^0 00'$

| | |
|---|---|
| $\angle A = 53^0 30'$ | Theoretical Check |
| $\angle B = 106^0 30'$ | $(2n - 4)\ 90^0$ |
| ĐC = 129°.00 | (2x 4 - 4) 90° |
| $\angle D = 71^0 00'$ | $4 \times 90^0 = 360^0$ |

Fig 9

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Total $360^0$ 00’

------------------

| | |
|---|---|
| Fore bearing of AB | = $46^0$ 00’ |
| Add | = $180^0$ 00’ |
| | --------------- |
| B.B of AB | = $226^0$ 00’ |
| Subtract $\angle B$ | = $106^0$ 30’ |
| | --------------- |
| Fore bearing of BC | = $119^0$ 30’ |
| Add | = $180^0$ 00’ |
| | --------------- |
| Corrected B.B of BC | = $299^0$ 30’ |
| Subtract $\angle C$ | = $129^0$ 00’ |
| | --------------- |
| Corrected fore bearing of CD | = $170^0$ 30’ |
| Add | = $180^0$ 00’ |
| | --------------- |
| Corrected B.B of CD | = $350^0$ 30’ |
| Subtract $\angle D$ | = $71^0$ 00’ |
| | --------------- |
| Corrected fore Bearing of DA | = $279^0$ 30’ |
| Subtract | $180^0$ 00’ |
| | --------------- |
| Corrected B.B of DA | $99^0$ 30’ |
| Subtract $\angle A$ | $53^0$ 30’ |
| Check | --------------- |
| Fore bearing of AB | = $46^0$ 00’ |

which agrees to the given FB of AB observed at station A, which is free from local attraction.

**Exercise 1**

The following bearings were observed on a compass traverse

| Line | F.B | B.B |
|---|---|---|
| AB | $80^0$ 30’ | $260^0$ 00’ |
| BC | $130^0$ 30’ | $311^0$ 30’ |
| CD | $240^0$ 30’ | $60^0$ 30’ |
| DA | $290^0$ 30’ | $11^0$ 00’ |

make correction for local attraction and declination of 1$^{0}$ 30’W and calculate true bearings.

**Exercise 2**

The following are the bearings taken on a closed compass traverse

| Line | F.B | B.B |
|---|---|---|
| AB | S37$^{0}$30’E | N37$^{0}$30’W |
| BC | S43$^{0}$15’W | N44$^{0}$15’E |
| CD | N73$^{0}$00’W | S72$^{0}$15’E |
| DE | N12$^{0}$45’E | S13$^{0}$15W |
| EA | N60$^{0}$00’E | S59$^{0}$00’W |

Compute the interior angles and correct them for observational errors.

**Permissible Error in compass surveying:** The Permissible Error should not exceed 7½ minute. But due to magnetic changes and variations of declination the error should not exceed 10minutes.

**Plotting of a campass traverse**

Before plotting a traverse survey on the drawing sheet, first to draw a rough sketch on the paper.

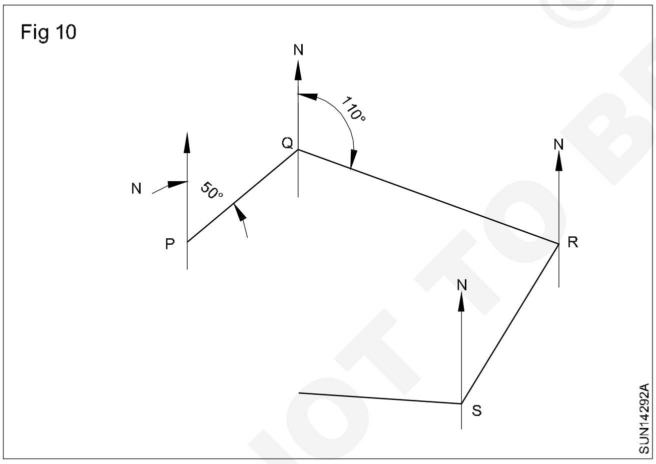
From this we can able to know the size and shape of the plan and also the best way to arrange it on the drawing sheet.

From the observed bearings, corrected bearings are calculated before plotting.

The following methods are used for plotting a traverse survey.

**By parallel meridian through each station (Fig 10)**

Fig 10




First fix the position of the starting point P on the paper.

From this point P draw the magnetic meridian.

Plot the bearing of the line PQ with the protractor.

Cut the length of the line PQ with suitable scale.

Now the station point Q is fixed.

From Q, draw a line which is parallel P to magnetic meridian.

Plot the bearing of the line QR and cut off the length of the line QR.

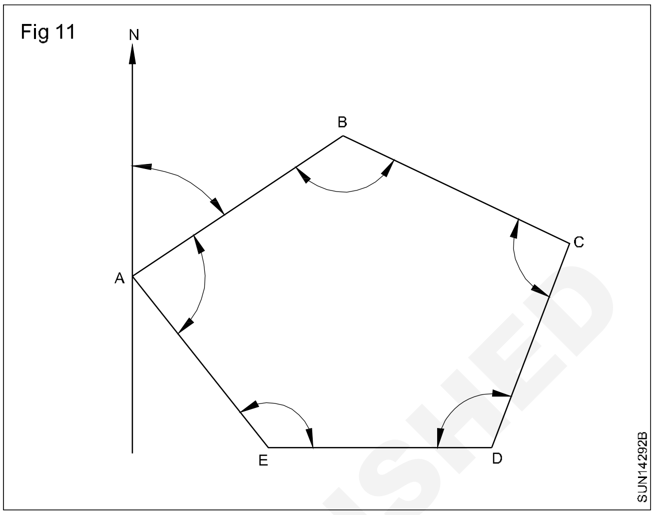
Repeat the same process until all the lines are drawn.

If the traverse is a closed one the last line must coincise with the starting station P.

If not the error is called as closing error.

**By included angle method (Fig 11)**

Fig 11




Before plotting the included angle method of the corrected bearings are calculated first, from the observed bearings.

From the corrected bearings, the included angles are calculated.

From the starting station A, draw a line representing the magnetic meridian.

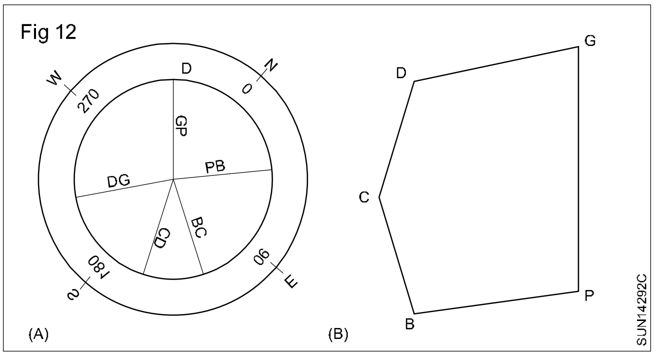
From A, draw the bearing of the line AB, and cut off the length AB according to scale, thus fixing of the station 'B'.

From B draw the included angle ABC.

The same process may be repeated at each successive stations.

**By paper protractor (Fig 12)**

Fig 12



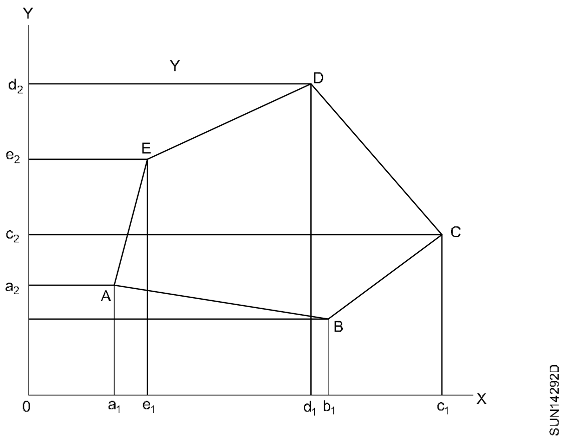

First mark any point 'O' on the paper and draw the bearing of each line with reference to the magnetic meridian by using large circular paper protector is shown in Fig. (a).

Transfer the direction of all the lines to their proper positions and taking length of each line is shown in Fig. (b).

**By rectangular co-ordinate method (Fig 13)**

Firstly, the points of the traverse are plotted by their coordinates with respect to x-axis and y-axis. The x axis and y axis are intersecting at 'O'.

Fig 13




- The line OX is representing the magnetic meridian.
- Every point is plotted independently with reference to the axes.

Firstly, the co-ordinates of each point are calculated.

This method is mainly used in plotting of traverse by using Theodolite instrument.

- It is more accurate method of plotting.
- In this method the errors are not accumulate.

**Closing Error And its graphical Adjustments:** While plotting a closed traverse the starting and the ending points will coincide otherwise if the ending points fails to meet with the starting one is called the closing error or error of closure.

**The closing error occurs due to wrong measurement of lengths and bearing of lines in the field and due to faulty plotting.**

**When the closing error exceeds permissible limit, the field work is repeated. But the error is found to be within the permissible value, the traverse may be adjusted.**

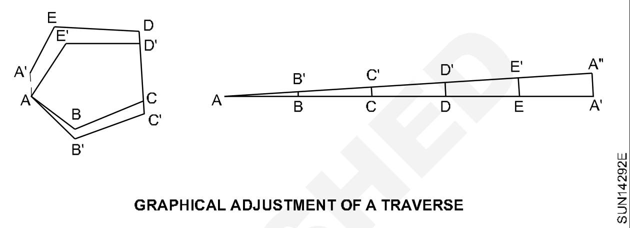
When the angular and linear measurements are of equal precision graphical adjustment of the traverse may be used. This method is based on the Bowditch's rule.

**The correction may be applied both lengths as well as to bearings of the lines in proportion to their lengths.**

The adjustment of a compass traverse graphically, may be made as under.

**Procedure** (Fig 14)

Fig 14




GRAPHICAL ADJUSTMENT OF A TRAVERSE

Let ABCDEA' be a closed traverse as plotted from the observed magnetic bearings and linear measurements of the traverse lengths. A is the starting station and A' is the location of the station A as plotted. Hence, A'A is the closing error.

## Introduction of CAD

**Objectives :** At the end of this lesson, you shall be able to
- **define the computer and CAD**
- **describe history of computer**

**Autocad**

AutoCAD is the leading computer -aided design and drafting (CAD) program in the world. Since its original introduction in November, 1982, AutoCAD has grown in sales and functionality to become the standard PC-based CAD program against which all other similar programs complete and against which they are judged. Over the years, AutoCAD has kept pace with developments in the computer industry. The program has grown from its original command line driven DOS-based roots to become a fully compatible windows application.

There are two main categories of computer software:

- **System software**
- **Application program**

The system software manages the internal operations of the computer. The application programs are tools that help you accomplish your work, such as CADD.

**CADD HARDWARE**

The following are the main hardware components of CADD

- System unit
  - Central processing unit
  - Memory
  - Hard disk, CD-ROM pen drive
- External storage devices
- Monitor
- Printers and plotters
- Keyboard
- Digitizer, puck and mouse

**System Unit**

The system unit is the computer that is used for all data processing. The main components of the system units are the central processing unit (CPU) and memory. In mainframe and minicomputers CPU and memory are usefully separate compartments that house thousands of devices. In today's PCs, however, they all fit in a small box commonly known as a desktop computer. Most desktop computers today come equipped with a hard disk, and CD ROM. Let us have a look at the components of a system unit:

- Central processing unit
- Memory
- Hard disk, CD-ROM

**External storage devices**

There are a number of external storage devices available such as magnetic tapes, zip drives and removable hard disks. They are commonly used to keep backup copies of electronic files for safekeeping.

Magnetic tapes are quite common for storing large volumes of data. A magnetic tape that looks like a small videocassette can store thousands of megabytes of data. However, they are quite slow and require a lot of time to store or retrieve data.

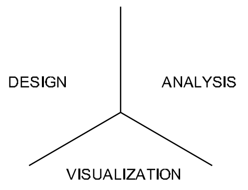
The new option for data storage is the removable hard disk. You can remove the entire hard disk from your computer and use it on another computer. This approach is commonly used when you need to work on different computers and you want the same information to be available instantly.

**Computer Aided Design (CAD):** is simply, design and drafting with the aid of a computer. Design is creating a real product from an idea. Drafting is the production of the drawings that are used to document a design. CAD can be used to create 2D or 3D computer models. A CAD drawing is a file that consists of numeric data in binary form that will be saved onto a disk.

Learning to use a CAD system is similar to learning a new language. It is necessary to begin with the basic alphabet and learn how to use it correctly and effectively through practice. This will require learning some new concepts and skills as well as learning a different vocabulary. Today, the majority of the Mechanical CAD systems are capable of creating three-dimensional solid models. Nonetheless, all CAD systems create designs using basic geometric entities and many of the constructions used in technical designs are based upon two-dimensional planar geometry. The method and number of operations that are required to accomplish the basic planar constructions are different from one system to another.

In general, a Computer Aided Design (CAD) package has three components: a) Design, b) Analysis, and c) Visualization, as shown in the sketch. A brief description of these components follows.

Fig 1




COMPONENTS OF COMPUTER AIDED DESIGN

DC2601E1

## Hardware and Software Overview

There are two parts of a computer system, hardware and software, and a CADD system in no exception. Computer hardware is the physical components of the computer such as system unit, monitor and plotter. Computer software is the program that determines the application of a system.

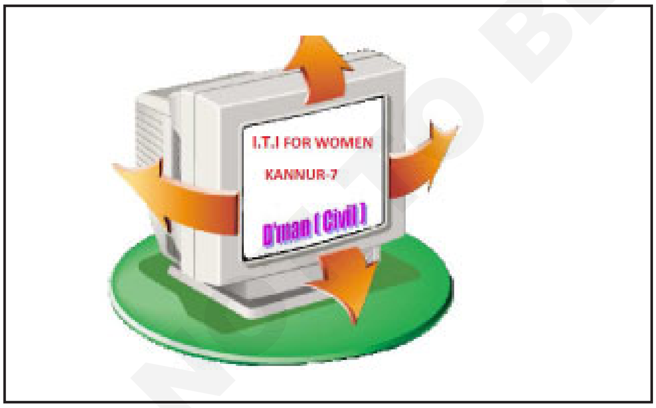
There are three main categories of computers with respect to hardware:

- Mainframe
- Minicomputer
- Microcomputers, for example personal computers (PCs)

## The Monitor

The monitor is the computer screen and is used to display information. A good monitor is very important for CADD in order to display fine graphics. A colour monitor is essential because many CADD drawing techniques are

based on colours. Monitors are available in various sizes ranging from 13" to 30" or more. Today, average monitors have the ability to display millions of colours.



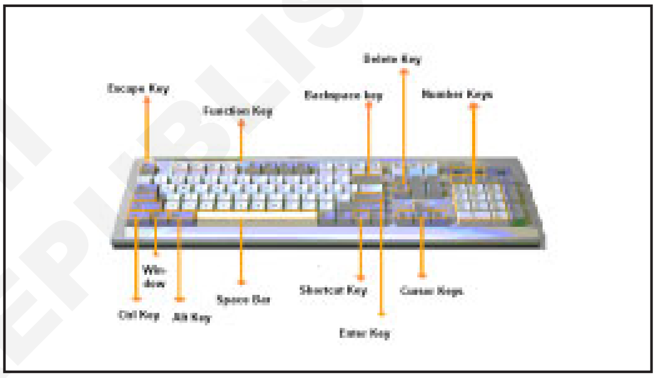

## Printers and Plotters

CADD drawings are printed using fine-quality printers and plotters. Drawings are neat and clean and as accurate as the naked eye can see. You can print drawings at as much as 1200-dpi (dots per inch) accuracy. This means 1200 dots are printed in a non-inch-long line! All the text dimensions and other graphics are printed highly accurate, neat and crisp. You can print drawings with a lot of variations; for example, drawings can be printed with different sizes, line types, text fonts and colours.

There are a variety of printers and plotters available in the computer industry. They work on different principles and their prices very significantly. There are many types of pen plotters, ink-jet printers, laser printers and plotters, electrostatic printers, etc.


## Key board

**Key board** - This is an input devices. Which contains keys to feed information in to the computer.




**Type writer key**: Used for letters, numbers and punctuation symbol.

**Function Keys:** F1 to F12 performs depend on the software use.

**Cursor control keys**: To move the cursor to the left, right, up, or down.

**Page up and Down key:** To move the preceding page and to move the text page.

**Home Key:** To the top of the Document

**End Key:** To end of the Document

**Num Lock Key:** Numeric 0-9, pressing any of them, a number gets displayed on the screen.

**Caps Lock Key:** By pressing, type letters will appear in the small or capital.

**Shift Key:** To appear the upper symbol, if Hold Down this key.

**Ctrl & Alt Key:** Often used in combination with other keys to carry out special actions. By pressing Ctrl, Alt 7 Delete keys simultaneously, the machine automatically Restart.

**Enter Key:** In alert PC that finish given instruction to execute the Instructions.

**Tab Key:** Move the cursor along the line to a preset point and also to move from one option to another in a menu.

**ESC KEY:** To cancel or to ignore the entry or command that just Entered.

**Delete Key:** Erase the character to the place to the right side of the Blinking cursor.

**Back Space Key:** Erase the character to the left side of the blinking curser, also it moves the cursor back.

**Digitizer, Puck and Mouse**

The digitizer (also known as a graphic tablet) and the puck are the data input devices most commonly used in CADD systems. These devices allow you to enter point locations on the screen and to make selections from the menus. As the puck is moved over the surface of the digitizer, it moves the indicator (cursor) on the screen relatively. To enter a point, you need to position the cursor at the appropriate position on the screen and then press the "Enter" button on the puck.

**CADD Software**

A CADD program contains hundreds of functions that enable you to accomplish specific drawing tasks. A task may involve drawing an object, editing and existing drawing, displaying a view of the drawing, printing or saving it, or controlling any other operation of the computer. The functions contain a number of commands that enable you to specify exactly what you want to do and how you want to do it.

The functions are organized into modules that provide easy access to all the commands. The program is divided into modules such as draw, edit, data output, function control, data storage and management. A program may also have a number of specialized functions such as layers, database and 3D. Let s have a look at the CADD modules:

- Draw
- Edit
- Data output
- System control
- Data storage and management
- Special features

**Draw**

The draw module provides access to all the drawing functions of CADD. Whenever you need to draw something this group of functions is used. The draw module enables you to draw lines, arcs, circles, ellipses, text, dimensions, symbols, borders and many other drawing components.

Draw is CADD s most frequently used module because all drawing work is accomplished using it.

**Edit**

The edit module lets you change existing drawing elements and manipulate them in a number of ways. You can move, copy or erase drawing components. You can enlarge or reduce the sizes of diagrams or change the colour and line type of drawing components. You can also change the size and style of text and dimensions, as well as edit a dimension to show different units of measurement. A good CADD program is designed to change the appearance of all drawing elements created with CADD.

The edit functions also act as convenient drawing-aid tools. They enable you to join missing corners of lines, trim drawing components along a line, stretch them to fit a new shape, etc. The list of editing capabilities goes on and on. The edit functions make CADD a dynamic drawing tool.

**Data Output**

The data output module enables you to display drawings on the screen and then print them on paper. There are two separate sets of functions that help accomplish this:

- **View - display functions**
- **Print/plot functions**

The view-display functions allow you to display different views of a drawing on the screen. These functions are used quite often, because every time you need to draw something or edit something, you need to focus on that portion of the drawing. With the help of view-display functions, you can zoom in on a specific portion of the drawing.

The print and plot functions allow you to print drawings using a printer or a plotter. You can control many aspects of printing and plotting. You can print the same drawingin different sizes by applying the appropriate scale factor. You can plot the drawings with specific colours, pen thickness, and line types.

**Data storage and Management**

The data storage and management module allows you to store and manage drawing data. Through the use of the functions in this module, you can store drawings as files on the hard disk. You can manage the files in directories and sub-directories, and move, copy or delete them as needed.

CADD data management functions also let you translate drawings created by other CADD programs. These functions convert drawing data to a generic format that can be read by any CADD program. Data exchange format

(DXF) is one of the common data translation formats used by CADD program. There are a number of data exchange formats available.

**System Control**

The system control module (also known as system defaults) allows you to control how CADD works. CADD programs are designed for a broad range of professionals, including architects, designers, engineers and surveyors. With the help of system control functions, you can set the working environment of CADD to suit your needs.

**Example:** You can set the type of units that you will be using, the accuracy of the units, a style for dimensions and text, colours, layers, line type in a drawing, etc. Additionally, you can customize screen menus, the display of colours on the screen, resolution of the screen, size, the speed of the cursor, etc.

You can also specify whether the selected defaults should apply to a single drawing, to a specific project, or to all the projects in a specific category. The defaults can be set on a temporary or permanent basis.

**Special Features**

CADD programs usually offer a number of special features that make working with CADD easier and allow you to automate many drawing tasks. For example, you can create layers in a drawing that allow you to segregate drawing components. You can develop spreadsheets and databases that can be used to create many types of project reports. You can create three-dimensional (3D) drawings, such as isometrics and perspectives, with the help of 3D functions. You can also accomplish many other automated tasks with the help of macros.

The number of special features a CADD program has or how elaborate they are various from one program to another. Some vendors sell specialized features as separate packages, while others include them in a single package. It all depends how a program is written, how big or small it is, and how it is sold.

**CADD User Interface**

CADD user interface provides the environment and the tools that allow you and the computer to communicate. Each CADD program establishes an environment that best suits its purpose. The goal is to make working with CADD efficient. Most programs use a Graphic User Interface (GUI) to communicate with the user. The GUI provides visual aids for quick data entry. You are given tools to select functions, enter textual or mathematical data, locate points in the drawing window, select objects in the drawing window, etc.

## Computer Aided drafting and designs

**Objectives :** At the end of this exercise, you shall be able to
- **define CAD**
- **enumerate System requirement for CAD,2015**
- **explain starting up CAD 2015.**

**Introduction** - Computer Aided Design the ideas of a designer can be represented as mathematical and graphical models in a computer. Further, it involves the use of a computer to develop analysis or modify an engineering design. The designs process is an iterative procedure which involves the following four steps.

i Geometric modelling
ii Engineering analysis
iii Design review and evaluation
iv Automated drafting

**Definition**: Auto CAD is the most popular computer Aided Designs and Drafting software from Auto desk, a leading U.S based company.

**System requirements for AutoCAD 2015**

| | |
|---|---|
| Operating System | Microsoft windows 8/8.1<br>Microsoft windows 8/8.1 pro<br>Microsoft windows 8/8.1 Enterprise<br>Microsoft windows 7 Enterprise<br>Microsoft windows 7 Ultimate<br>Microsoft windows 7 Professional<br>Microsoft windows 7 Home Premium |
| CPU | Type: For 32-bit AutoCAD 2015:<br>32-bit Intel Pentium 4 or AMD Athlon Dual Core, 3.0 GHz or higher with SSE2 technology<br>For 64 -bit AutoCAD 2015: |

| | |
|---|---|
| | AMD Athlon 64 with SSE2 technology<br>AMD Opteron with SSE2 technology<br>Intel Xeon with Intel EM64T support with SSE2 technology<br>Intel Pentium 4 with Intel EM64T support with SSE2 technology |
| Network | Development via Deployment Wizard.<br>The license server and all workstations that will run application dependent on network licensing must run TCP/IP protocol.<br>Either Microsoft or Novell TCP/IP protocol stacks are acceptable.<br>Primary login on workstations may be Netware or Windows.<br>In Addition to operating systems supported for the application, the license server will run on the windows Server 2012, windows Server 2012 R2, Win dows Server 2008, Windows 2008 R2 Server editions.<br>Citrix XenApp 6.5 FP1, Citrix Xen Desktop 5.6 |

| **System requirements of AutoCAD 2015** | |
|---|---|
| Memory | 2GB (8 GB recommended) |
| Display Resolution | 1024x768 (1600x1050 or higher recommended) with True Colour |
| Display Card | Windows display adapter capable of 1024x768 with True Colour capabilities.<br>DirectX 9 or DirectX 11 compliant card recommended but not required. |
| Disk space | Installation 6.0 GB |
| Pointing Device | Ms-Mouse compliant device |
| Digitizer | WINTAB support |
| Plotter/Printer | Same as AutoCAD 2013-2014 - System printer and HDI support |
| Media (DVD) | Download and installation from DVD |
| Browser | Windows internet Explorer 9.0 (or later) |
| Side-by-side Install | Supported |
| Tool Clips Media Player | Adobe Flash Player v10 or up |
| .NET Framework | .NET Framework Version 4.5 |

**Additional requirements for large datasets, point clouds, and 3D modelling**

| | |
|---|---|
| CPU Type | Intel Pentium 4 processor or AMD Athlon, 3.0 GHz or higher with SSE2 tech nology; Intel or AMD Dual Core processor, 2.0 GHz or higher(minimum). |

**Applications of CAD**

CAD is used in various fields as listed below

1 Preparing architectural drawing
2 Interior design and modelling
3 Tool and fixture design
4 Production planning and control
5 Preparation of assembly lists and bill of materials
6 Computer aided inspection
7 Preparation of programs for CNC machines
8 Circuit layout and panel design
9 Mapping, building drawing
10 Communication network
11 Piping and instrumentation design
12 Automotive industries and
13 Computer aided manufacturing

CAD packages

**Differentiate Between Manual and Machine Drafting**

| Traditional drafting | Computer aided design |
|---|---|
| 1 Uses traditional drafting board and usual skill. | 1 Uses a larger digitizer and plotter tools for design |
| 2 Designs cannot be reproduced since there is no means of storage. | 2 Designs can be stored in computer memory and cab be retrieved at any time. |
| 3 Accuracy and design are not consistent. | 3 Designs such as straight lines, smoothing curves and lines at proper angles can be done. |
| 4 Text formatting facility is not allowed. | 4 Allowed. |
| 5 Cross hatching is done manually. | 5 Automated cross hatching design is allowed. |
| 6 Hollow section is done manually and inaccurate. | 6 Automated hollow section is done and is accurate. |
| 7 Cannot view in different dimensions | 7 Dimensions can be changed as per user's wise. |
| 8 Sweeping of images is impossible | 8 Done automatically. |
| 9 Image and designs cannot be viewed in different angles | 9 Can be viewed in different angles and dimensions |
| 10 Application designs consume more time and hinders productions. | 10 Application designs are faster and favourably production. |

| Traditional draughting | Auto CAD Draughting |
|---|---|
| **1 Scale**<br>For all the drawing we want to choose separate scales like full size scale (eg.1:1), reduced scale (eg.1:100) or enlarged scale (eg.100:1) | Scaling is not necessary. Enter all the dimensions in real size (1=1) |
| **2. Paper size**<br>First select a drawing sheet according to the size of the drawing i.e A1, A2 ,A3, A4 etc. | In any size paper we can take print out after completing the drawing. |
| **3. Unit**<br>Select any one of the unit like meter, Centimetre, millimetre, feet, Inch etc. According to the importance of each are drawing. | We can set units simply by using command UNITS, select appropriate unit from the unit dialogue box. |
| **4. Drawing instruments**<br>It requires many instruments like T-square, set squares, pen, pencil, eraser, protractor, etc. | User interface provides many tools which makes the drawing process more easily |
| **5. Drawing board**<br>A good quality drawing board is necessary for accurate drawing work. | It is not required. |
| **6. Drawing process**<br>It is very difficult to make alterations in the drawing and much time consumes. | It is very easy to make and alter different types of drawings. |

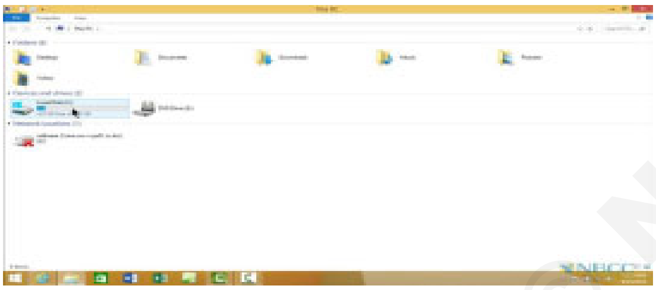
**Installation Auto CAD**

1. Switch on the computer wait for few minutes to do the process of ROM. Now we see the monitor screen as shown fig.

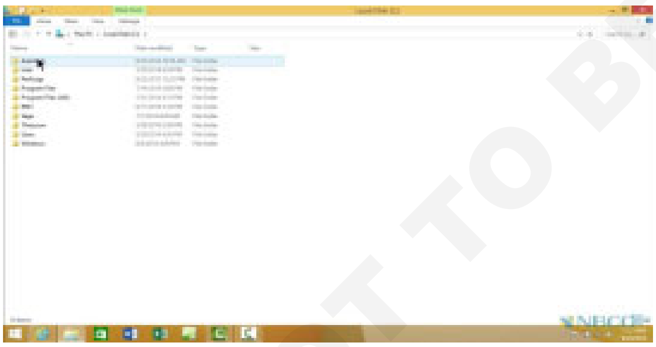
Insert the Auto CAD CD in to CD-ROM drives; double click on My Computer icon then a display as follow.

Open file explorer

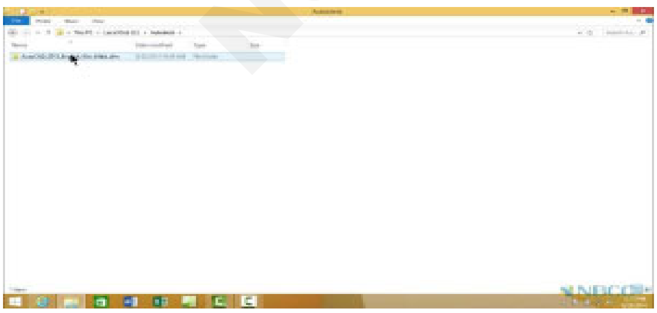
Open local disk(C)



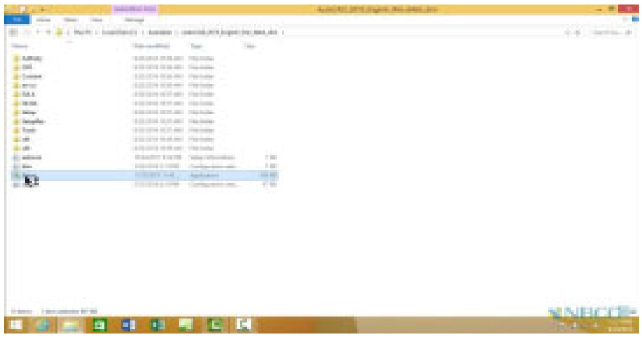
Open Autodesk



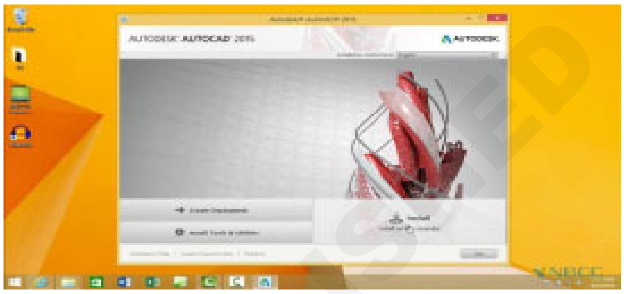
Open Autocad_2015



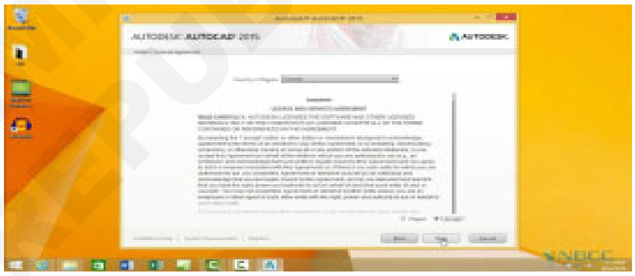
Run setup



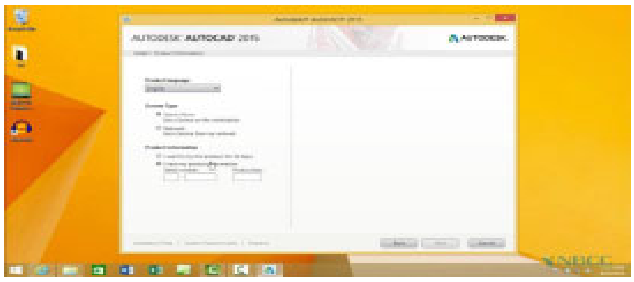
The installer will start once setup is clicked. Please click on install



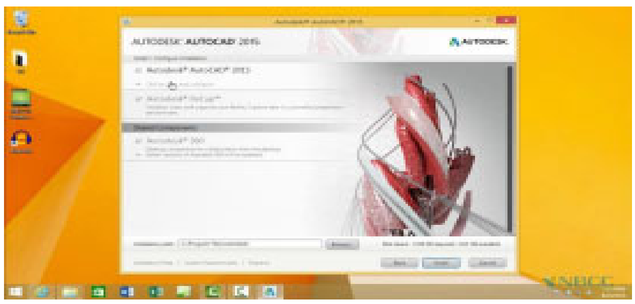
Change country to India, and accept the license terms, Now click next.



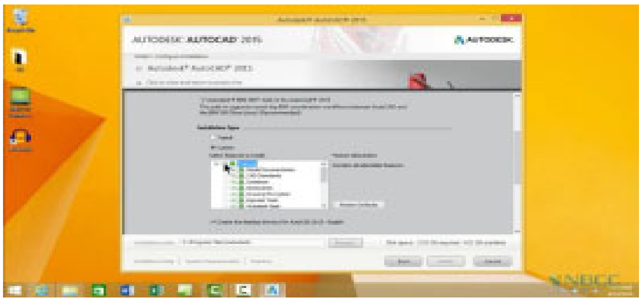
Select your language preference, stand alone licence, and input and product key that you made note of while downloading the software. Now click next.



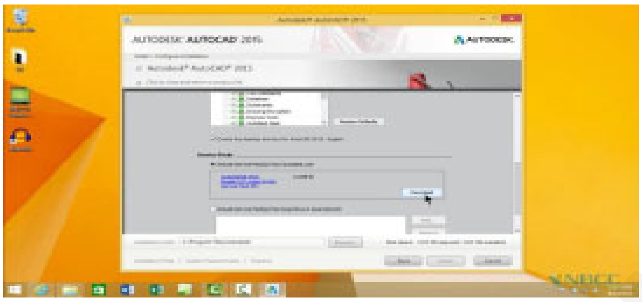
Click on Autodesk AutoCad 2015 to open and configure the options.



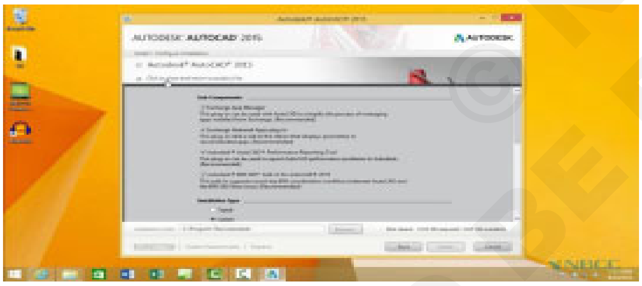
Under installation type select custom then make sure you place a green check mark next to feature. This will ensure all components get installed.



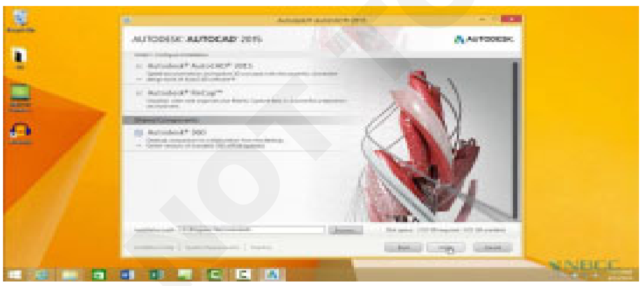
Scroll down a bit further and you will see on option for including service packs. Click include service packs and then click the download button. Wait for the service pack to download. Note that this step requires an internet connection.



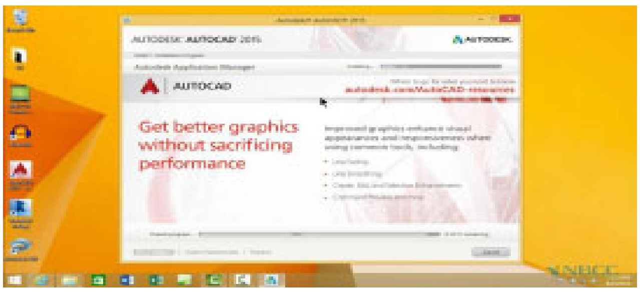
Go back to the top and click on the “Click to close and return to product list” banner.



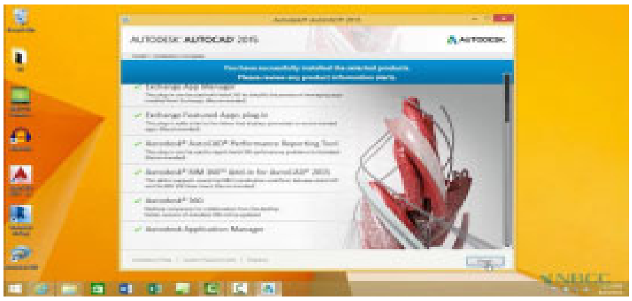
Now click install



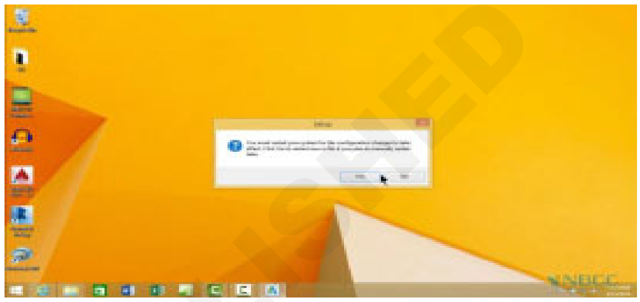
The install will take some time. Please be patient.




Once the install is complete you should see this message. Press finish to complete the install.

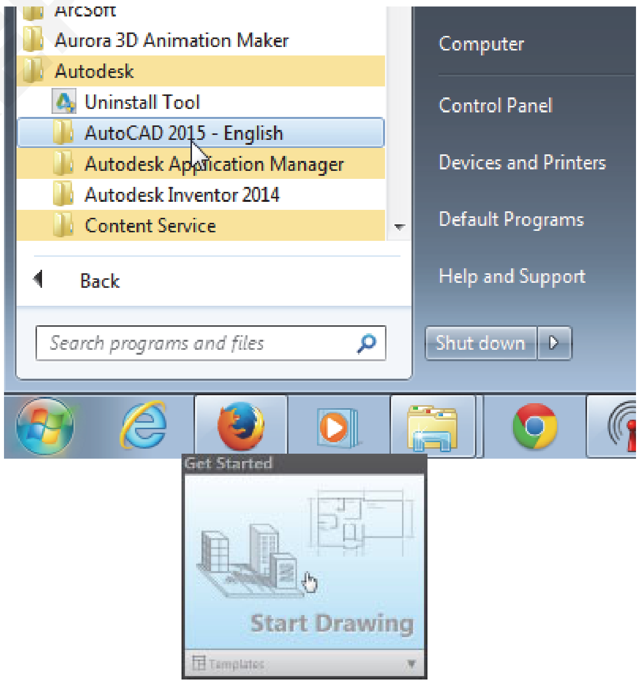


Your system may ask to reboot once the install has finished. Click yes to reboot your system. You have now successfully installed AutoCAD 2015.



The finally restart the computer.

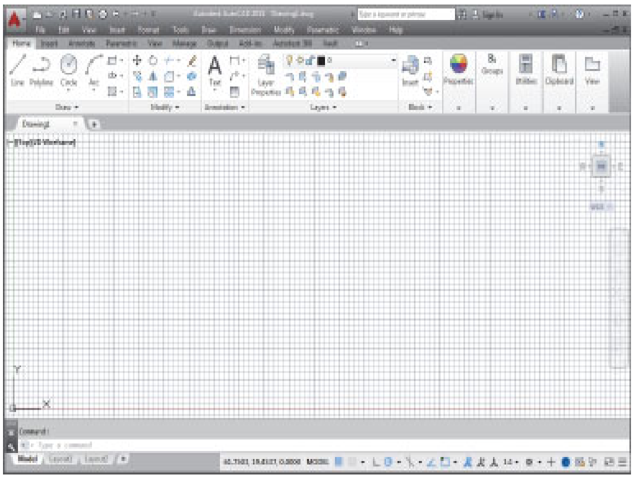
1 Select the AutoCAD 2015 option on the program menu or select the AutoCAD 2015 icon on the Desktop. Click Start Drawing to start a new drawing.

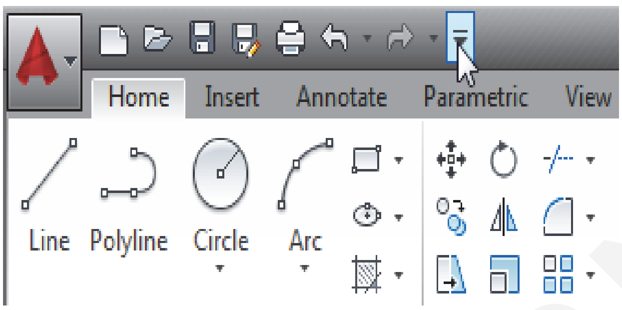


## Graphical user interface (GUI)

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

- **describe graphical interface of Auto CAD**
- **explain key board function keys.**







### Quick Access Toolbar

1 Click on one of the following icons for quick access to commands QNEW, OPEN, SAVE, PLOT, and UNDO/ REDO.

Right- click the Quick toolbar and click Customize


Quick Access Toolbar. The Customize User Interface dialog opens and displays the list of commands available.

Drag commands you want to add from the command list pane in the Customize User Interface dialog box to the Quick Access toolbar.

By click on the down arrow in the quick access bar and can select show menu bar to display the autocad menu bar. The menu bar provides access to all autocad commands.

### Info Center

Quickly search for a variety of information sources, access product updates and announcements, and save topics with info Center.

### Ribbon

The ribbon provides a single, compact placement for operations that are relevant to the current workspace. It eliminates the need to display multiple toolbars, reducing clutter in the application window. The ribbon maximizes the area available for work using a single compact interface.

The ribbon can be displayed horizontally, vertically, or as a floating palette. The horizontal ribbon is displayed at the top of the drawing window by default when you create or open a drawing.

You can create your own panels to display on the ribbon; you can also modify the commands and controls on existing ribbon panels.

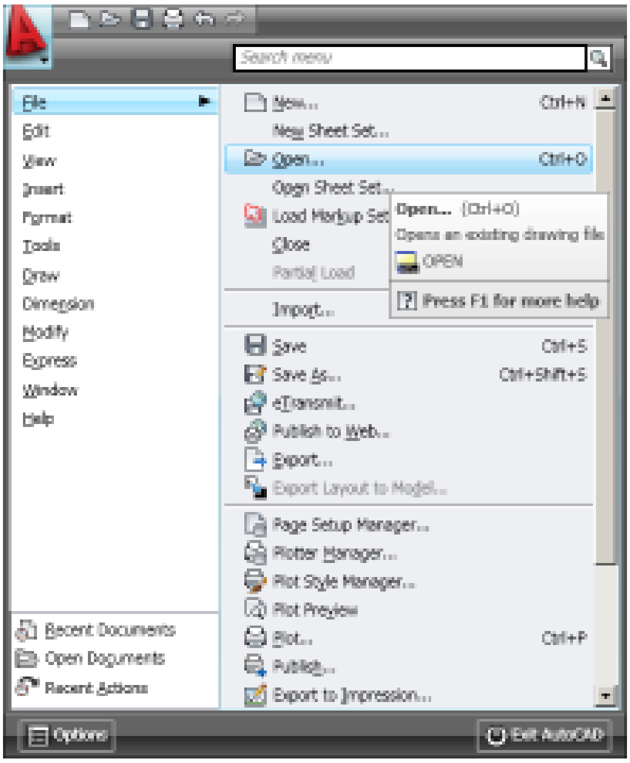
Menus and Colours

Menu Browser

1 Click on the A icon in the upper left corner of the drawing area.

2 Click the desired pulldown menu.

3 Click on the command to be executed from the pulldown.



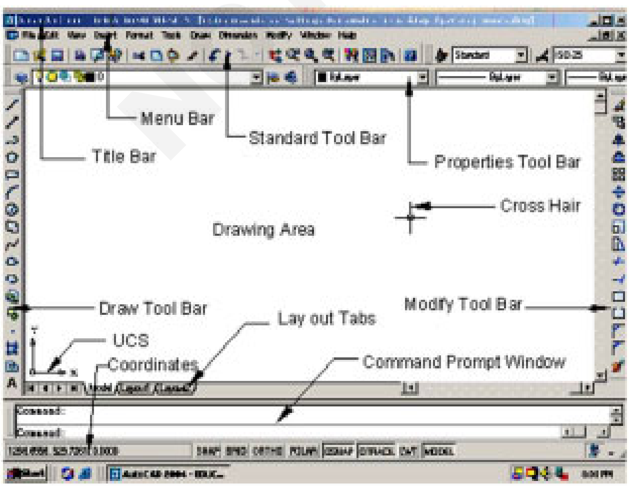

## Workspaces

You can switch between the workspaces from the menu browser.

1 Click the Workspace switching icon in the lower left corner of the screen.


2 Click on one of the following workspace options.

AutoCAD classic workspace




**Title bar:** This shows the name of drawing which is currently used.

**Menu bar:** This menu bar help us quicker way to access the general controls and setting for AutoCAD. The main commands and functions are available in this menu bar it has the following facilities.

1 It gives a command that requires key board or drawing input.

2 It displays additional menus choice with > symbol, in this menu called cascading menus.

3 It displays a dialogue box that contains settings which have changing options.

**Standard tool bar :** This tool bar contains the standard functions of commands which is used for getting information's and modifications.

**Properties tool bar :** This tool bar have the properties of the entity such as thickness of line, colour, layer type of line etc. We can change the properties of the entity by using this tool bar.

**Draw tool bar :** This tool bar contains the group of drawing commands such as line, arc, circle etc.

**Modify tool bar :** This tool bars are used to do the modifications in the entities such as erase, trim etc.

**Draw area :** This is a black space to draw the drawings. This area has formed as grids, we can increase or decrease the area by using boundary limit command.

**UCS:** UCS (User Coordinate system is an indication to the use of for which plane the drawing is drawn. We can change any plane according to our wish to draw the drawing in views.

**Command prompt window :** This window is used to give commands by typing in key board.

**Cross hair** : This is the pointer used to draw, select and to locate.

**Layout tabs** : These tabs are used to select the particular lay out of the drawing.

**Function tabs :** Below the command prompt window drawing function tabes are available. These tabs show us the position of grid, ortho, o snap etc. The functional keys are used for effective function of the drawing.

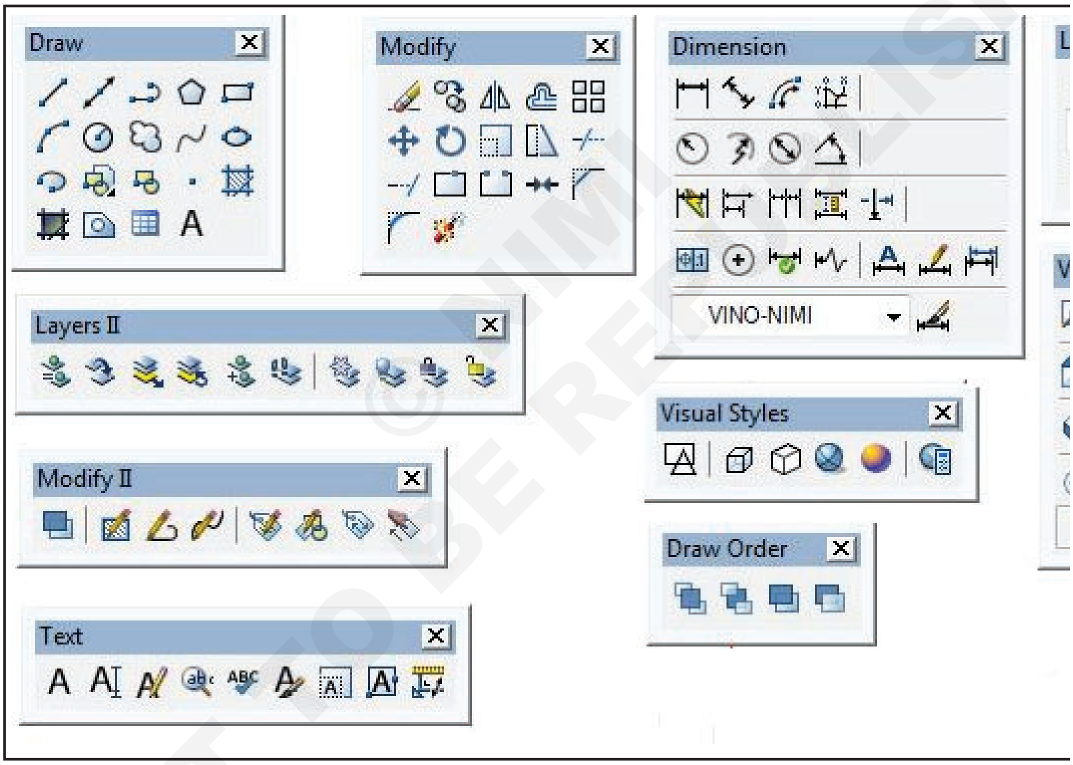
### Key board Function Keys

There are some function keys in the keyboard for quick access to certain commands.

You can disable the group selection quickly by pressing FUNCTION KEYS (Ctrl + Key) combination to quickly toggle some of the modes and invoke some of the commands.

### Function keys used in Auto CAD

| Key Strokes | Function Defined |
|---|---|
| Ctrl+Z | Undo |
| Ctrl+C | Copy Clip |
| Ctrl+E | Osoplane Top/Right /Left |
| Ctrl+G | Grid On/Off |
| Ctrl+L | Ortho On/Off |
| Ctrl+O | OPEN command |
| Ctrl+S | QSAVE command |
| Ctrl+U | Polar Tracking ON/Off |
| Ctrl+W | Object Snap Tracking ON/Off |
| Ctrl+Y | Redo |
| Ctrl+2 | ADCENTER command |
| Ctrl+F6 | Switch between open drawings |
| Ctrl+B | Snap On/Off |
| Ctrl+D | Coordinate Display ON/Off |
| Ctrl+F | Osnap Setting Dialog box $\angle A = \angle C = \angle D$ |
| Ctrl+K | HYPERLINK command |
| Ctrl+N | NEW command |
| Ctrl+P | PRINT command |
| Ctrl+T | Tablet On /Off |
| Ctrl+V | Paste |
| Ctrl+X | Delete |
| Ctrl+1 | Object Properties window On/Off |
| Ctrl+6 | DBCONNECT command |
| Ctrl + Tab | Switch between open Drawings.? |






The functionality of these Ctrl + Key combination depends on the settings done on the User Preferences tab on the option dialog box.

**Example:**

That is to say Ctrl+ C works for COPYCLIP command, if the check box is cleared, Ctrl + C works for the CANCEL command.

**Text edit keys**

The following accelerator keys, which are effective within the Multilane Text Editor, dialog box.

| Key Strokes | Function Defined |
|---|---|
| Ctrl+A | Select all text in the Multiline Text Editor |
| Ctrl+B | Applies or removes bold format for selected text |
| Ctrl+C | Copies selected text to the Clip board |
| Ctrl+1 | Applies or removes italic format for selected text |
| Ctrl+Shift+L | Converts selected text to lower case |
| Ctrl+Shift+U | Converts selected text to upper case |

| | |
|---|---|
| Ctrl+U | Applies or removes underline format for selected text |
| Ctrl+V | Pastes Clipboard contents to cursor location |
| Ctrl+X | Cuts selected text to the Clipboard |
| Ctrl+SPACE | Removes character formatting in selected text. |

Loading Toolbars

Right- clicking on an icon in any toolbar

This will show a list of all available toolbars.




## Practice on AutoCAD

**Objectives :** At the end of this exercise, you shall be able to
- **explain practice on CAD**
- **explain method of giving commands**
- **explain drawing area set up**
- **explain drawing & settings.**

**Practice on Auto cad**

**Introduction**

**Entity** : A drawing element like line, arc and circle is called an entity.

it is necessary to study the sequence of commands, their operation to prepare the 2D Drawing knowledge of their tools will assist to create better design.

**Command :** The instruction to be input into a drafting software for making a drawing, modifying, copying, saving, etc. Are called commands. Command can be typed on the keyboard. It may be picking from a menu or table or selected from a bar like standard toolbar and modify toolbar by using a mouse.

**Prompt** : Drafting software gives textual indication the type of instruction to be fed into it at different stages. Such indication is called prompt. For example, after the issue of LINE command, AutoCAD gives a prompt "from point". After having received instructions about from point, the software shows the prompt "To point:"

**Options:** Different alternative procedures are available for drawing an entity or solid. These alternative procedures are known as options.

**File :** A file is a collection of data pertaining to a drawing or set of related drawings.

**Directory or folder :** A collection of files is called a directory or folder.

**User**: The person operating the computer to perform tasks is said to be the user.

**Programmer:** The person who writes computer program is called a programmer.

**Default** : Default value or default option denotes the value or option that is retained by the software. Default is denoted by <> or <current>. The 'default' is also called the 'current'. The default or current value can be used as such by just pressing the Enter key. The default value can be altered by typing the required value. Radius<1.000>:2 Enter means that the default value for Radius is 1. But you have selected a value of 2 for Radius instead of 1.000.

**Dialog box:** The user- graphic interface that appears on the screen as response to certain commands is called dialog box. It has check boxes, buttons to click on for alternative options.

There are boxes for OK, apply, cancel and so on. Click on OK will return the user to the usual user interface.

To start with, Auto CAD it would be desirable to study that user-system graphic interface.

Show a typical user-system graphic interface. If consists of menu bar, standard toolbar, draw toolbar, modify toolbar, status bar, vertical scroll bar, horizontal scroll bar, drawing area and command area. Command area is generally a three-line area.

The menu bar has as set of text items like file, edit and draw. Standard toolbar and modify toolbar have a number of window like graphic symbols each representing one feature like line and circle. Items like copy, fillet and chamfer are also represented in the relevant toolbar by graphic images which will depict copying, filleting, etc. These graphic images are called icons.

The menu bar and the toolbars enable the user to select commands quickly. For example, if the user want to send in command for drawing a polygon, the moves such that the cursor point is on 'draw' in the menu bar and presses the left button. A sub-menu listing different entities like line, arc, polygon and circle appears on the screen as a string of texts under the highlighted draw heading. The cursor is than taken onto 'polygon' by using mouse and than the left button is pressed. Now, the software gives prompts in the command area to complete drawing the required polygon ultimately.

**Picking Point by Using Cursor**

If you move the mouse, you can see a cursor in the form of cross hairs with square appears to move within the drawing area. This is drawing cursor. It is standard cursor. This cursor tells you that Auto CAD is waiting for instructions. When the drawing cursor moves, the co-ordinate display in the status line change i.e. it tells the cursor location it shows the co-ordinates in an x,y format. (x,y axis)

Place the cursor in any point of the drawing area and do left clicking. Now you have just picked a point. If you move the cursor in any direction rectangle follow.

Like this move the cursor a bit and do left clicking, the rectangle disappears. (try picking several more points in the drawing area.)

If the cursor if you move the arrow cursor over the draw option given in the draw tool bar and do clicking on any command (for example, clicking on line command), the cursor appears as cross

Hairs (+). This is point selection cursor; it can also appear in conjunction with a rubber banding line. This tells Auto CAD expects point input.

When we are selecting an object, the drawing cursor changes into a small square. This is object selection cursor. It tells you must select objects.

**Methods of giving command**

There are three ways, to enter commands for constructing or editing a drawing.

**I Directly from key board :** Commands may be entered (typed) in directly from the key board against the command: prompt. The entered command may be cancelled by pressing ESC key.

**II From the screen menu :**There is a menu displayed at the right side of the drawing screen, this menu is known as screen menu. Moving the arrow, the curser to the screen menu, high lighting the required command and doing left clicking may select commands.

**III From pull down menu :** There is a menu bar displayed at the top or side of the screen. This menu is known as pull down menu. In this menu bar, the commands are shown in the form of symbols. Moving the arrow cursor over the required command and doing left clicking may select the commands.

**Command, Unit :** Format, Units:- Auto CAD does not use a predefined system of unit measure such as meters or inches. For example, a distance of one unit may represent one centimetre.

One foot, or one mile in real-world units. Before you begin drawing, decide what distance one unit will represent, and then create your drawing with that convention.

Command line: Units (or 'units for transparent use)

Defines the Length and Angle formats.

**Length**: Specifies the current unit of measurement and the precision for the current units.

**Type:** Sets the current format for units of measure. The values include Architectural, Decimal, Engineering, Fractional, and Scientific. The Engineering and Architectural formats produce feet-and -inches display and assume that each drawing unit represents one inch. The other formats can represent any real-world unit.

**Precision**: Sets the number of decimal places or fractional size displayed for linear measurements.

**Angle**: Specifies the current angle format and the precision for the current angle display.

**Type:** Sets the current angle format.

**Precision**:- Sets the precision for the current angle display.

AutoCAD uses the following conventions for the various angle measures:

Decimal degrees appear as decimal numbers, grads appear with a lowercase g suffix, and radians appear with a lowercase r suffix. The degrees/minutes/seconds format uses d for degrees, 'for minutes, and "for seconds, for example: 123d45'56.7"

Surveyor's units show angles as bearings, using N or S for north or south, degrees/minutes/seconds for how far east or west the angle is from direct north or south, and E or W for east or west, for example: N 45d0'0" E

The angle is always less than 90 degrees and is displayed in the degrees/minutes/seconds format. If the angle is precisely north, south, east, or west, only the single letter representing the compass point is displayed.

**Clockwise :** Calculates positive angles in the clockwise direction. The default direction for positive angles is counterclockwise.

When AutoCAD prompts for an angle, you can point in the desired direction or enter an angle regardless of the setting specified for clockwise.

**Polar Spacing:** Controls the Polar Snap increment distance.

**Polar Distance:** Sets the snap increment distance when Polar Snap is selected under Snap Type & Style. If this value is 0, the Polar Snap distance assumes the value for Snap X Spacing. The Polar Distance setting is used in conjunction with polar tracking and/or object snap tracking. If neither tracking feature is enabled, the Polar Distance setting has no effect. (POLARDIST system variable)

**Grid On:** Turns the grid dots on or off. You can also turn grid dots mode on off by clicking Grid on the status bar, by pressing F7, or by using the GRIDMODE system variable.

**Grid:** Controls the display of a dot grid that helps you visualize distances.

**Note:** The limits of the dot grid are controlled by the LIMITS command.

**Grid X Spacing:** Specifies the dot spacing in the X direction. If this value is 0, the grid assumes the value set for Snap X Spacing. (GRIDUNIT system variable)

**Grid Y Spacing:** Specifies the dot spacing in the Y direction. If this value is 0, the grid assumes the value set for Snap Y Spacing. (GRIDUNIT system variable)

**Snap Type & Style:** Controls Snap mode settings.

**Grid Snap**: Sets the snap type to Grid. (SNAPTYPE system variable)

i **Rectangular Snap:** Sets the snap style to standard Rectangular snap mode.

When the snap type is set to Grid snap and Snap mode is on, the cursor snaps to a rectangular snap grid. (SNAPTYPE system variable)

**ii Isometric Snap:** Sets the snap style to Isometric snap mode. When the snap type is set to Grid snap and Snap mode is on, the cursor snaps to an isometric snap grid. (SNAPSTYL system variable)

**Polar Snap**: Sets the snap increment distance when Polar Snap is selected under Snap Type & Style. If this value is 0, the Polar Snap distance assumes the value for Snap X Spacing. This value is also controlled by the POLARDIST system variable. The Polar Distance Setting is used in conjunction with polar tracking and /or object snap tracking. If neither tracking feature is enabled, the Polar Distance setting has no effect.

**Polar Tracking Tab (Drafting Setting dialog Box) :**

Controls the Auto Track settings

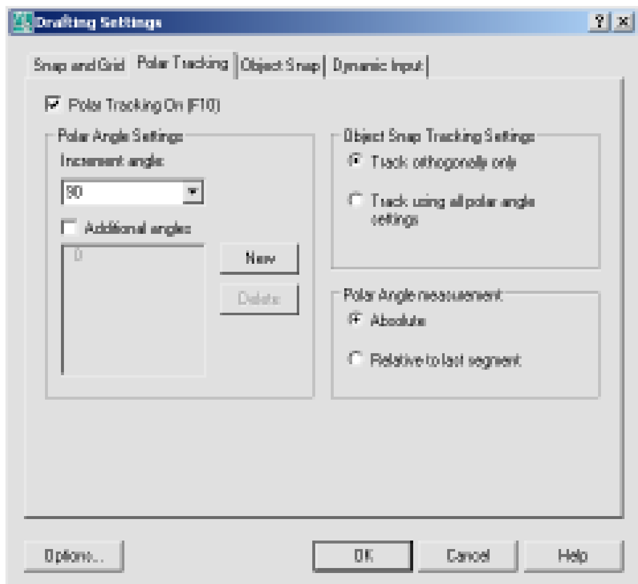
**Polar Tracking On:** Turns Polar tracking on and off. You can also turn polar tracking on or off by pressing F10 or by using the AUTOSNAP system variable

**Polar Angle Settings:** Sets the angles used with polar tracking.

**Increment Angle:** Sets the polar increment angle used to display polar tracking alignment paths. You can enter any angle, or select a common angle of 90, 45,30,22.5,18,15,10, and 5 degrees from the list (POLARANG system variable)

**Additional Angles:** Makes any additional angles in the list available for polar tracking. The additional Angles check box is a also controlled by the POLARMODE system variable, and the list of additional angles is also controlled by the POLARADDANG system variable.

Note Additional angles are absolute, not incremental.



**New:** Adds up to 10 additional polar tracking alignment angles.

**Track Using All Polar Angle Settings:** Permits the cursor to track along any polar angle tracking path for acquired O snap points when object snap tracking is on while specifying points. This setting is also controlled by the POLARMODE system variable.

Note Clicking Polar and O track on the status bar also turns polar tracking and object snap tracking on and off.

**Polar Angle Measurement:** Sets the basis by which polar tracking alignment angles are measured.

**Absolute:** Bases polar tracking angles on the current uses coordinate system (UCS).

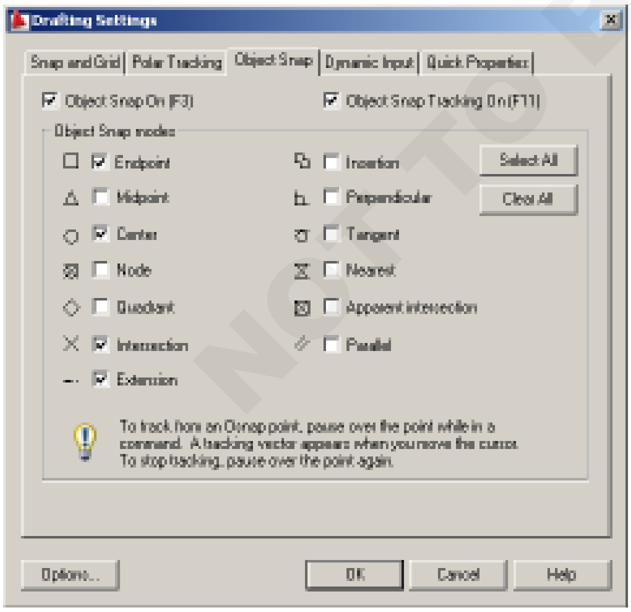
**Relative to Last Segment:** Bases polar tracking angles on the last segment drawn.

**Object Snap Tab (Drafting Setting Dialog Box)** :Controls running object snap settings. With running object snap settings, also called O snap, you can specify a snap point at an exact location on an object. When more than one option is selected, AutoCAD applies the selected snap modes to return a point closest to the center of the aperture box. Press TAB to cycle through the options.

**Object Snap On:**- Turns running object snaps on and off. The object snaps selected under Object Snap Modes are active while object snap is on. (OSMODE system variable)

**Object Snap Tracking On:** Turns object snap tracking on and off. With object snap tracking, the cursor can track along alignment paths based on other object snap points when specifying points in a command. To use object snap tracking you must turn on one or more object snaps. (AUTOSNAP system variable)

**Object snap Modes:** Specifies the running object snap modes. Select one or more options.




**Endpoint :** Snaps to the closest endpoint of an arc, elliptical arc, line, multiline polyline segment, spline, region, or ray, or to the closest corner of a trace, solid or 3D face.

**Mid point :** Snaps to the midpoint of an arc, ellipse, elliptical arc, Line, multiline polyline segment, region, Solid, Spline, or Xline.

**Center:** Snaps to the center of an arc, circle, ellipse, or elliptical arc.

**Node:** Snaps to a point object, dimension definition point, or dimension text origin.

**Quadrant :** Snaps to a quadrant point of an arc, circle, ellipse, or elliptical rc.

**Intersection:** Snaps to the intersection of an arc, circle, ellipse, elliptical arc, line, multiline, polyline, ray, region, spline, or xline.

Intersection and Extended Intersection work with edges of regions and curves but not with edges or corners of 3D solids.

**Extension:** Causes a temporary extension line to display when you pass the cursor over the endpoint of objects, so you can draw objects to and from point on the extension line.

**Insertion:** Snaps to the insertion point of an attribute, a block, a shape, or text.

**Perpendicular:** Snaps to a point perpendicular to an arc, circle, ellipse, elliptical arc, line, multiline, polyline, ray region, solid, spline, or xline. AutoCAD automatically turns on Deferred Perpendicular snap mode when the object you are drawing requires that you complete more than one perpendicular snap. You can use a line, arc, circle, polyline, ray, xline, multiline, or 3D solid edge as an object from which to draw a perpendicular line. You can use deferred perpendicular to draw perpendicular lines between such objects.

**Tangent :** Snaps to the tangent of an arc, circle, ellipse, elliptical arc, or spline AutoCAD automatically turns on Deferred Tangent snap mode when the object you are drawing requires that you complete more than one tangent snap.

**When you use the From option in conjunction with the Tangent snap mode to draw objects other than lines from arcs or circles, the first point drawn is tangent to the arc or circle in relation to the last point selected in the drawing area.**

**Nearest :** Snaps to the nearest point on an arc, circle, ellipse, elliptical arc, line multiline, point, polyline, ray, spline, or xline.

**Apparent Intersection:** Apparent Intersection includes two separate snap modes: Apparent intersection and Extended Apparent Intersection. You can also locate intersection and Extended Intersection snap points while running Apparent Intersection object snap mode is on. Apparent Intersection snaps to the apparent intersection of two objects (arc, circle, ellipse, elliptical arc, line, multiline, polyline, ray, spline, or xline) That do not intersect in 3D space but may appear to intersect in the current view.

**You might get varying results if you have both the intersection and Apparent Intersection running object snaps turned on at the same time.**

**Parallel :** Draws a vector parallel to another object whenever AutoCAD prompts you for the second point of a vector. After specifying the first point of a vector, if you move the cursor over a straight line segment of another object, AutoCAD acquires the point. When the path of the object you create is parallel to the line segment, AutoCAD displays an alignment path, which you can use to create the parallel object.

**Select All:** Turns on all object snap modes.

**Clear All:** Turns off all object snap modes

**Options:** Displays the drafting tab in the option dialog box you cannot access the option dialog box from the drafting setting dialog box if you are running DSETTINGS transparently.

**Command: grid :** The grid is for visual reference only. It is not plotted, and it is not part of the drawing. You can turn the grid display on and off with the grid button on the status bar. Or press Key button F7,

Specify grid spacing(x) or [ON/OFF/Aspect] <current>:

**Grid Spacing(X):** Sets the grid to the specified value. Entering x after the value sets the grid spacing to the specified value multiplied by the snap interval.

On turns on the grid using the current spacing.

Off turn off the Grid

Aspect Changes the grid spacing in the X and Y directions.

**Specify the horizontal spacing(x) <current>:** Enter a value or press ENTER

**Specify the vertical spacing (Y) <current>:** Enter a value or press ENTER

Entering X following either value defines it as a multiple of the snap interval rather than the drawing units.

The Aspect option is not available when the current snap style is isometric.

**Command Line:** Snap specify snap spacing or

[ON/OFF/Aspect/Rotate/Style/Type] <current>:

Snap spacing Activates Snap mode with the value you specify

**On:** Activates Snap mode using the current resolution, rotation, and style of the snap grid.

**Off:** Turns off Snap mode but retains the current settings

**Aspect :** Specifies different spacing in the X and Y directions. This option is no available if the current snap style is Isometric.

**Specify horizontal spacing <current>:** Specify a distance, or press ENTER

**Specify vertical spacing<current>:** Specify a distance, or press ENTER

**Specifies the horizontal and vertical spacing of these snap, grid seperately.**

**Rotate:** Sets the origin and rotation of the snap grid. The rotation angle is measured relative to the current UCS. You can specify a rotation angle between-90 and 90 degrees. A positive angle rotates the grid counterclockwise about its base point. A negative angle rotates the grid clockwise.

**Isometric**

**Isometric:** Sets an isometric grid, in which the grid points are initially at 30 degree and 150-degree angles. Isometric snap can be rotated but cannot have different Aspect values.

**Specify vertical spacing <current>:** Specify a distance or press ENTER

ISOPLANE determines whether the crosshairs lie in the top isometric plane (30 and 150-degree angles), the left isoplane (90-and 150-degree angles), or the right isoplane (30-and 90-degree angles).

**Type:** Specifies the snap type.

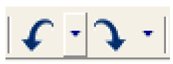
**Polar:** Sets the snap to polar tracking angles that are set in the POLARANG system variable.

**Grid:** Set of Snap to Grid

**Correcting Mistakes :** AutoCAD keeps track of all the commands you use and the changes you market. If you change your mind or make a mistake, you can undo, or reverse, the last action or several previous actions. You can also redo the last action that you reversed.

The Undo and Redo buttons on the Standard toolbar provide the easiest means to undo or redo the previous action.

To undo the most recent action, use one of the following



methods:

- On the Standard toolbar, click Undo
- From the Edit menu, choose Undo
- At the command line, type U and then press ENTER
- Press the CTRL-Z shortcut key combination
- Right-click to display the shortcut menu, and then choose Undo

You can also use the UNDO command to reverse several actions at once. To undo a specific number of actions:

1 At the command prompt, type UNDO.

2 On the command line, enter the number of actions to undo, and then press ENTER. For example, to reverse the last five actions, type 5.

**If you erase one or more objects by mistake, you can use the OOPS command to restore them to the drawing.**

**To redo an active, do one of the following:**

- On the Standard toolbar, click Redo
- From the Edit menu, Choose Redo
- At the command line, types REDO and then press ENTER
- Press the CTRL-Y shortcut key combination
- Right -click to display the shortcut menu, and then choose Redo

The REDO command reverse the action of the last U or UNDO command. To redo something, you must use the REDO command Immediately after using the U or UNDO command.

**Zoom/Pan**

Effective zooming can dramatically increase your speed one single command will give you the versatility to move around your drawing. This is the ZOOM command. Another useful command is PAN. These are both quicker than using the scroll bars on the side of the drawing area, unless you have a very short distance to move your drawing (and can make your scroll bars obsolete and thereby create more drawing space).

Start Zoom command by typing Z<ENTER>. When you do this, you will see the following options on the command line:

**Command:** Z <ENTER> ZOOM

Specify corner of window, enter a scale factor (nx or nxp), or [All/Center/Dynamic/Extents/previous/Scale/Window/Object] <real time>:

I generally use them in conjunction with each other. I'll do a zoom extents to see what state the drawing is at, then perform a zoom window to get to the area I need to work in, then do a zoom Extents when I am done in that area. In between, I may need to use a combination of Zoom Window and Zoom Previous.

Additionally, using your mouse wheel to zoom can be very fast for moving in and out of an area - practice this technique as well.

The zoom command can also be invoked transparently. This means that you can start it up in the middle of a command. For example, if you are in the trim command and want to see a bit more of your drawing, just type 'Z (note the apostrophe) at the command line and you can then zoom using any of the available options. Press <ENTER> to get back to your command.

| Command option | Icon | | Description |
|---|---|---|---|
| Zoom Extents | Extents |  | This option will display all the graphics that are contained in the drawing (referred to as the drawing extents) with the largest image possible. |
| Zoom window | Window |  | This option (also a 'hidden' default) prompts the user to pick two corners of a box on the existing view in order to enlarge that area to fill the display. |
| Zoom Previous | Previous |  | This option restores the displayed view prior to the current one. For the purpose of this option. Up to 10 views are saved so that the last ten views can be recalled. This option includes every time you use the scroll bar, which is one reason to avoid the scroll bars for panning a lot in your drawing. |
| Zoom Real-time | Realtime |  | Zoom Realtime provides interactive Zooming capability. Pressing <ENTER> (after entering Zoom ) on the command line automatically places you in Realtime mode. Hold the left mouse button down at the midpoint of the drawing and move the cursor vertically to the top (positive direction) of the window to zoom in up to 100% (2xmagnification). Hold the left mouse button down at the midpoint of the drawing and move the cursor vertically to the bottom (negative direction) of the window to zoom out to 100% (5 x magnifications). You cannot zoom out beyond the extents of the current view. |

| Command option | Icon | Description |
|---|---|---|
| | | When you release the pick button, zooming stops. You can release the pick button, move the cursor to another location in the drawing, and then press the pick button again and continue zooming from that location. To exit Realtime zoom mode, press <ENTER> or <ESC>. |
| Zoom All | All   | This option causes AutoCAD to display the whole drawing as far as its drawing limits or drawing extents (whichever is the greater of the two). |
| Zoom Dynamic | Dynamic   | This is a very useful Zoom option once it is understood. It permits very quick movement around the drawing. Once selected, this option redraws the graphics area of the screen and displays two rectangles. The larger box shows the extents of the current drawing. The smaller box shows the current view with an "X" in the middle. This moves with the mouse. This view box should be positioned so that its lower left corner is at the lower left corner of the view required. By pressing the left button on the mouse, the "X" is replaced by an ">" pointing to the right side of the view box. This allows you to change the magnification. As the mouse is moved, the view box shrinks and expands so that the size of the required view can be set. The left mouse button toggle between PAN "X" and ZOOM">" mode so that fine adjustments can be achieved. When the view required has been selected, press <ENTER> or right click to cause AutoCAD to display it. |
| Zoom Scale | Scale   | This is a 'hidden' default option. You do not have to type "S" to choose this option. It simply requires the entry of a number that represents a magnification factor. Note that the factor is applied to the entire drawing (as defined by the drawing's limits). Numbers less than 1 will reduce the displayed size of the drawing, while numbers greater than 1 will enlarge it. If "X" is inserted after the number (e.g.0.8x) then the factor is applied to the current view. If "XP" is inserted after the scale factor, then the view is scaled relative to paper space. This is useful for zooming a view within a paper space viewport to a specific scale, for example, "1/48XP" will produce a view of model space at a scale of ¼"=1' relative to paper space. |
| Zoom Center | Center   | This option requires two things: a point that is to be the center of the new display and a value to be its new height in drawing units. The existing height is the default for the new height to allow for panning across the drawing. If the new height value is followed by "X" (e.g..2x), then it is taken as a magnification factor relative to the current height. If followed by "XP", then it is taken as a scale factor relative to paper space and can be used for scaling the contents of paper space viewports. |

| Command option | Icon | Description |
|---|---|---|
| Aerial view command | Obsolete in 2010 and newer | Aerial view is a zooming tool that displays a view of the drawing in a separate window so that you can quickly move to that area. If you keep the Aerial View window open as you work, you can zoom and pan without choosing a menu option or entering a command. You can change the view by creating a new view box in the Aerial view window. To zoom in to the drawing, make the view box smaller by left clicking a rectangle. To zoom out of the drawing, make the view box larger. As you zoom in or out of the drawing, a real-time view of the current zoom location is displayed in the graphics area. The screenshot shows how the view box looks. Right click in the box and you can move the box to where you want to zoom to. |
| Zoom object | Object  | This option asks you to select an object or objects, then press <ENTER> and the screen will zoom to those objects only. This is great for when you want to work on object. |
| Zoom In | In  | Clicking this icon will zoom in to the drawing by about 50%. This option is only available as an icon and cannot be invoked by the command line. |
| Zoom Out | Out  | Similar to 'Zoom In' - this icon will zoom out of your drawing and allow you to see about 50% more of your drawing space. |
| Mouse scroll | NO Icon | If you have a scrolling wheel on your mouse, you can use it to zoom in and out of your drawing. Scroll towards you to zoom out and away from you to zoom in. You have a option to change the amount of zoom per wheel click with the Zoomfactor system variable. Keep in mind that you will zoom in and out using your mouse location as a 'center point' |
| PAN | Pan  | Panning allows you to quickly move around the drawing area at the same magnification you currently have set. Type in PAN (or P) <ENTER. And a hand will appear on the screen. Left click and hold to move around your drawing. |
| Use the Zoom> Previous option to return to where you were. | | |

## CAD basics

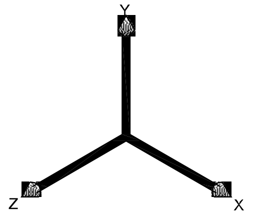
**Objectives :** At the end of this exercise, you shall be able to
- **explain user co-ordinate system**
- **enumerate AutoCAD commands.**
- **express line & Erase commands**

The CAD Database and the User Coordinate System

Designs and drawings created in a CAD system are usually defined and stored using sets of points in what is called world space. In most CAD systems, the world space is defined using a three-dimensional Cartesian coordinate system. Three mutually perpendicular axes, usually referred to as the X-, Y-, and Z-axes, define this system. The intersection of the three coordinate axes forms a point called the origin. Any point in world space can then be defined as the distance from the origin in the X-, Y- and Z-directions. In most CAD systems, the directions of the arrows shown on the axes identify the positive sides of the coordinates.

A CAD file, which is the electric version of the design, contains data that describes the entities created in the CAD system. Information such as the coordinate values in world space for all endpoints, center points, etc., along with the descriptions of the types of entities are all stored

Fig 1




USER COORDINATE SYSTEM

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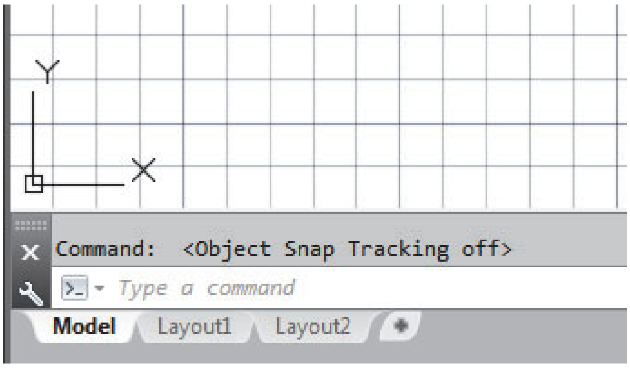
in the file. Knowing that AutoCAD stores designs by keeping coordinate data helps us understand the inputs required to create entities.




The icon near the bottom left corner of the default AutoCAD graphics window shows the positive X-direction and positive Y-direction of the coordinate system that is active. In AutoCAD, the coordinate system that is used to create entities is called the user coordinate system (UCS). By default, the user coordinate system is aligned to the world coordinate system (WCS). The world coordinate system is a coordinate system used by AutoCAD as the basis for defining all objects and other coordinate systems defined by the users. We can think of the origin of the world coordinate system as a fixed point being used as a reference for all measurements. The default orientation of the Z-axis can be considered as positive values in front of the monitor and negative values inside the monitor.

AutoCAD uses points to determine where an object is located. There is an origin where it begins counting from. This point is (0,0). Every object is located in relation to the origin. If you were to draw a line straight out to the right from the origin, this would be considered the positive X-axis. If you were to draw a line straight up, this would be the positive Y-axis. The picture above shows a point located at (9,6). This means that the point is 9 units over in the X-axis and 6 units up in the Y-axis. When you are working with points, X always comes first. The other point shown is (-10-4). This means that the point is 10 units in the negative X-axis (left) and 4 units in the negative Y-axis (down)

A line has two points, a start point and an end point. AutoCAD works with the points to display the line on the screen. Move your cursor over the picture above and you will see line drawn from the absolute points of (-10-4) to (9,6).

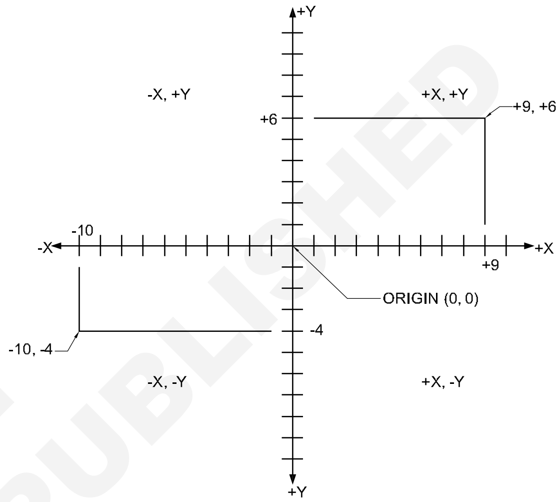
Most of the time you will not have an indication of where the origin is. You may need to draw a line from the endpoint of an existing line. To do this you use relative points. These work the same way, but you have to add the @ symbol (shift+2) to tell AutoCAD that this next point is relative from the last point entered.

To review:

ABSOLUTE POINTS are exact points on the drawing space.

RELATIVE POINTS are relative to an OBJECT on the drawing space.

Fig 2




USER COORDINATE SYSTEM

SUN153322

Its simple system, but mastering it is the key to working with AutoCAD and is explained in more detail further below. In order to work effectively with AutoCAD, you have to work with this system. Until you are comfortable and familiar with it, learning AutoCAD will be more of a chore. My experience in teaching is that the better a student is with coordinates, the faster they will learn.

**Entering Points in AutoCAD**

You can enter points directly on the command line using three different systems. The one you use will depend on which is more applicable for the situation. The first assignment will get you used to this. The three systems are as follows:

**Absolute co-ordinates:** Using this method, you enter the points as they relate to the origin of the WCS. To enter a point just enter in the exact point as X,Y.

**Relative co-ordinates :** This allows you to enter points in relation to the first point you have entered. After you've entered one point, the next would be entered as @ X,Y. This means that AutoCAD will draw a line from the first point to another point X units over and Y units up relative to the previous point.

**Polar co-ordinates:** You would use this system if you know that you want to draw a line a certain distance at a particular angle. You would enter this as @ D<A. In this case, D is the distance and A is the angle. Example: @10<90 will draw a line 10 units straight up from the first point.

The three ways of entering coordinates shown above are the ONIY way AutoCAD accepts keyboard input. First decide which style you need to use, and then enter as shown. Remember that X is always before Y (alphabetical). Don't forget the '@' symbol when you are entering relative points. Any typing error or omission will give you results you don't want. If you make a mistake and need to see what you typed, Press F2 to bring up the text screen and check your typing. (press F2 to get back to your drawing.)

| Term | Description |
|---|---|
| Absolute coordinates | Distance measured from a fixed reference point. |
| Aperture | Effective diameter of the cursor on the screen. |
| Cartesian coordinates | A rectangular system of measurement to locate points in the drawing area. |
| Object snaps | A method for indicating point locations using existing drawing objects as a reference. |
| Origin point | The 0,0 location of the coordinate system. |
| Polar coordinates | A system to locate of the coordinate system. |
| Prototype drawing | A template drawing that has a last location of the cursor. |
| Relative coordinates | Distance measured from the last location of the cursor |
| User-defined co-ordinates System | A mode of measurement that allows the user to set up a customized coordinate system. |

**Key Terms**

Angular Measurement

AutoCAD measures angles in a particular way also. Look at the diagram below and then place your mouse on it to see how this is

Degrees are measured counterclockwise starting at 3 O'CLOCK

When drawing lines at an angle, you have to begin measuring the angle from 0 degrees, Which is at the 3 O'clock position. If you drew a line at 90 degrees, it would go straight up. The example above (When you move your mouse over it) shows a line drawn at+300 degrees (270+30), or-60 degrees.

You might not always have an obvious reference point for 0 degrees. Look at the example below and place your mouse on the image to find out the angle in question.

In this example, you are given information about the lines, but not the angle AutoCAD needs to draw the line from the start point. What you are given though, is (a) the knowledge that 0°is at the 3 o'clock position (b) the knowledge that180° is at the 9 o'clock position and (c) the angle between 180° and the line you want to draw is 150°. With this information, you can figure out what angle you need. Here is a fool-proof way of getting the angle you need:

Fig 3

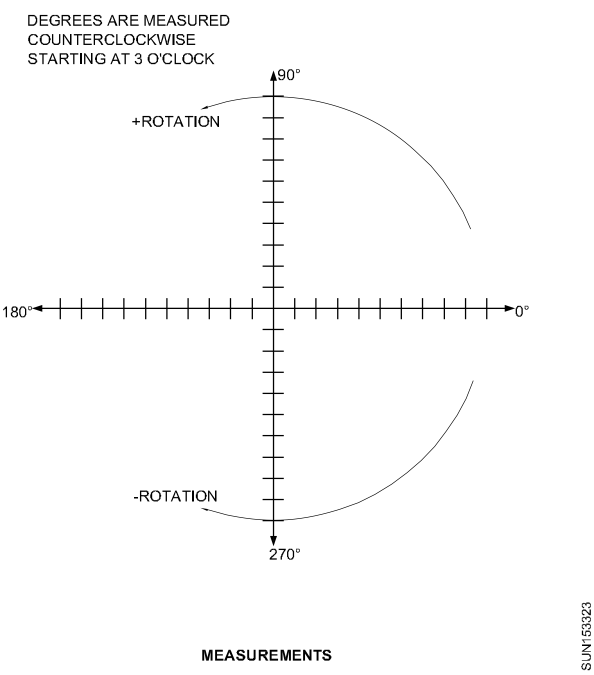
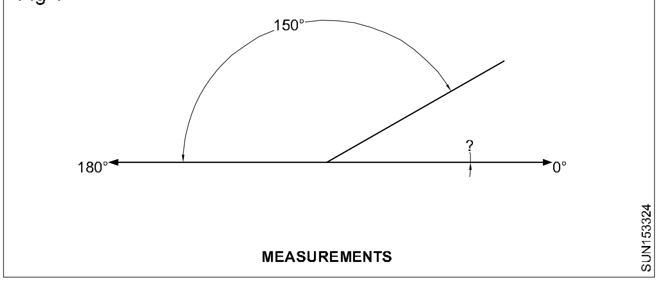


Fig 4




1.) Start at the 0° position and measure counter-closkwise (+) to 180°

2.) From 180°, measure clockwise 150°(-)

3.) Consider that you just went+180-150 and use that as an equation:+180-150=30

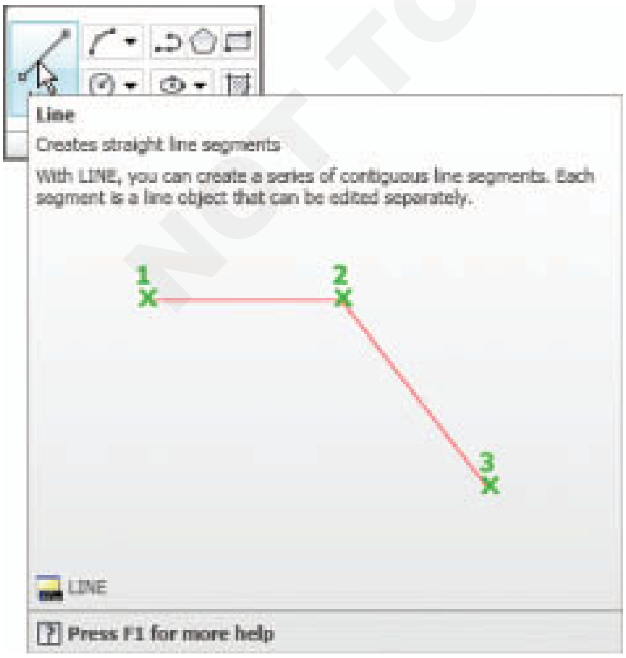
4.) Now you can draw your line using polar coordinates (discussed below)

There are many ways to do things in most windows programs. AutoCAD is no exception. Everyone will develop a way that works best for him or her. In this course, we will primarily be working with the keystroke commands. The reason for this is because they will work in most AutoCAD versions (including DOS versions), and in some other CAD programs. The icons work well, but as you will see, icons can be placed anywhere on the screen and can be difficult to find quickly. You may be working on another employee's computer that is set up differently than what you're used to. The pulldown menus will access almost all commands, but are a slower way of doing things. Icons in AutoCAD 2010 are found on the ribbon, divided into panels-just click on the appropriate tab to open thepanel you need.

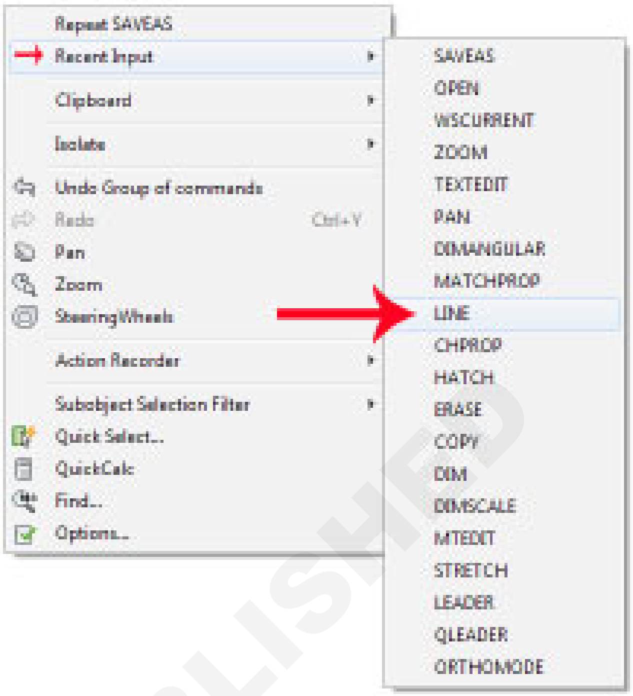
Example: If you want to draw a line, you can do it a few ways:

At the command line type: LINE (or) L and press the ENTER key.

Select the line icon from the DRAW Panel.



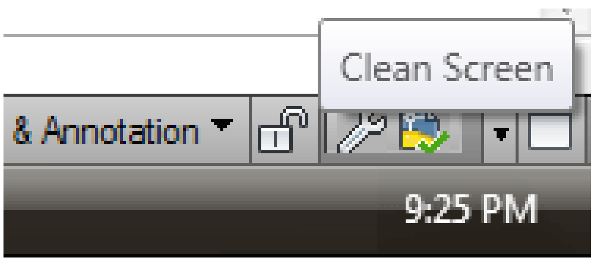

Another way is to Right-Click on the drawing space and choose "Recent Input" from the menu. This will give a list of the most recent command that you have used.

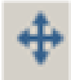
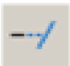
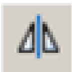
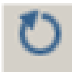



All three approaches will do the same thing: prepare AutoCAD to draw a line where you tell it.

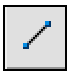
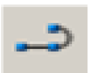
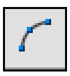
AutoCAD is a popular program because it can be customized to suit an individual's needs. The toolbars are a good example of this. You can have the toolbars you use most often on the screen all the time. You can easily make them go away so that you have more drawing space. You can also customize them so you have the most common commands on one toolbar. For example, the dimensioning toolbar is one that you will not want taking up space on your screen while drawing, but is very handy when you're dimensioning your drawing.

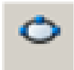
To remove the ribbon and have the most drawing space available, click on the "Clean Screen" icon in the bottom right corner of the screen (or press CTRL+O[letter O]. To go back the to the standard display, click again on the same icon.



| Symbol | Command | Purpose |
|---|---|---|
|  | Erase | Delete object |
|  | Move | Move object one place to other place |
|  | Copy | Create one or more copies of object |
|  | Stretch | Stetch, shorte, or move object |
|  | Trim | Shorten object using other object |
|  | Extend | Lengthen object using object |
|  | Mirror | Creates a mirror image of objects. |
|  | Rotate | Rotate objects around a specified point. |
|  | Offset | Create a new object at a specified distance from an existing object or through a specified point. |
| | Array | Each object in an array can be manipulated independently. |

**Auto CAD Drawing Commands**

| Symbol | Command | Major option | Toolbar button | Draw menu |
|---|---|---|---|---|
|  | Line | Start, End Point | Line | Line |
|  | Mline | Justification, Scale Style | None | Multiline |
|  | Pline | Vertices | Polyline | Polyline |
|  | Polygon | Number of sides, Inscribed / Circumscribed | Polygon | Polygon |
|  | Rectangle | Two Corner | Rectangle | Rectangle |
|  | Arc | Various methods of definition | Arc | Arc, submenu for definition methods |
|  | Circle | Three point, two point, Tangent | Circle | Circle submenu for definition methods |
|  | Donut | Inside, Outside Diameters | None | Donut |

| Symbol | Command | Major option | Toolbar button | Draw menu |
|---|---|---|---|---|
|  | Spline | Convert polyline or Create new | Spline | Spline |
|  | Ellipse | Arc, center, axis | Ellipse | Ellipse, submenu for definitionmethods |
|  | Revcloud | Arc Length | Revcloud | Revision cloud |

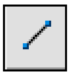
**Line Command**

Create single straight line segments

1 Choose draw, Line

(or)

2 Click the Line icon.



(or)

3 Type LINE from the command prompt command: LINE or L

4 Press Enter

5 Pick From point: (point)

6 Pick Specify next point or [Close/Undo]: (point)

7 Pick Specify next point or [Close/Undo]: (point)

8 Press ENTER to end line sequence

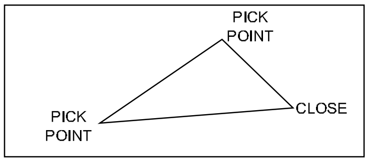
(or)

9 Type U to undo the last segment To point: U (undo)

(or)

10 Type C to create a closed polygon To point: C (close)

Fig 5




LINE COMMAND

SUN153325

**Erase and Selection Sets**

**Erasing Objects**

1 Choose Modify, Erase

Or

2 Click The Erase icon

Or

3 Type ERASE at the command prompt.

Command: ERASE or E

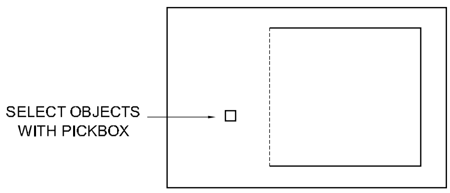
4 Pick Object at the select object prompt.

5 Press ENTER when you are done

choosing objects.

Select objects: ENTER

Fig 6




ERASE COMMAND

SUN153326

# Basic commands - I

**Objectives :** At the end of this exercise, you shall be able to
- **circle, arch**
- **ellipse, polygon**

### Introduction

The important thing to remember is that AutoCAD will expect you give it information in a very particular order. The most frustrating thing when you begin using this program is that you will try to do something, but AutoCAD will not work. In most cases, it means that you are trying to input information at the wrong time. This is why it is very important to be in the habit of looking at the command line.

The command line tells you what information AutoCAD requires to continue.

### Circles

### Circle Command

| | | |
|---|---|---|
| 1 | Choose | Draw, Circle. |
| | | Or |
| 2 | Click | the Circle icon. |
| | | Or |
| 3 | Type | CIRCLE at the command prompt. |
| 4 | Type | One of the following options: |
| | | 3P/2P/TTR/<<center point>>: |
| | | Or |
| 5 | Pick | A center point |
| 6 | Type | A radius or diameter. |
| | | Or |
| 7 | Pick | A radius or diameter Diameter/<<radius>>: |

### TIPS

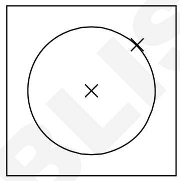
- To create circles that are the same size, press ENTER when asked for the circle radius.
- When selecting a circle with a pick box, be sure to select the circumference of the circle.

Your first drawing alignment will be to use the drawing commands in conjunction with the co-ordinate system it is very important to understand how to give the program accurate information. You will use the following commands.

### Drawing Arcs and Circles

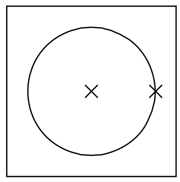
CADD provides many ways to draw arcs and circles. There are a number of advanced techniques available for drawing arcs and circles, which can simplify many geometrical drawing problems. You can draw an arc by specifying circumference and radius, radius and rotation angle, chord length and radius, etc.

Fig 1



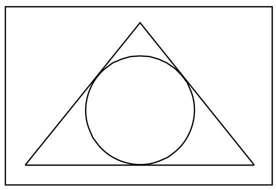

CIRCLE COMMAND

Fig 2




CIRCLE COMMAND

Fig 4

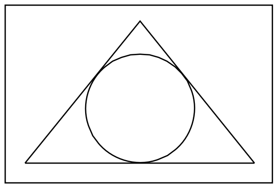



CIRCLE COMMAND

## Arc Command

| | | |
|---|---|---|
| 1 | Choose | Draw, Arc. |
| | | Or |
| 2 | Click | the Arc icon. |
| | | Or |
| 3 | Type | ARC at the command prompt Command: ARC |
| 4 | Draw | One of the arcs. |

Fig 4

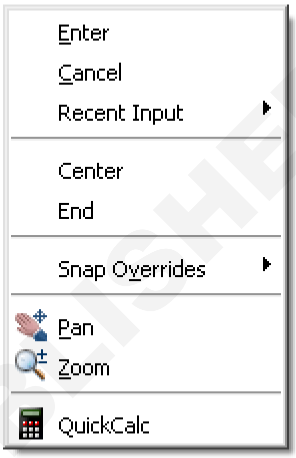


CIRCLE COMMAND

SUN153334

### TIPS

- Except for 3 point arcs, arcs are drawn in a COUNTERCLOCKWISE direction.
- While in the arc command, press the right mouse button to select the following options for arcs:






Arc Examples

3 point arc

Start, centre, chord length

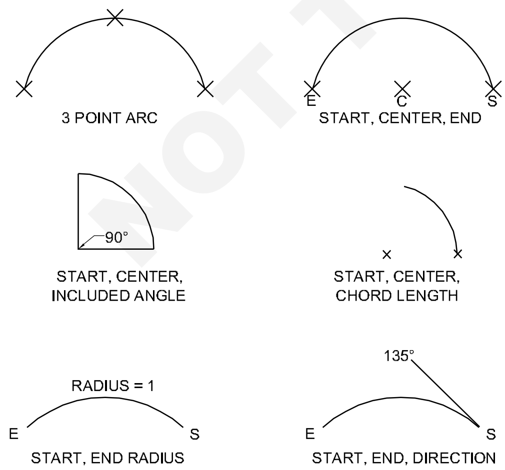
Start, centre, end

Start, end, radius

Start, centre, included angle

Start, end direction

Fig 5




ARC COMMAND

SUN153335

### Drawing Ellipses and Elliptical Arcs

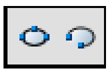
Ellipses are much easier to draw with CADD than on a drawing board. On a drawing board, you need to find the right size template or draw a series of arcs individually to draw an ellipse. With CADD, all you need to do is specify the size of the ellipse.

The following are two basic methods for drawing ellipses:

- Length and width
- Axis and rotation angle

### Ellipse

Creates an ellipse or an elliptical arc;

| | | |
|---|---|---|
| 1 | **Choose** | Draw, Ellipse. |
| | | Or |
| 2 | **Choose** | the Ellipse or Partial Ellipse icon |
| | | Or  |
| 3 | **Type** | ELLIPSE at the command prompt |
| | | Command: ELLIPSE |
| 4 | Type | One of the following options: |
| | | Arc/Center/Isocircle/<Axis endpoint1>: |

**Ellipse options**

**Axis endpoint 1:** Defines the first axis by two specified endpoints. The angle of the first axis determines the angle of the ellipse. The first axis can define either the major or the minor axis of the ellipse.

**Axis endpoint 2:** <Other axis distance>/Rotation: Specify a point or enter a distance

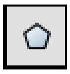
**Arc :** Creates an elliptical arc. The angle of the first axis determines the angle of the elliptical arc. The first axis can define either the major or the minor axis of the elliptical arc.

**Center :** Creates the ellipse by a specified center point.

**Isocircle :** Creates an isometric circle in the current isometric drawing plane.

**Rotation :** The major axis is now treated as the diameter of a circle that will be rotated a specified amount around the axis. You enter an angle between 0 and 89.4 degrees.

**Polygon**

1 Choose Draw, Polygon. 

Or

2 Click The polygon icon.

Or

3 Type Polygon at the command prompt.

Command: POLYGON

4 Type The number of sides for the polygon (31024)

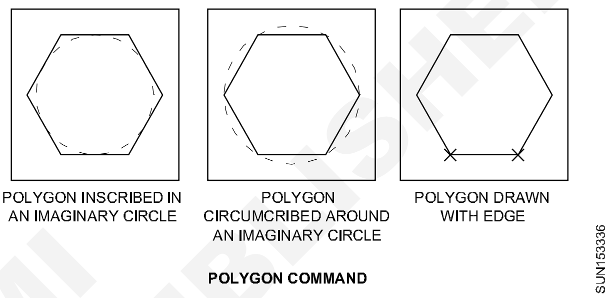
5 Pick The center of the polygon. Edge/ <Center of Polygon>: pick

Or

6 Type E to define the polygon by two edges.

7 Type I or C to place the polygon inside or outside of an imaginary circle. Inscribed in circle/ Circumscribed about circle (IC):

Fig 6




POLYGON COMMAND

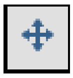
## Basic commands - II

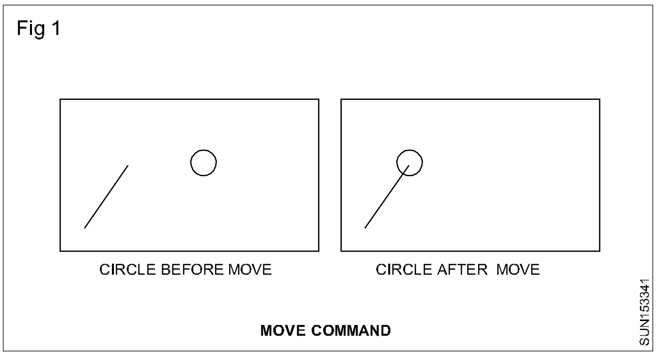
**Objective :** At the end of this exercise, you shall be able to
- **express move, copy, offset, rotate, trim, on, fillet, array, straiten, lengthen**

The previous lesson dealt with drawing commands. This lesson will introduce some common modifying commands. In AutoCAD, you may actually use modifying commands more often than drawing commands. Now that you know the basics, here's some more commands to add to your collection. Three commands, Trim, Extend and Offset are used often in 2D AutoCAD work.

| Command | Keystroke | Location | Result |
|---|---|---|---|
| Rectangle | RECTANGLE/REC | Home>Draw>Rectangle | Draws a rectangle after you enter one corner and then the second. |
| Trim | TRIM/TR | Home>Modify>Trim | Trims objects to a selected cutting edge. |
| Extend | EXTEND/EX | Home>Modify>Extend | Extends objects to a selected boundary edge. |
| Offset | OFFSET/O | Home>Modify>Offset | Offsets an object (parallel) by a set distance. |
| Object snaps | OSNAP/OS/F3 | Tools>Object Snap Settings | Brings up the OSNAP dialog box. |
| Move | Move/M | Home>Modify>Move | Moves an object or objects |
| Copy | Copy/CP | Home>Modify>Copy | Copies object(s) once or multiple times |
| Stretch | Stretch/S | Home>Modify>Stretch | Stretches an object after you have selected a portion of it |
| Mirror | Mirror/MI | Home>Modify>Mirror | Creates a mirror image of an object or selection set |
| Rotate | Rotate/RO | Home>Modify>Rotate | Rotates objects to a certain angle. |
| Fillet | Fillet/F | Home>Modify>Fillet | Creates a round corner between two lines |
| Chamfer | Chamfer/CHA | Home>Modify>Chamfer | Creates an angled corner between two lines |
| Array | Array/AR | Home>Modify>Array | Creates a repeating pattern of the selected objects |

## Move Command

| | | |
|---|---|---|
| 1 | Choose | Modify, Move. Or |
| 2 | Click | The Move icon or  |
| 3 | Type | MOVE at the command prompt com mand: MOVE or M |
| 4 | Pick | Objects to move Select objects: (se lect) |
| 5 | Pick | A point to move from Base point or displacement: (pick point) |
| 6 | Pick | A point to move to second point of dis placement: (pick point) |




### TIP

To move an object a specified distance, type a distance at the second point of displacement prompt:@1<0

### Moving Drawing Objects

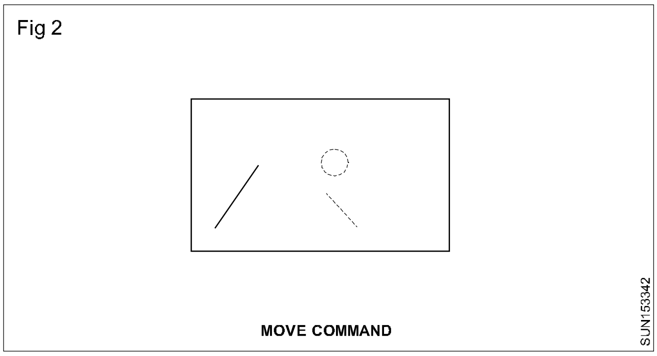
CAD drawing allows you to move drawing objects within a drawing in a convenient manner. Unlike on a drawing board, you don't need to first erase and then redraw in a new place. You can simply rearrange the existing drawing objects, as you like. This is a very useful tool for analyzing design alternatives and making quick adjustments to drawings.

### Previous Selection

Places selected objects in the previous selection set

| | | |
|---|---|---|
| 1 | Choose | Modify, Move. |
| | | Or |
| 2 | Click | the Move icon. |
| | | Or |
| 3 | Type | MOVE at the command prompt. |
| | | Command: MOVE or M |
| 4 | Pick | Objects to move. |
| | | Select objects :(P) |

### Previous Selection set Highlighted




### TIP

AutoCAD requires that objects be selected in order to be processed. The Select Objects prompt occurs after many commands, including the SELECT command itself.

### Copying Drawing Objects

CAD drawing allows you to make quick and easy copies of existing drawing objects. You can copy individual drawing objects or the entire drawing all at once. You can even make multiple copies of drawing objects within seconds.

Using the copy function is quite similar to the way the move function is used. First, you need to select objects using any of the methods described earlier. Then you need to indicate a base point and a relocation (or destination) point. The copied objects are placed according to the relocation point.

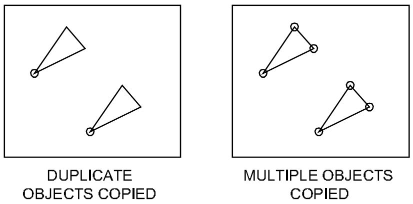
### Making Multiple Copies in a Rectangular Fashion

There are separate functions available in CADD that allow you to make multiple copies in a linear or rectangular fashion (commonly known as a rectangular array). You can make hundreds of copies within seconds. You don't need to enter a base point and a destination point. You just need to select the objects, specify how many rows and columns you need and the distance between them.

### Copy Command

| | | |
|---|---|---|
| 1 | Choose | Modify, copy.<br>Or |
| 2 | Click | the Copy icon <br>Or |
| 3 | Type | COPY at the command prompt. |
| 4 | Pick | Objects to copy.<br>Select objects: (select) |
| 5 | Pick | A point to move from.<br>Base point or displacement /Multiple: (pick point). |
| 6 | Pick | A point to copy to.<br>Second point of displacement: (Pick point)<br>Or |
| 7 | Type | A point to copy to.<br>Second point of displacement: @1<0 |

Fig 3




COPY COMMAND

SUN153343

### TIP

To copy many objects in the same copy command, type M for Multiple at the "Base point or displacement/Multiple" option.

### Offset Command

### Offset Distance

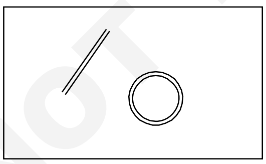
To offset a specified distance:

| | | |
|---|---|---|
| 1 | Choose | Modify, Offset. Or |
| 2 | Choose | the Offset icon.  |
| | | Or |
| 3 | Type | OFFSET at the command prompt. Command: OFFSET or O |
| 4 | Type | The distance to offset. Offset distance or <Through point>: (number) |
| 5 | Pick | The object to offset. Select object to offset: (select object) |
| 6 | Pick | A side to offset object to. Side to off set: (pick side) |
| 7 | Pick | Another object to offset |
| | | Select object to offset: (Pick side) |
| | | Or |
| 8 | Press | Enter to end the command. |

Offsetting objects by specifying a distance

### Offset Through Point

Fig 4



OFFSET COMMAND

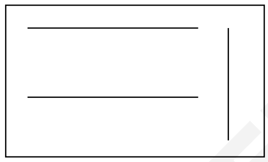
SUN153344

To offset through point

| | | |
|---|---|---|
| 1 | Type | OFFSET at the command prompt |
| | | Command: OFFSET |
| 2 | Type | T to specify a through point |
| | | Offset distance or <Through point>: (T) |
| 3 | Pick | A point to offset through (HINT: use ob ject snaps) Select object to offset: (pick) through point: (select object) |

### Offset through a point

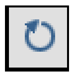
Fig 5



OFFSET COMMAND

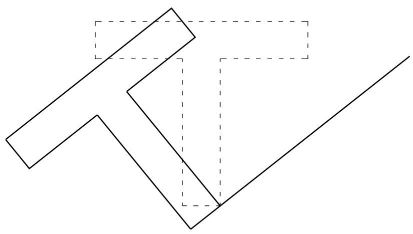
SUN153345

### Rotate command

| | | |
|---|---|---|
| 1 | Choose | Modify, Rotate |
| | | Or |
| 2 | Click | the Modify icon.  |
| | | Or |
| 3 | Type | ROTATE at the command prompt |
| | | Command: ROTATE |
| 4 | Pick | Objects to rotate: |
| | | Select objects: ( select) |
| 5 | Pick | A pivot point to rotate around |
| | | Base point: (point) |
| 6 | Type | A rotation angle<Rotation angle>/Refer ence: (number) |
| | | Or |
| 7 | Pick | A rotation angle<Rotation angle>/Refer ence: (point) |

### Rotating the Drawings

Fig 6



ROTATE COMMAND

SUN153346

CAD drawing allows you to rotate selected drawing objects to a specified angle. To rotate, you need to select the drawing objects, enter a reference point (or base point) and the rotation angle. The base point acts as a pivot point around which the objects are rotated. The rotation angle determines by how much the objects will be rotated and in which direction.

### Reference Angle Rotation

A positive angle causes counterclockwise rotation, and a negative angle produces clockwise rotation. If you respond to the last prompt with r, you can specify the current rotation and the new rotation you want. AutoCAD prompts

| | | |
|---|---|---|
| 1 | Type | R for a rotation angle<Rotation angle>/ Reference: (R) |
| 2 | Choose | An existing rotation angle Rotation angle: (number or points) |
| 3 | Choose | A new rotation angle New angle: (number or points) |

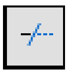
### TIP

You can show AutoCAD the reference angle (by pointing to the two endpoints of a line to be rotated), and then specify the new angle. You can specify the new angle by pointing or by dragging the object.

### Trim

The TRIM command allows you to trim objects in a drawing so they end precisely at a cutting edge defined by one or more other objects in the drawing.

1 Choose Modify, Trim
Or

2 Click the Trim icon. 
Or

3 Type Trim at the command prompt
Command: Trim
Select cutting edge(s)

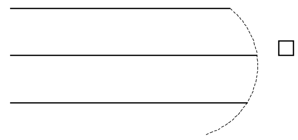
4 Pick The CUTTING edge to extend to
Select objects: ( select)

5 Press Enter to accept the cutting edge
Select objects: (press enter)

6 Pick Objects to trim
<Select object to trim>/Project/Edge/ Undo:
Select an object, enter an option, press enter

7 Press ENTER when you are done choosing objects
Select object to trim/Undo: (press enter)

Fig 7



TRIM COMMAND

SUN153347

**TIP** : Hold the SHIFT key to interactively extend instead of trim.

### Cutting drawing objects along an edge

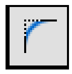
CADD allows you to erase drawing objects along a selected edge (this technique is often called trimming).When you use this function, you are prompted to select the drawing object that is to be used as the cutting edge and then select the objects that are to be erased along that edge.

### Making Sharp and Rounded Corners

CADD allows you to make fine corners of any two lines or arcs. This technique, often called filleting, is the quickest way to join the missing corners of lines and arcs. With this function active, to make a corner all you need to do is select the lines or arcs that have missing corners. CADD automatically extends or shortens the selected objects to form a corner. You can also specify whether you want a sharp corner or a rounded corner.

### Fillet

1 Choose Modify, Fillet.
Or

2 Click the fillet icon. 
Or

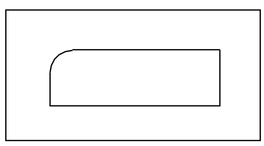
3 Type FILLET at the command prompt. Command: FILLET

4 Pick First object to fillet. Polyline/Radius/ Trim<Select two objects>: Select first object.

5 Pick Second object to fillet.
Select second object: select second object.
Or

6 Type One of the following options:
- P Fillets an entire Polyline
- R Sets the fillet radius.
- T Sets the trimmode (trim cuts the fillet corner and no trim keeps the fillet corner).

Fig 8



FILLET COMMAND

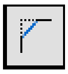
SUN153348

**TIP**

You can also fillet PARALLEL lines as well as PLINES with LINES

Type a radius of Zero (0) to create a clean 90 degree corner.

## Chamfer



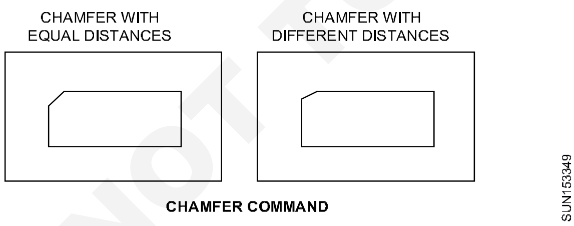
| | | |
|---|---|---|
| 1 | Choose | Modify, Chamfer. |
| | | Or |
| 2 | Click | the Chamfer icon. |
| | | Or |
| 3 | Type | CHAMFER at the command prompt. |
| | | Command: CHAMFER |
| 4 | Pick | First object to chamfer. Polyline/ Distance/Angle/Trim/ Method<Select first line>: select first object. |
| 5 | Pick | Second object to chamfer. |
| | | Select second object: select second object. |
| | | Or |
| 6 | Type | One of the following options: |

- P Chamfers entire Polyline.
- D Sets chamfer distances.
- A Uses a distance and angle method in stead of two distances.
- T Sets the trim mode
- M Sets the method to distance or angle.

Chamfer with equal distances

Chamfer with different distances

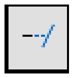
Fig 9




## Making Chamfered Corners

CADD allows you to make a chamfered corner between two lines. It works quite like the fillet command. When you enter the chamfer command, you are prompted to select the lines that are to be chamfered and enter a chamfer distance. The chamfer distance determines the size of the chamfer.

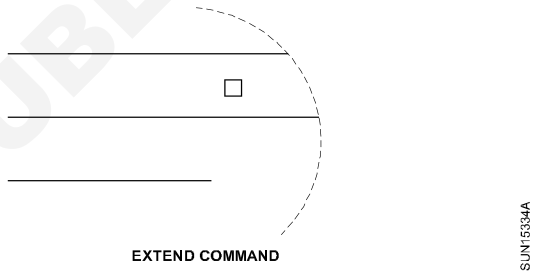
## Extend command



| | | |
|---|---|---|
| 1 | Choose | Modify, Extend, |
| | | Or |
| 2 | Click | the extend icon. |
| | | Or |
| 3 | Type | EXTEND at the command prompt command: EXTEND |
| | | Select boundary edge (s)... |
| 4 | Pick | The BOUNDARY edge to extend to select objects: (select) |
| 5 | Press | ENTR to accept the boundary edge select objects: (press enter) |
| 6 | Pick | The object to extend |
| | | <Select object to extend> / Project/ Edge/ Undo: Select an object, enter an option, or press enter: (select) |
| 7 | Press | ENTER when you are done choos ing objects |

Lines Extended to an Arc (Arc is boundary edge)

Fig 10




**TIP**

- use the object selection option FENCE to choose multiple objects

## Extending Drawing Objects to an Edge

CADD allows you to extend lines to a selected drawing object. Often you need to extend lines to construct a drawing and to fix any graphical errors. To extend lines, you need to select an edge to which the lines should extend and then select the lines to be extended.

## Dividing an Object into Equal Parts

CADD allows you place dividing marks on a drawing object such as a line, arc, ellipse or spline. To use this command, you need to select an object and specify how many divisions are required. This function places markers at equal distances on the drawing object.

**Break**

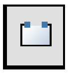
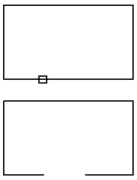
| | | |
|---|---|---|
| 1 | Choose | Modify, Break.  |
| | | Or |
| 2 | Click | the Break icon. |
| | | Or |
| 3 | Type | BREAK at the command prompt. Command: BREAK |
| 4 | Pick | Object to break. |
| | | Select object: (select one object) |
| 5 | Pick | A second break point. Enter second point: (point) |
| 6 | Type | F to choose a different break point Enter second point (or F for first point): (F) |

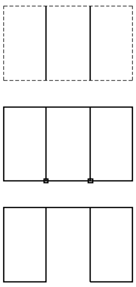
Fig 11




BREAK COMMAND

| | | |
|---|---|---|
| 7 | Pick | The first break point on the object |
| | | Enter first point: (point) |
| 8 | Pick | A second break point |

Fig 12




BREAK COMMAND

**TIP:**

You can also type coordinates instead of picking a break point. Enter second point (or F for first point): @3'<0

If you break a circle, it changes to an arc by deleting the portion from the first point to the second, going counter-clockwise.

Breaking a polyline with nonzero width will cause the ends to be cut square.

**Mirror command**

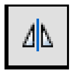
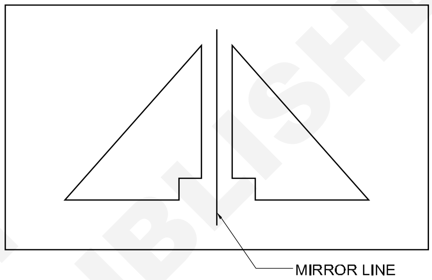
| | | |
|---|---|---|
| 1 | Choose | Modify, Mirror.  |
| | | Or |
| 2 | Click | the Mirror icon |
| | | Or |
| 3 | Type | MIRROR at the command prompt. |
| | | Command: MIRROR |
| 4 | Pick | Objects to mirror. Select objects: (Se lect) |
| 5 | Pick | First point of mirror line: (point) |
| 6 | Pick | Second point: (Point) |
| 7 | Type | Yes to delete the original objects and No to keep them. |
| | | Delete old objects? Y or N |

Fig 13




MIRROR COMMAND

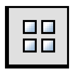
**Mirroring Drawings**

CADD allows you to create mirror images of drawings. This capability is very useful when you want to draw something that is symmetrical on both sides. You need to draw only one half of the drawing; the rest of the drawing can be completed using the mirror function. To make a mirror image, you need to select the objects to be mirrored and indicate a mirror axis. The mirror axis is an imaginary line along which the diagram is mirrored.

**Array commands**

**Rectangular Array**

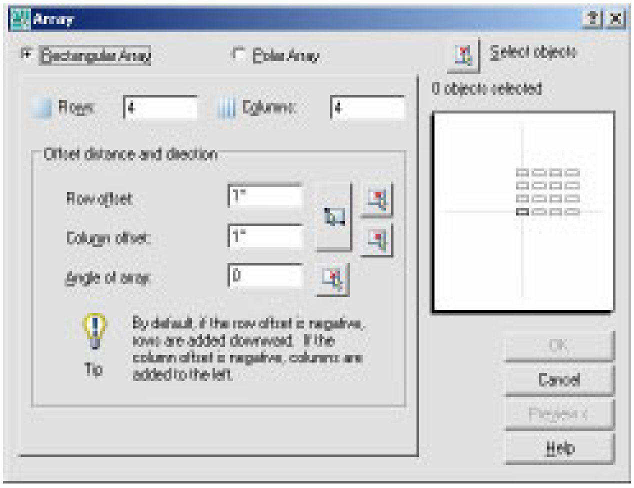
To draw rectangular array:

| | | |
|---|---|---|
| 1 | Choose | Modify, Array. |
| | Or | |
| 2 | Click | the Array icon.  |
| | | Or |
| 3 | Type | ARRAY at the command prompt. Command: ARRAY Objects to array. Select |
| 4 | Pick | Objects to array. Select |
| | | Objects: (select) |
| 5 | Type | The number of rows top to bottom. Number of rows (----) <1>: (number) |
| 6 | Type | The number of columns left to right. Number of columns (III) <1>:(num ber) |

7 Type The unit cell distance between items in each row. Distance between rows: (+number=up, number = down)

8 Type The unit cell distance between items in each column.

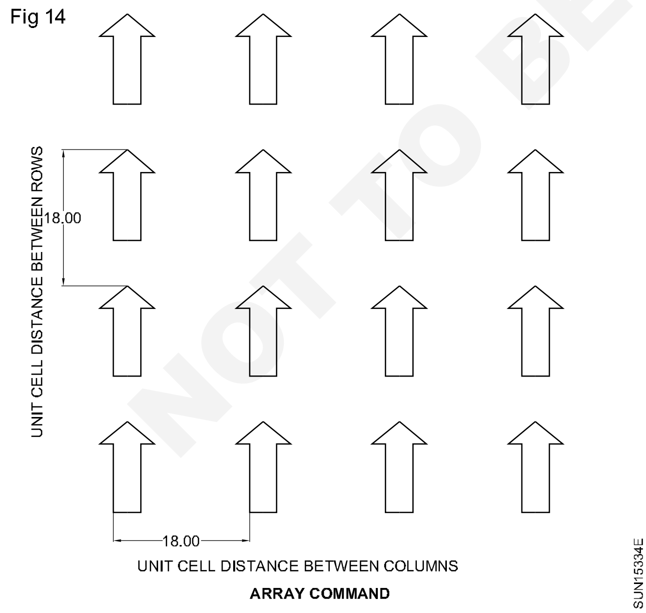
Distance between columns: (+ number = right, -number = left)




### Creating an Array of objects

The array command in AutoCAD is used to make multiple copies of objects. Although you can use the copy command to duplicate objects, the array command is more flexible and precise. One advantage of using the array command is that it allows you to copy objects in a defined angle and exact number of copies. Therefore, you can create array in various pattern. For example, you can show multiple objects in a row, column, or irregular pattern such as a spiral. Let's look at a few examples below:

Fig 14




### Polar Array

To draw a polar array:

1 Choose Modify, ARRAY. Or

2 Click The Array icon. Or

3 Type ARRAY at the command prompt. Com mand: ARRAY

4 Pick Objects to array. Select Objects: (select)

5 Type P to draw a polar array. Rectangular or Polar array (R/P):P

6 Pick A center point for the array. Center point of array. Pick point

7 Type The TOTAL number of items in the ar ray. Number of items: number

8 Type The number of degrees to rotate the objects. Degrees to fill (+=CCW, -+CW) <360>: Number

9 Type Yes No to rotate objects. Rotate objects as they are copied? <y> Y or N

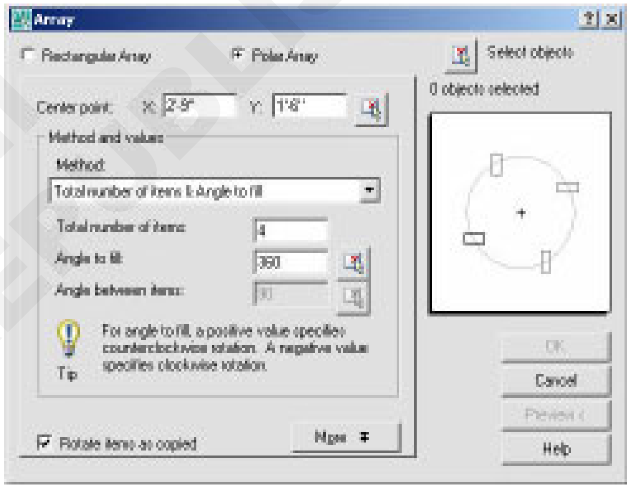
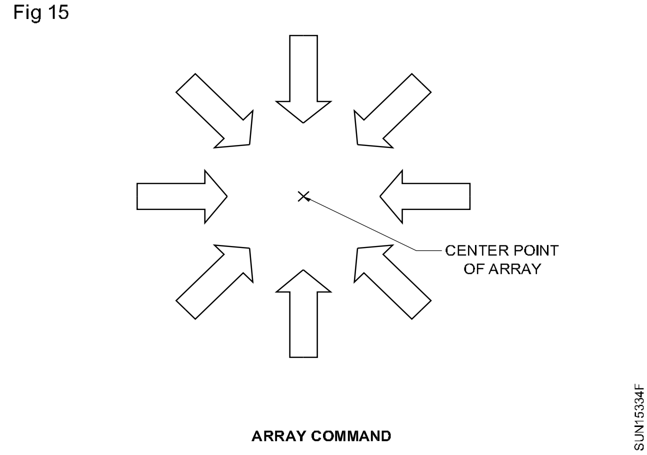


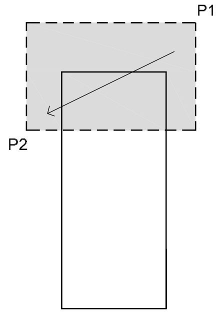

Fig 15



## Stretch

| | | |
|---|---|---|
| 1 | Choose | Modify, stretch<br>Or |
| 2 | Click | the stretch icon. |
| 3 | Type | STRETCH at the command prompt. Command: STRETCH Select objects to stretch by window. |
| 4 | Type | C to choose CROSSING window Select objects: C |
| 5 | Pick | A first corner to stretch. First corner: (point) |
| 6 | Pick | The opposite corner to window the ob jects to stretch.<br>Other corner: (point) |
| 7 | Press | ENTER to accept objects to stretch |
| 8 | Pick | A base point to stretch from Base point: (point) |

Fig 16




STRETCH COMMAND

SUN15334G

### Stretching Diagrams

CADD allows you to quickly change the size of diagrams by stretching lines, arcs, splines, etc. This function is very helpful to make quick alterations to drawings. To use the stretch function, you need to select the drawing objects to be stretched and specify the distance and direction of stretching.

| | | |
|---|---|---|
| 9 | Pick | A point to stretch to New point: (point) |
| 10 | Type | A distance to stretch. New point: @ 1<0 |

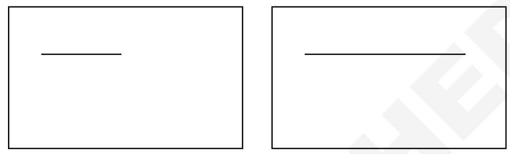
**TIP**

The Stretch command must use a CROSSING window or a CROSSING POLYGON window.

## Lengthen

| | | |
|---|---|---|
| 1 | Choose | Modify, LENGTHEN.<br>Or |
| 2 | Type | LENGTHEN at the command prompt. Command:_ lengthen<br>Select an object or [DElta/Percent/Total/ Enter delta length or [Angle]<0.0000>:2<br>Select an object to change or [Undo]: pick object<br>Object before lengthen<br>Object after lengthen |

Fig 17



OBJECT BEFORE LENGTHEN OBJECT AFTER LENGTHEN

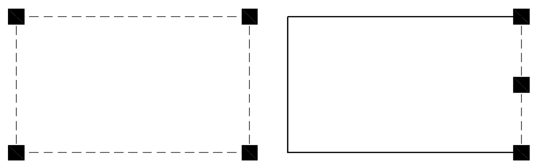
LENGTHEN COMMAND

SUN15334H

## Explode Command

| | | |
|---|---|---|
| 1 | Choose | Modify, Explode.<br>Or |
| 2 | Pick | the explode icon. |
| 3 | Type | EXPLODE at the command prompt.<br>Command: EXPLODE<br>Or |
| 4 | Pick | The object to explode. Select objects: (pick) |

Fig 18



POLYLINE BEFORE EXPLODE POLYLINE (LINE) AFTER EXPLODE

EXPLODE COMMAND

SUN15334I

## 4.3 OOPS commands

Reinserts the last erased set of objects or block even if it was not the last command issued. Otherwise Oops acts like UNDO.

| | | |
|---|---|---|
| 1 | Type | OOPS at the command prompt to rein sert erased objects<br><br>Command: OOPS |

# Other CAD commands

**Objectives :** At the end of this exercise, you shall be able to
- **points, rectangle, polyline, spline, multiline, construction line**
- **adding patterns to drawings.**

## Introduction

### Drawing Multiple Parallel Lines

CADD allows you draw parallel lines simultaneously just by indicating a starting point and an end point. These lines can be used to draw something with heavy lines or double lines. For example, they can be used to draw the walls of a building plan, roads of a site map, or for any other presentation that requires parallel lines.

### Drawing Flexible Curves

CADD allows you to draw flexible curves (often called splines) that can be used to draw almost any shape. They can be used to create the smooth curves of a sculpture, contours of a landscape plan or roads and boundaries of a map.

To draw a flexible curve, you need to indicate the points through which the curve will pass. A uniform curve is drawn passing through the indicated points. The sharpness of the curves, the roughness of the lines and the thickness can be controlled through the use of related commands.

### Adding Hatch Patterns to Drawings

The look of CADD drawings can be enhanced with the hatch patterns available in CADD. The patterns can be used to emphasize portions of the drawing and to represent various materials, finishes, and spaces. Several ready-made patterns are available in CADD that can be instantly added to drawings.

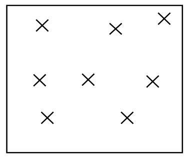
Hatch patterns are quite easy to draw. You don't need to draw each element of a pattern one by one. You just need to specify an area where the pattern is to be drawn by selecting all the drawing objects that surround the area. The selected objects must enclose the area completely, like a closed polygon. When the area is enclosed, a list of available patterns is displayed. Select a pattern, and the specified area is filled.

### Point Command

1 Choose Draw, Point, Single or Multiple Point
Or
2 Click the Point icon
Or
3 Type POINT at the command prompt
Command: POINT

4 Pick A point on the drawing

Fig 1



POINT COMMAND

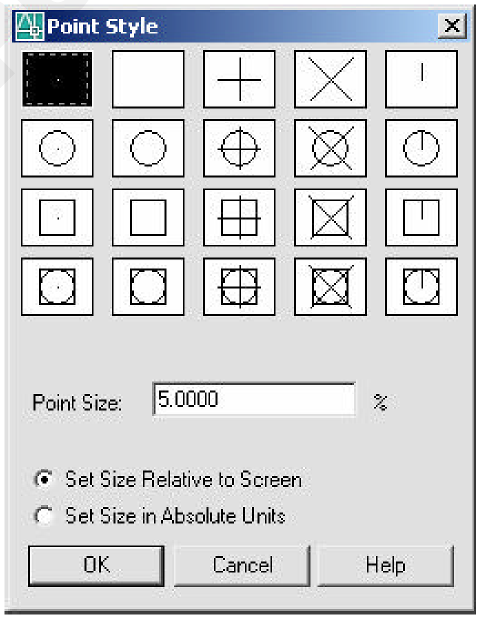
SUN153351

### Point (point)

### Point Styles 21.1

Changes the appearance of points and point sizes.

1 Choose Format, Point Style...
Or
2 Type DDPTYPE at the command prompt.
Command: DDPTYPE




### Rectangle 2

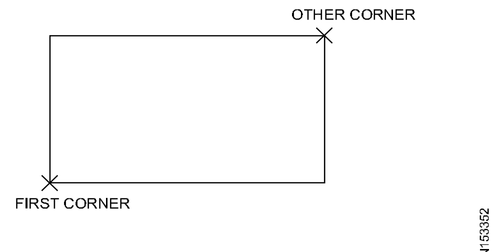
1 Choose Draw, Rectangle.
Or
2 Click the Rectangle icon
Or

3 Type Rectangle at the command prompt Command: RECTANG chamfer/Elevation/Fillet/Thickness/Width/<First corner>

4 Pick first corner

5 Pick other corner or type coordinates (i.e. @ 4,2)

Fig 2



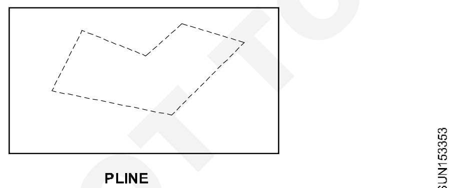

RECTANGLE COMMAND

**Pline Command**

A polyline is a connected sequence of line segments created as a single object. You can create straight line segments, arc segments, or a combination of the two.

1 Choose Draw, Polyline.
Or
2 Pick the Pline icon.
3 Type PLINE at the command prompt Command: PLINE or PL
4 Pick A Point on the drawing to start the polyline
Form point: (select)
5 Type One of the following options Arc/Close/Halfwidth/Length/Undo/Width/<endpoint of line>:
Or
6 Pick A point to continue drawing Arc/Close/Halfwidth/Length/Undo/Width/<endpoint of line>: (pick point)

Fig 3




PLINE

**PLINE options:**

**Arc** : Toggles to arc mode and you receive the following: Angle/CEnter/CLose/Direction/Halfwidth/Line/Radius/Second Pt/Undo/Width/<enter of arc>:

**Close :** Closes a polyline as it does in the line command.

**Halfwidth** : Specifies the halfwidth of the next polyline segments. Can be tapered.

**Length** : Specifies the length to be added to the polyline in the current direction.

**Undo :** Undoes the previous pline segment as with the line command.

**Width :** Specifies the width of the next polyline segments. Can be tapered.

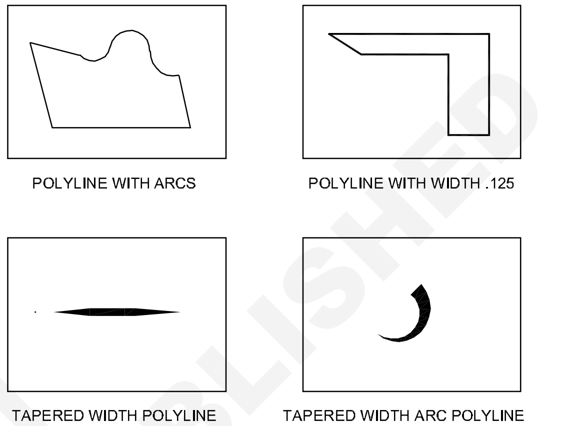
Polyline with arcs

Polyline with width 125

Tapered width polyling

Tapered width arc polyline

Fig 4




PLINE

**Convert PLINE to Spline**

1 Draw A PLINE.

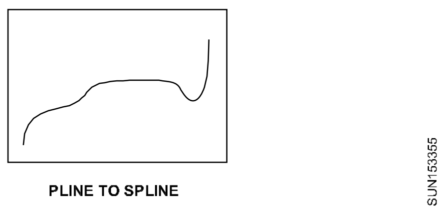
2 Type PEDIT to edit the polyline as a spline.

3 Choose Draw, Spline

4 Type Object at the command prompt.

5 Click Once on the polyline to turn it into a spline.

Fig 5

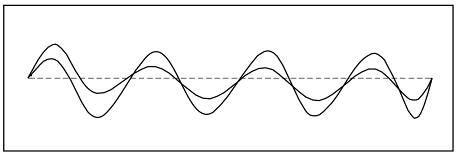



PLINE TO SPLINE

**Spline**

The SPLINE command creates a particular type of spline known as a nonuniform rational B-spline (NURBS) curve. A NURBS curve produces a smooth curve between control points.

Fig 6



SPLINE

SUN153356

1 Choose Draws, Spline.

Or

2 Click the Spline icon

Or

3 Type SPLINE at the command prompt Com mand: SPLINE

4 Pick A start point for the spline Object /<En ter first point> (pick point)

5 Pick Points until you are done drawing splines Enter point: (pick points)

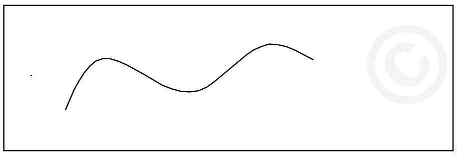
6 Press Enter or close to complete the spline

7 Pick Starting tangent point for the spline En ter start tangent (pick point)

8 Pick Ending tangent point for the spline

Enter end tangent: (pick point)

Fig 7



SPLINE

SUN153357

**Spline options**

**Object** Convers 2D or 3D spline-fit polylines to equivalent Splines

**Points** Points that defines the spline

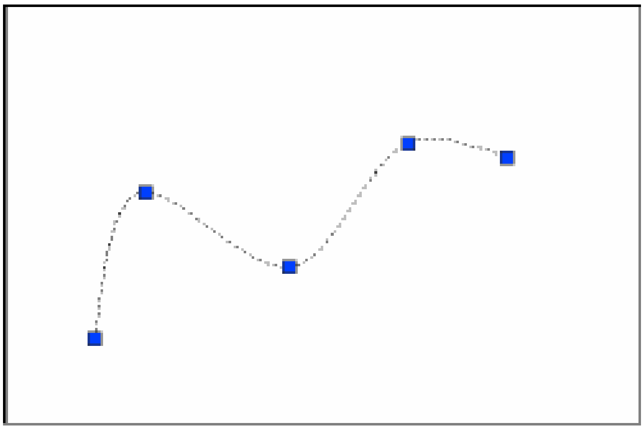
**Close** Closes a spline

**Fit Tolerance** Allows you to set a tolerance value that creates a smooth spline.

TIP: Refer to AutoCAD online help topic for more information on spline options.

Editing Splines

1. Choose Modify, Object, Spline.



TIP:

Drawings containing splines use less memory and disk space than those containing spline-fit polylines of similar shape.

Multilines1

MLINE Command

1. Choose Draw, Multiline.

Or

2. Type MLINE at the command prompt Com mand: MLINE

3. Pick A point to start the multiline.

Justification/Scale/Style/<From point>: pick point

4. Pick A second point to continue the multiline. <To point>: Pick point

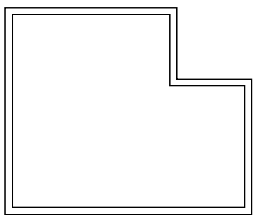
5. Pick The next point to continue drawing Multilines. Undo/<To point>: pick point

6. Press ENTER to end the multiline

Close/Undo/<To point>: press enter or

7. Type C to close the multiline back to the first point. Close/Undo/<To point:C

Fig 8



MULTILINES

SUN153358

## Multiline Styles

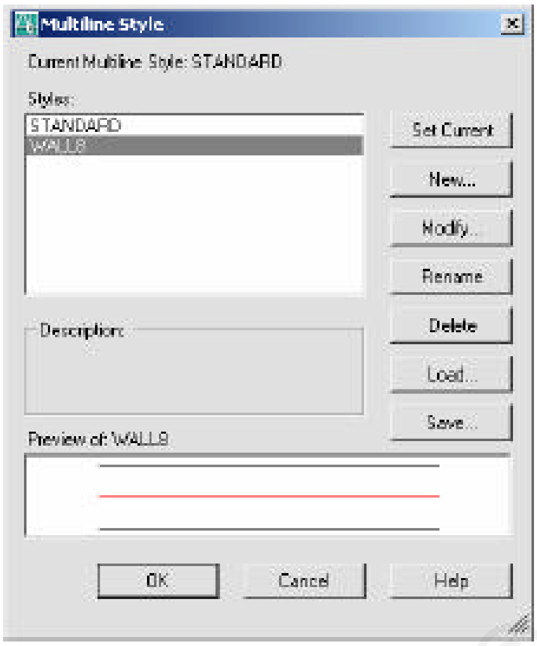
1 Choose Format, Multiline Style..

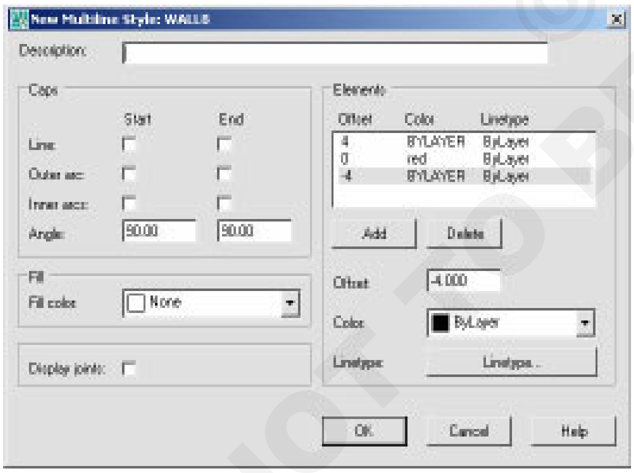
2 Type MLSTYLE at the command prompt.
Command: MLSTYLE

3 Rename The existing style called STANDARD to your new style.

4 Choose Element Properties to change the ap pearance of the Multilines.

5 Choose ADD to create the new multiline.




Editing Multilines 1

1 Choose Modify, Multiline...

Or

2 Type MLEDIT at the command prompt

Command: MLEDIT

3 Choose from one of the mledit options:

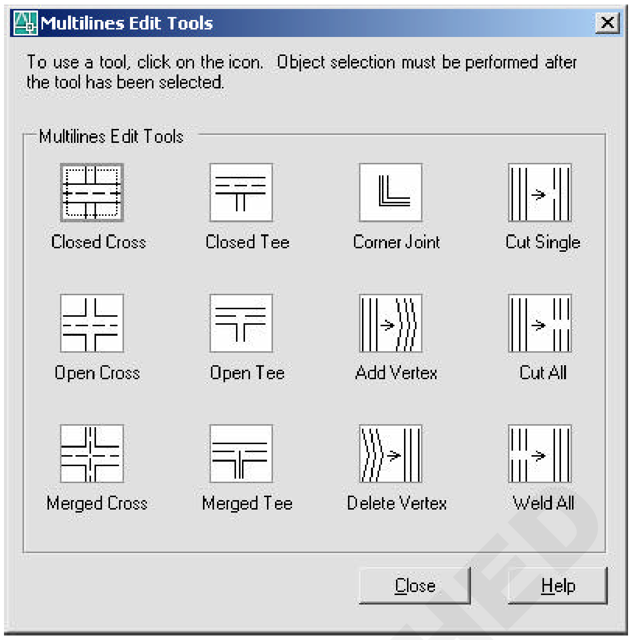
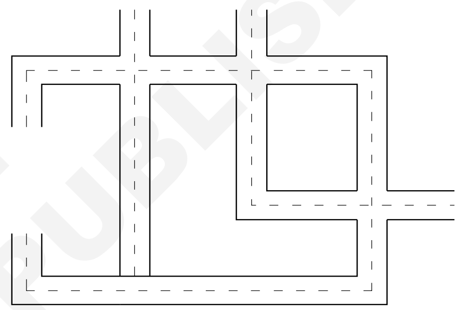



Fig 9



MULTILINES

SUN153359

## Construction Line

Creates an infinite line.

1 Choose Draw, Construction Line

Or

2 Choose the XLINE icon.

Or

3 Type XLINE at the command prompt. Com mand: XLINE

Specify a point or [Hor/Ver/Ang/Bisect/Offset]:

XLINE Options

HOR Creates a horizontal xline passing through a specified point

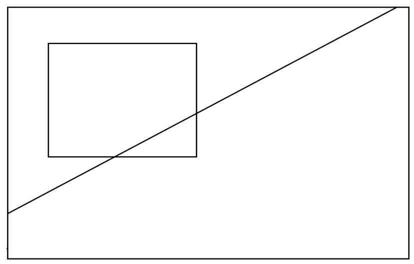
VER Creates a vertical xline passing through a specified point

ANG Creates an xline at a specified angle.

BISECT Creates an xline that passes through the selected angle vertex and bisects the angle between the first and second line

OFFSET Creates an xline parallel to another object.

Fig 10




Ray Command

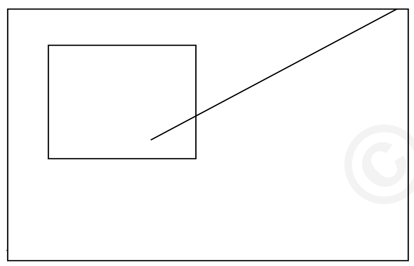
Creates an infinite line in one direction

1 Choose Draw, RAY

Or

2 Type RAY at the command prompt. Com mand: RAY Specify a point: (pick through point)

Fig 11




HATCH Command

1 Choose Draw, Hatch...

Or

2 Click the Hatch icon.

Or

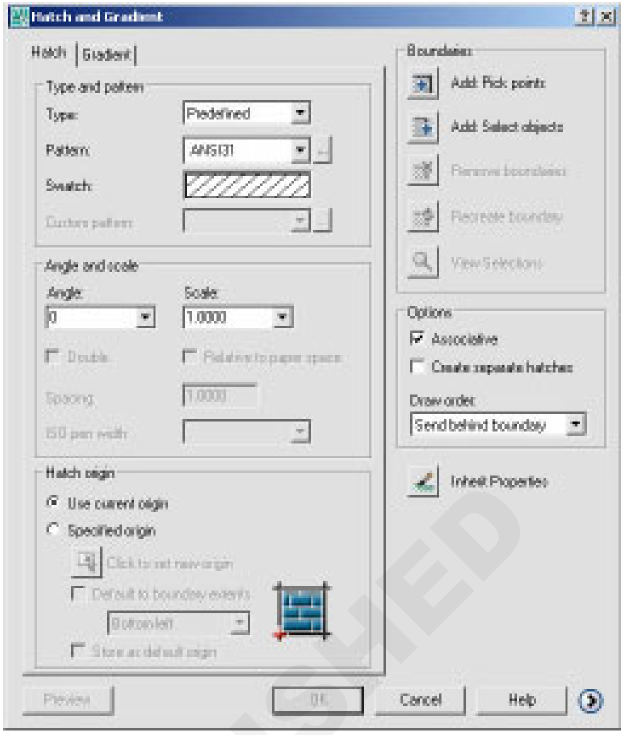
3 Type HATCH at the command prompt Com mand: HATCH

**HATCH options**

Pattern Type: Sets the current pattern type by using AutoCAD's Predefined patterns or user defined patterns.

Pattern Properties: Sets the current pattern, scale, angle, and spacing, Controls if hatch is double spaced or exploded.

Pick Points: Constructs a boundary from existing objects that form an enclosed area.




**Select Objects:** Selects specific objects for hatching. The Boundary Hatch dialog box disappears and AutoCAD prompts for object selection.

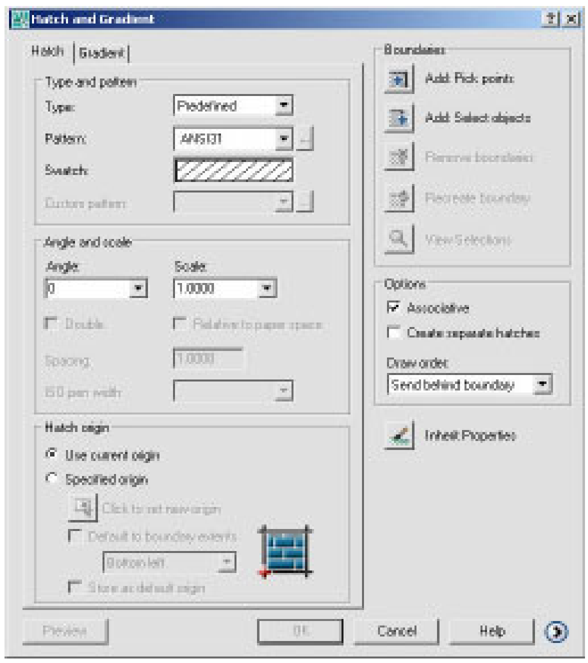
Inherit Properties: Applies the properties of an existing associative hatch to the current Pattern Type and Pattern Properties options.

Preview Hatch: Displays the hatching before applying it. AutoCAD removes the dialog box and hatches the selected areas.

Associative: Controls associative hatching.

Apply: Crates the crosshatching in the boundary.

**Annotative Hatch**



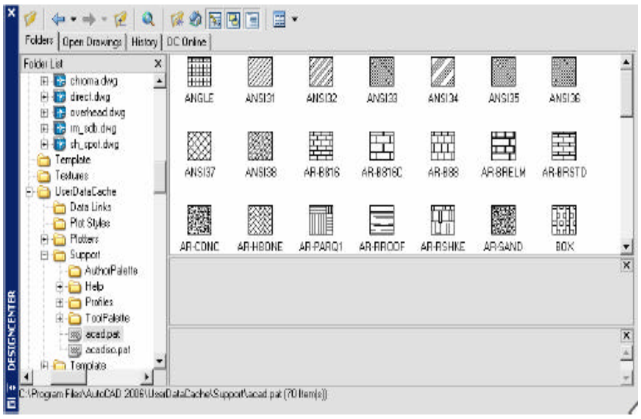
### Hatching from the Design Center 20.3

1 Choose: A cross hatch pattern from the following AutoCAD directly\AutoCADxxxx\Support\acad.pat or \AutoCADxxxx\Backup

2 **Drag:** and drop a pattern into a drawing.

TIP:

Be sure the HPSCALE is set before dropping a hatch pattern into a drawing.




## Text & dimensions

**Objectives :** At the end of this exercise, you shall be able to
- **define text & dimensioning**
- **explain adding text to drawing**
- **explain common methods of dimensioning**

### Introduction

### Defining a Text Style

As discussed, there are a number of factors that control the appearance of text. It is time-consuming to specify every parameter each time you need to write text. CADD allows you to define text styles that contain all the text information such as size, justification and font. When you need to write text, simply select a particular style and all the text thereafter is written with that style. CADD offers a number of ready-made text styles as well.

### Adding Text to Drawings

You can use text to write notes, specifications and to describe the components of a drawing. Text created with CADD is neat, stylish and can be easily edited. Typing skills are helpful if you intend to write a lot of text.

Writing text with CADD is as simple as typing it on the keyboard. You can locate it anywhere on the drawing, write it as big or as small as you like and choose from a number of available fonts.

### Drawing Dimensions

CADD's dimensioning functions provide a fast and accurate means for drawing dimensions. To draw a dimension, all you need to do is to indicate the points that need to be dimensioned. CADD automatically calculates the dimension value and draws all the necessary annotations.

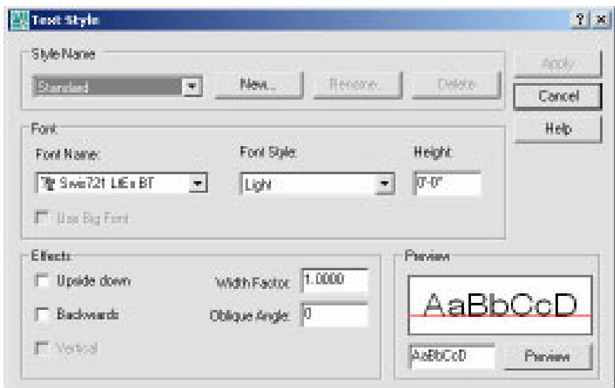
The annotations that form a dimension are: dimension line, dimension text, dimension terminators and extension lines (see fig.) you can control the appearance of each of these elements by changing the dimensioning defaults.

The following are the common methods for drawing dimensions:

- Drawing horizontal and vertical dimensions
- Dimensioning from a base line
- Dimensioning arcs and circles

### Text Style Command

| | | |
|---|---|---|
| 1 | Choose | Format, Text Style... |
| | | Or |
| 2 | Type | STYLE at the command prompt. Command: STYLE |
| 3 | Pick | The Text Style icon from the Text Toolbar. |
| 4 | Choose | a style from the menu or create a NEW style |
| 5 | Choose | a font file. |
| 6 | Type | a height for the text (set to zero to vary heights) |
| 7 | Type | a width factor for each character. Width fac tor<1>: (enter) |
| 8 | Type | an obliquing (slant) angle. |
| | | Obliquing angle <0>: (angle or enter) |
| 9 | Type | Yes or No to place characters backwards. Backwards? (Y or N) |
| 10 | Type | Yes or No to draw characters upside down. Upside down? (Y or N) |
| 11 | Type | Yes or |



## Font Files

AutoCAD supports the following font types:

| | |
|---|---|
| .SHX | AutoCAD Fonts |
| .PFB | Adobe Type I Fonts |
| .PFA | |
| .TTF | Windows True Type Fonts |

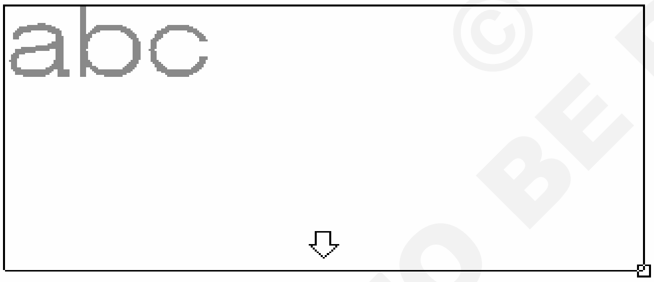
**TIP:**

To replace the font globally in a drawing, type style at the command prompt and keep the same style name but replace the font file with the new font. When AutoCAD regenerates, it will replace all text drawn with that style with the new font.

## Multiline Text

Mtext Command

| | | |
|---|---|---|
| 1 | Choose | Draw, Text, Multiline Text... |
| | | Or |
| 2 | Pick | the Mtext icon. |
| | | Or |
| 3 | Type | MTEXT at the command prompt. Com mand: MTEXT / MT |
| 4 | Type | One of the following options height/Jus tify/Rotation/Style /Width: |
| 5 | Pick | 2 points to define the text window. |
| 6 | Type | text or change an MTEXT setting. |




**MTEXT options:**

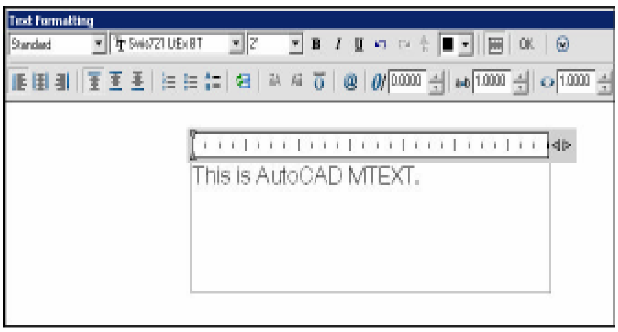
**Rotation** : Controls the rotation angle of the text boundary.

**Style :** Specifies the text style to use in paragraph text.

**Height :** Specifies the height of uppercase text

**Direction :**Specifies whether text is vertical or horizontal

**Width :** Specifies the width of the text boundary.

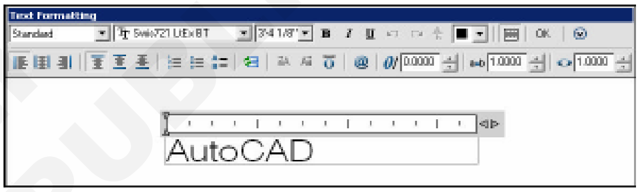



## Editing Text

**DDEDIT**

| | | |
|---|---|---|
| 1 | Choose | Modify, Text... |
| | | Or |
| 2 | Click | the Edit Text icon from the Text toolbar. |
| | | Or |
| 3 | Type | DDEDIT at the command prompt. Com mand: DDEDIT or ED |
| 4 | Pick | The text to edit. |
| 5. | Pick | Additional text or ENTER to end the Command. |
| | | Select objects: ENTER |

Text Edit Dialog Box for TEXT and DTEXT commands.

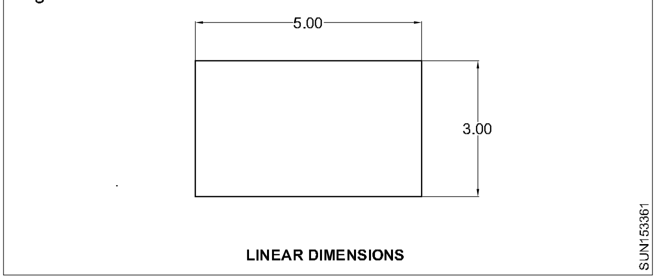




## Dimensions

### Linear Dimensions

| | | |
|---|---|---|
| 1 | Choose | Dimension, Liner. |
| | | Or |
| 2 | Click | the Linear Dimension command from the toolbar. |
| | | or |
| 3 | Type | DIM at the command prompt. Com mand: DLI |

Fig 1



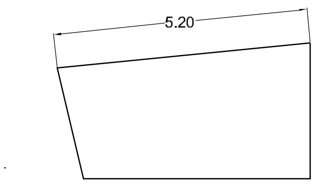

### Aligned Dimensions

| | | |
|---|---|---|
| 1 | Choose | Dimension, Aligned. |
| | | Or |
| 2 | Click | the Aligned Dimension command from the toolbar. |

3 Type DIM at the command prompt.

Command: DAL

Fig 2




ALIGNED DIMENSIONS

SUN153362

## Radial Dimensions

1 Choose Dimension, Radius or Diameter.

Or

2 Click the Radial Dimensions command from the toolbar.

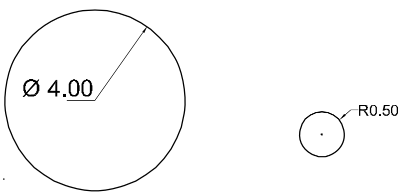
or

3 Type DIM at the command prompt.

Command: DIM

DIM: RADIUS or DIAMETER

Fig 3




RADIAL DIMENSIONS

SUN153363

## Angular Dimensions

1 Choose Dimension, Angular.

Or

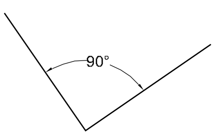
2 Click the Angular Dimensions command from the toolbar

3 Type DIM at the command prompt.

Command: DIM

Dim: ANGULAR

Fig 4




ANGULAR DIMENSIONS

SUN153364

## Continued and Baseline Dimensions

1 Choose Dimension, Continue or Baseline.

Or

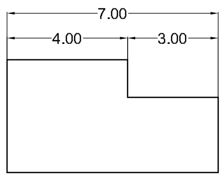
2 Click the Continue or baseline Dimensions command from the toolbar.

3 Type DIM at the command prompt.

Command: DIM

Dim: CONTINUE or BASELINE

Fig 5




CONTINUED AND BASELINE DIMENSIONS

SUN153365

## Leaders

1 Choose Dimension, Leader... or

2 Click the Leader icon from the Dimension toolbar. or

3 Type QLEADER at the command prompt. Command: QLEADER

Fig 6


QLEADER

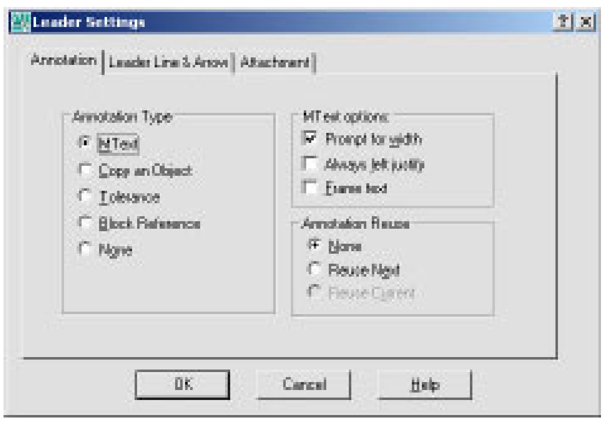
SUN153366

## Leader Settings

1 Type QLEADER at the command prompt. Command: QLEADER

2 Type "S" at the QLEADER prompts to change the leader settings.

3 Choose a setting from the following dialog box.



### Quick Dimensions

Quickly creates dimension arrangements from the geometry you select.

1 Choose Dimension, QDIM or

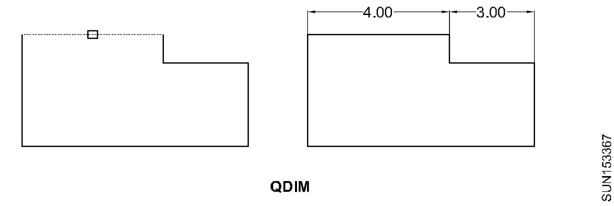
2 Click the Quick Dimension icon from the Dimensions toolbar. Or

3 Type QDIM at the command prompt.

Command: QDIM

4 Pick the objects to dimension.

Fig 7

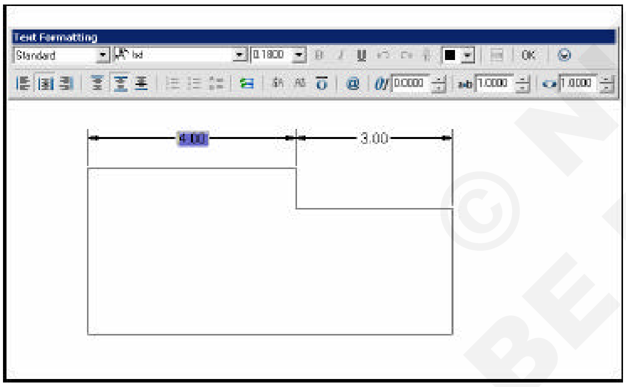



### Modifying Dimensions

**DDEDIT**

1 Choose Modify, Object, Text.

2 Choose the dimension text to modify.




**TIP:** The actual dimension is placed in brackets <>. Text can be placed in front of or behind these brackets. If text is placed between the brackets, the dimension loses its associative properties.

### Stretching Dimensions

1 Choose Modify, Stretch.

2 Choose a crossing window around the area to stretch. Be sure to include the dimension endpoints.

### Dimtedit

Moves and rotates dimension text

1. Choose Dimension, Align Text. Or

2. Type DIMTEDIT at the command prompt.

Command: DIMTEDIT

Select dimension: select object

Enter text location (Left/Right /Angle):

### Dimension Edit Commands

**HOMetext :** Moves the dimension text back to its home (default) position.

**NEWtext :** Modifies the text of the Dimensions.

**Rotate :** Rotates dimension text.

**Oblique :** Sets the obliquing angle of Dimension extension lines.

**Over ride :** Overrides a subset of the Dimension variable settings.

**Update :** Redraws the Dimensions as directed by the current settings of all dimensioning variables.

### Ordinate Dimensions

1 Choose Dimension, Ordinate or

2 Type DIMORDINATE at the command prompt. Command: Dimordinate

### Creating Dimension Styles

1 Choose Format, Dimension Style... or

2 Choose Dimension, Style. or

3 Choose Dimension Style icon from the Diameter Style toolbar.

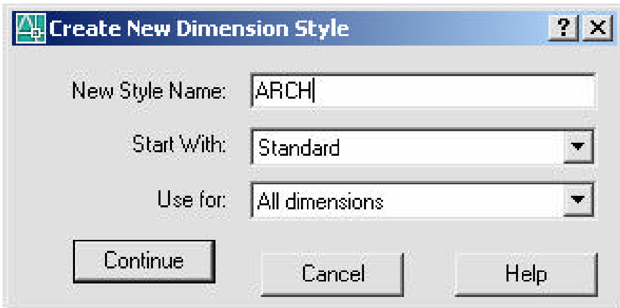
4 Type DDIM at the command prompt

Command: DDIM

5 Choose New...From the dialog box.

6 Create a new style from the existing styles.

7 Click the Continue button.




**TIP:**

All dimension variables except for DIMSHO and DIMASO can be saved as a style.

### Lines and Arrows

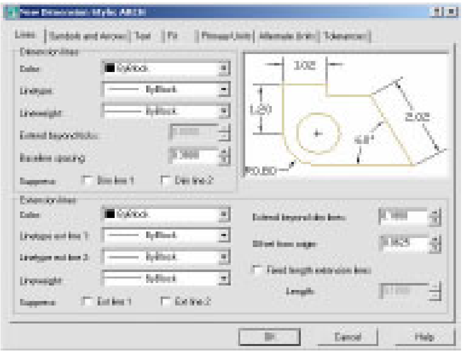
Edits Dimension Lines, Extension Lines, and Arrows.

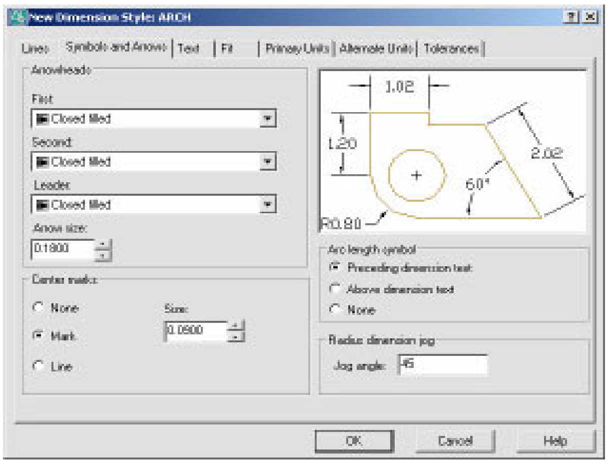
**1 Pick :** the Lines and Arrows tab from the Dimension variables and Styles dialog box.

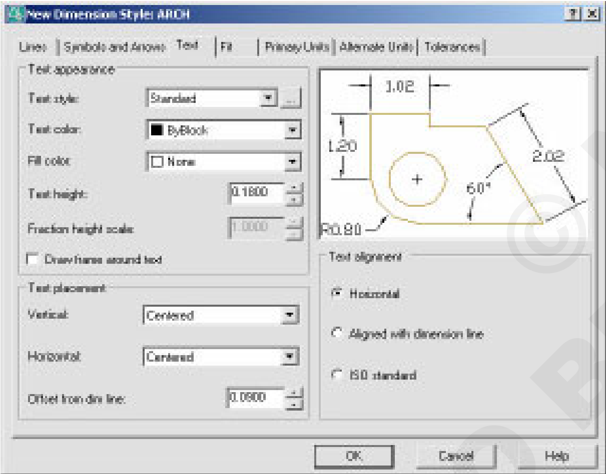
### Text

Edits Text Appearance, Text Placement and Text Alignment.

1 **Pick** the Text tab from the Dimension Variables and Styles dialog box.



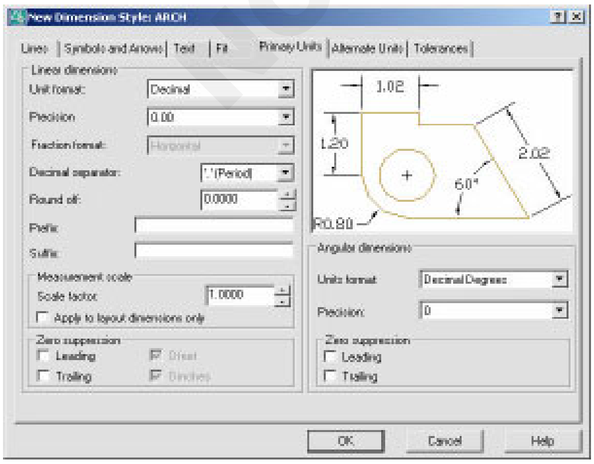



## Primary Units

Edits Unit options for dimension's primary units.

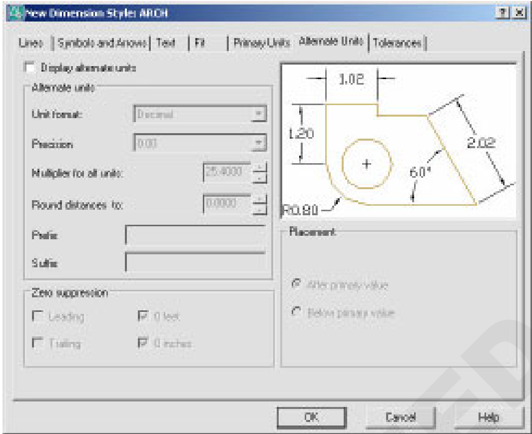
**Pick :** the PRIMARY UNIT tab from the Dimension variables and Styles dialog box.




## Alternate Units

Edits Unit options for dimension's alternate units.

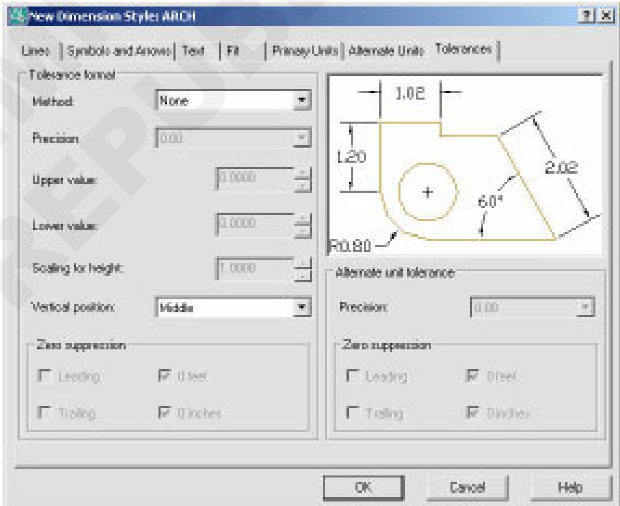
**Pick :** the ALTERNTE UNIT tab from the Dimension Variables and Styles dialog box.




## Tolerances

Edits Unit options for tolerances.

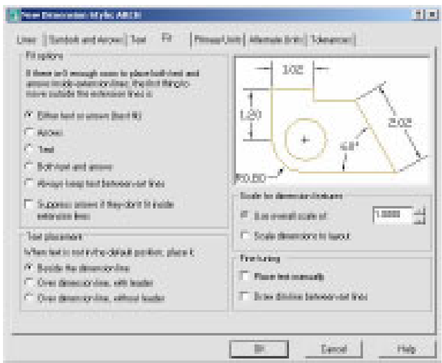
**1 Pick :** the TOLERANCES tab from the Dimension Variables and Styles dialog box.




## Fit

Edits Unit options for fitting dimensions and dimension scales.

1 Pick the FIT tab from the Dimension Variables and Styles dialog box.



**Dimension Override**

1 Choose Dimension, Override.

2 Type a dimension setting to change (i.e. DIMSE1 which suppresses the first ex tension line).

Command:_dimoverride

Enter dimension variable name to over ride or [Clear overrides]: dimse 1

3 Set The new value.

4 Press enter.

5 Pick the dimension to override.

## Printing & plotting

**Objectives :** At the end of this exercise, you shall be able to
- **state printing & plotting**
- **illustrate setting a scale for drawing**
- **explain steps to plotting & printing.**

**The Printing and Plotting Process**

CADD drawings are printed using a printer or a plotter. The process of printing is as simple as selecting the print or plot function from the menu. This action sends data from the computer to a printer or plotter, which produces the final drawing. The drawings are neat, clean and, depending on the quality of the printer, highly accurate.

You can specify a number of parameters to control the size and the quality of a plot. You can plot a drawing to any size by applying an appropriate scale factor. You can specify line thickness and colours for different drawing objects. You can make a number of other adjustments as well, including rotating a plot, printing only selected areas of a drawing, or using specific fonts for text and dimensions.

The following are the important considerations for plotting:

- Selecting a scale for drawings
- Composing a drawing layout
- Selecting text and dimension heights
- Choosing pens colours and line weights.

**Selecting a Scale for Drawings**

When working on a drawing board, you use a specific scale to draw diagrams. For example, when you need to draw a plan of a building or a township, you reduce the size of the diagrams to 1/1000 of its actual size, that is, you use a 1:100 or 1:1000 scale. When you need to draw a small machine part, you draw it many times larger than its actual size. CADD uses the same principles to scale the drawings; however, a different approach is taken.

| Term | Description |
|---|---|
| Plotting scale | To proportionally reduce or enlarge diagrams for plotting. |
| Plotting scale factor | A degree to which drawings are proportionally reduced or enlarged. |

**Composing a Drawing Layout**

CADD provides a number of special functions to compose a drawing layout. You can arrange diagrams on a sheet as you like and apply any scale factor. Different programs use different protocols to accomplish this task.

The following table shows some of the standard sheet sizes (in inches):

| ANSI | | ISO | | Architectural | |
|---|---|---|---|---|---|
| Mark | Size | Mark | Size | Mark | Size |
| A | 8.5 x11 | A4 | 8.3 x11.7 | A | 9 x12 |
| B | 11x17 | A3 | 11.7x16.5 | B | 12x18 |
| C | 17x22 | A2 | 16.5x23.4 | C | 18x24 |
| D | 22x34 | A1 | 23.4x33.1 | D | 24x36 |
| E | 34x44 | A0 | 33.1x46.8 | E | 36x48 |

### Selecting Text and Dimension Heights

As diagrams are enlarged or reduced by applying scale factor, the size of text, dimensions, patterns and symbols is also changed. When you place different scale diagrams on the same sheet, you may get different sized text for each diagram. This is generally not acceptable for professional drawings. It is better to have consistently sized text on the drawings regardless of their scale.

### Choosing Pens, Colors and Line Weights

CADD allows you to work with a variety of colors and line weights depending upon the plotter. In most CADD programs, the colors you use on-screen are configured with a specific line weight in the plotter. For example, the objects drawn with red color on-screen may be printed with.5mm line weight; the objects drawn with blue color may be printed with .2mm line weight. These are called pen assignments.

For details on this topic refer to CADD PRIMER.

### Steps to Plotting

The following are the basic steps to plotting.

| Step | Action |
|---|---|
| 1 | Set up the plotter according to the manufacturer is specifications and configure it with your CADD program. |
| 2 | Place paper in the plotter and run a self test to ensure that the paper path is clear and the pens or cartridges are in good working condition. |
| 3 | Display the drawing to be plotted on the screen and choose the plot function. |
| 4 | Respond to the specific prompts of your CADD program. In general, a CADD program will require the following information to plot the drawing.<br><br>**Plotting area :** You can plot a part of the drawing or the entire drawing. You will be able to indicate the plotting area by indicating a window (an imaginary rectangle formed by two diagonal points) or by selecting a specific view for plotting.<br><br>**Plotting scale factor :** Enter a scale factor based on how big or small you want to print the drawing and the sheet size used. (See topic selecting a Scale for Drawing.)<br><br>**Plotting origin :** The plotting origin is a point that allows you to align the drawing shown on the screen with the paper in the plotter (see Fig.8.2). You can place the diagrams on the paper anywhere by entering the exact coordinates of the plotting origin. |

### Plot Command

1 Choose File, Plot.

Or

2 Click the Plotter icon.

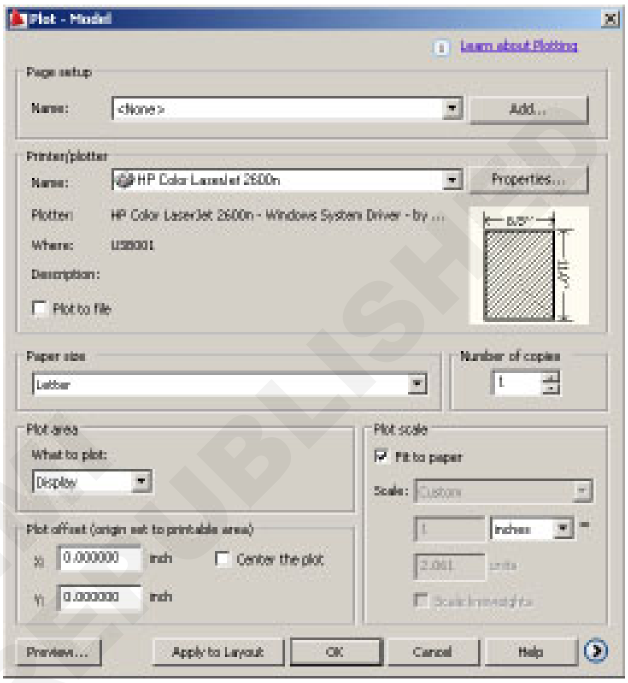
Or

3 Type PLOT at the command prompt.

Command: PLOT or PRINT

Or

4 Press CTRL + P




### Plot Settings

1 Choose the Plot Settings tab.

2 Choose the appropriate paper size based on the chosen plotter.

3 Choose the paper units (inches or mm).

4 Choose the drawing orientation (Portrait, Land scape, Upside down).

5 Choose the plotting area.

6 Choose the plot scale.

7 Choose plot to center or specify an x or y offset.

8 Click OK.

# Layers

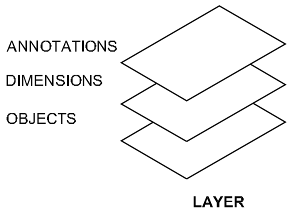
**Objectives :** At the end of this exercise, you shall be able to
- **define layer**
- **enumerate key Terms in layer**
- **explain making a layer correct**
- **explain setting layers.**

## Introduction

A layer is like a transparency. Have you ever used an overhead light projector? Remember those transparencies that are laid on top of the light projector? You could stack multiple sheets but the projected image would have the appearance of one document. Layers are basically the same. Multiple layers can be used within one drawing.

The explain, on the right, shows 3 layers. One for annotations (text). One for dimensions and one for objects.

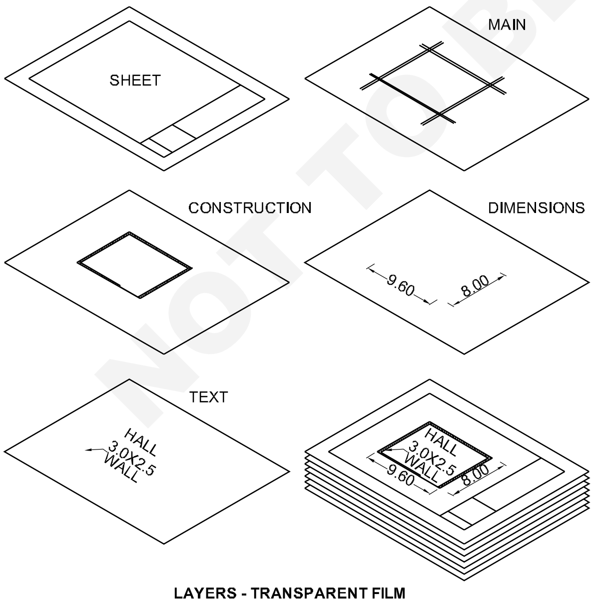
Fig 1




SUN153371

It is good "drawing management" to draw related objects on the same layer. For example, in an architectural drawing, you could have the walls of a floor plan on one layer and the Electrical and Plumbing on two other layers. These layers can then be Thawed (ON) or Frozen (OFF) independently. If a layer is Frozen, it is not visible. When you draw the layer it becomes visible again. This will allow you to view or make plots with specific layers visible or invisible.

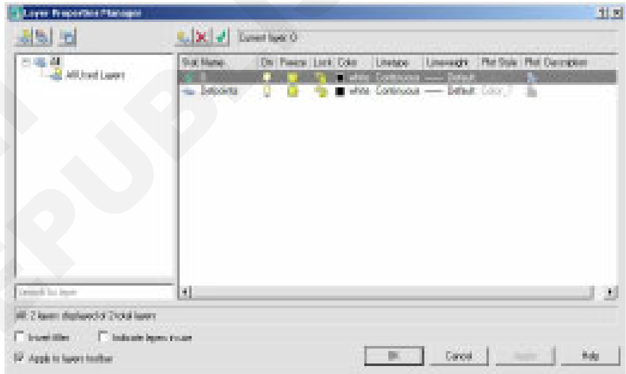
Fig 2




SUN153372

## Introduction to Layers and Layer Dialog Box 1

| | | |
|---|---|---|
| 1 Choose | Format, Layer. |
| | Or |
| 2 Type | LAYER at the command prompt. |
| | Command: LAYER (or LA) |
| | Or |
| 3 Pick | the layers icon from the Layer Control box on the object properties toolbar. |

## Layer Options

| | |
|---|---|
| ? | Lists layers, with states, colors and linetypes. |
| Make | Creates a new layer and makes it current. |
| Set | Sets current layer. |
| New | Creates new layers. |
| ON | Turns on specified layers. |
| OFF | Turns off specified layers. |
| Ltype | Assigns linetype to specified layers. |
| Freeze | Completely ignores layers during regenera tion. |
| Thaw | Unfreezes specified layers Ltype. |
| Lock | Makes a layer read only preventing entities from being edited but available visual refer ence and osnap functions. |
| Unlock | Places a layer in read write mode and avail able for edits. |
| Plot | Turns a Layer On for Plotting |
| No Plot | Turns a Layer Off for Plotting |

LWeight Controls the line weight for each layer.

**TIP**

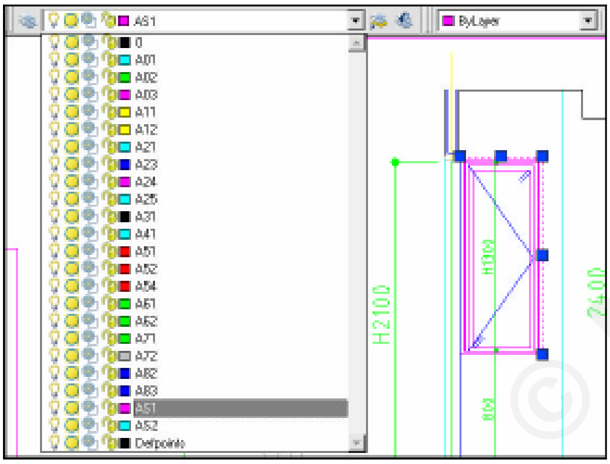
Layers can be set using the command line prompts for layers. To use this, type- LAYER or -LA at the command prompt

| | | |
|---|---|---|
| 1 | Type | command:-LAYER or LA\ |
| 2 | Type | One of the following layer options?/ Make/Set/New/ON/OFF/Color/Ltype/ Freeze/Thaw: |

**Layer Shortcuts**

Changing the Layer of an Object

| | | |
|---|---|---|
| 1 | Click | Once on the object to change. |
| 2 | Select | the desired layer from the Layer Control Box dropdown. |
| | | AutoCAD will move the object to the new layer. |

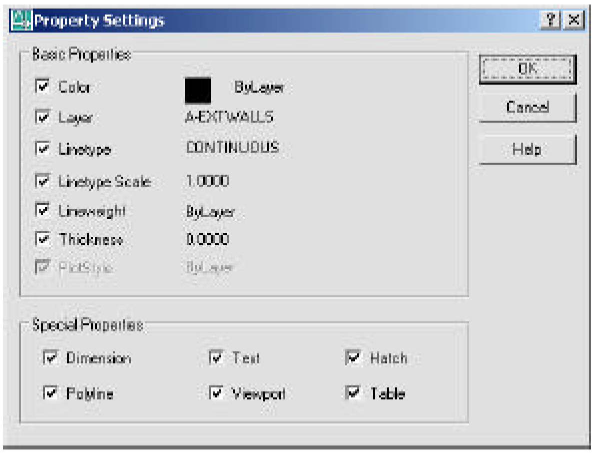



**Making a Layer Current**

| | | |
|---|---|---|
| 1 | Click | Once on the Make Object's Layer Cur rent icon. |
| 2 | Select | Object whose layer will become current. |

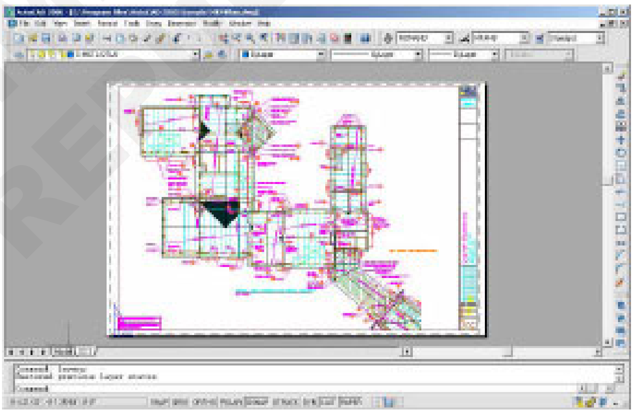
**Match Properties**

| | | |
|---|---|---|
| 1 | Choose | Modify, Match Properties. |
| | | Or |
| 2 | Click | the Match Properties Icon from the Stan dard toolbar. |
| | | or |
| 3 | Type | Command: MATCHPROP or MA |
| 4 | Select | the object whose properties you want to copy (1). |
| 5 | Select | the objects to which you want to apply the properties (2). |



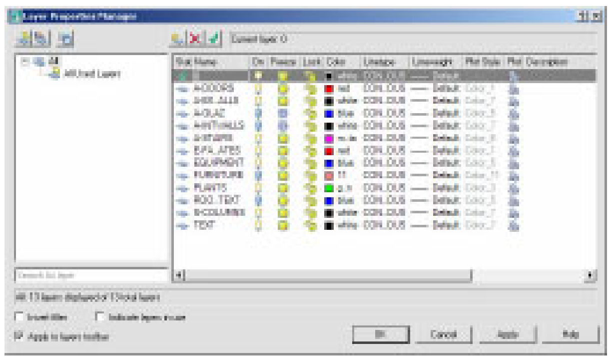

**Layer Previous**

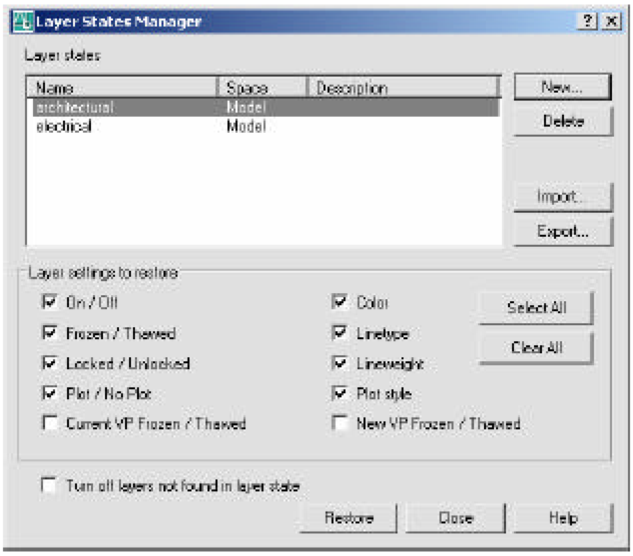
| | | |
|---|---|---|
| 1 | Open | an AutoCAD drawing with layers. |
| 2 | Turn | Layers on/off. |
| 3 | Zoom | or perform any AutoCAD Command. |
| 4 | Type | LAYERP at the command prompt. |
| | | Command: LAYERP |
| | | Or |
| 5. | Click | the Layer Previous icon. |



**Layer States**

| | | |
|---|---|---|
| 1 | Choose | the layer icon. |
| 2 | Select | Various layers to be ON, OFF, FROZEN, LOCKED, etc. |
| 3 | Choose | the Save State button. |
| 4 | Choose | Restore State to restore the layer settings. |






## Color Command

1 Choose Format, Color.

Or

2 Type DDCOLOR at the command prompt.

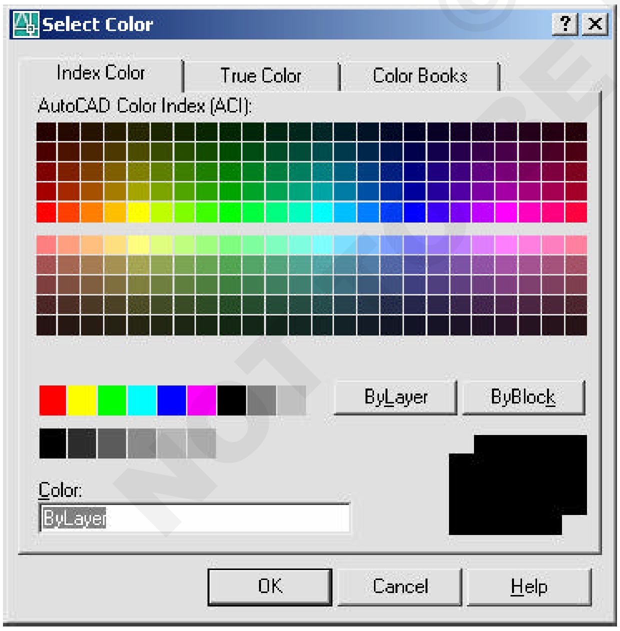
Command: DDCOLOR or COL

Or

3 Choose Color on the Object Properties toolbar and then select a color from the list or select Other to display the Select Color dialog box.

**TIP:**

These Settings ignore the current layer settings for color.




By Layer

If you enter by layer, new objects assume the color of the layer upon which they are drawn.

ByBlock

If you enter by block, AutoCAD draws new objects in the default color (white or black, depending on your configuration) until they are grouped into a block. When the block is inserted in the drawing, the objects in the block inherit the current setting of the COLOR command.

### Line types

### Loading and Changing Line types

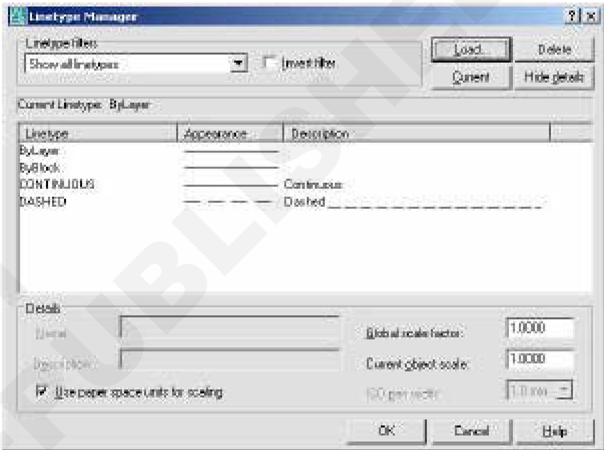
1 Choose Format, Linetype...

Or

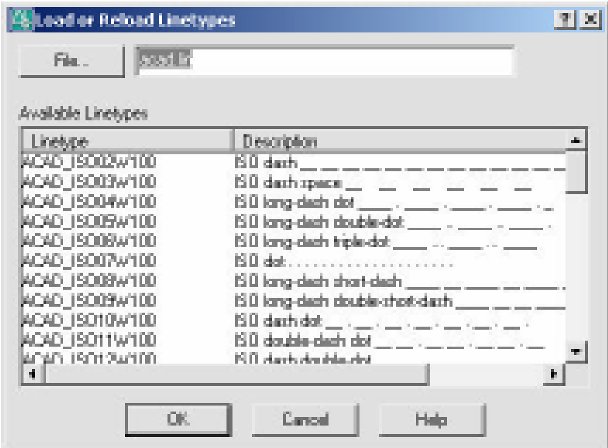
2 Type DDLTYPE at the command prompt.

Command: DDLTYPE or LT

3 Choose Load... to see a list of available linetypes.




4 Choose the desired linetype to assign.




5 Click OK.

# Properties and blocks

**Objectives :** At the end of this exercise, you shall be able to
- **express line weights.**
- **state object properties**
- **inserting blocks**
- **explain settings of O snap**
- **state redraw & regain, measuring distance**

## Introduction

### Line weights

You can differentiate objects in your drawing by controlling their line weights both in the drawing display and in plotting. For example, Sectioned objects should read heavier than objects in elevation and all object lines should be heavier than dimension lines, which in turn should be heavier than hatch pattern lines.

### 1. Object properties

You can organize objects in your drawing and control how they are displayed and plotted by changing their properties, which include layer, line type, line type scale, color, Line weight, thickness, and plot style.

Every object you draw has properties. Some properties are general and apply to most objects; for example, layer, color, line type, and plot style.

### Creating block attribute

A block attribute is a tag or label that attaches information to a block. The information is mapped as a column in a database table. It can be anything, for example room numbers, equipment tags, drawings numbers in a set etc... the advantage of using block attribute is that you can always extract the information into a spreadsheet or database to produce a list.

### Line weights

### Loading and Changing Line weights

1 Choose Format, Lineweight...

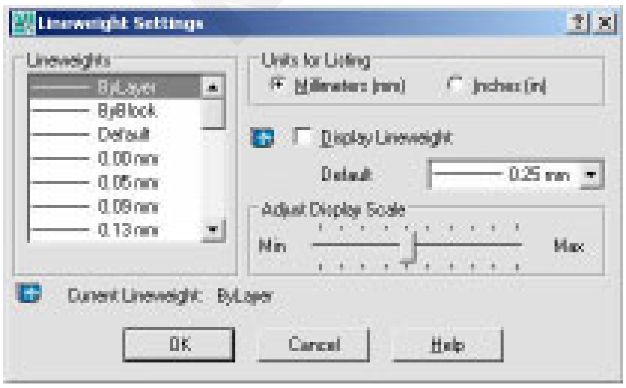
or

2 Type LINEWEIGHT at the command prompt.

Command: LINEWEIGHT or LWEIGHT

Or

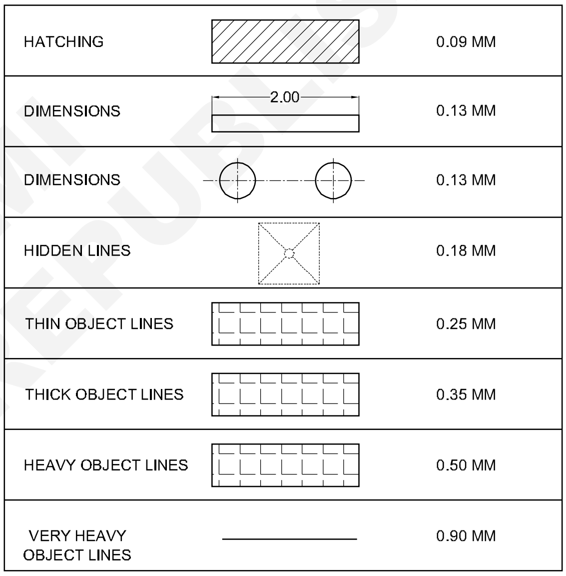
4 Pick a lineweight to make current from the ob ject properties menu.




### TIPS

- Line weights can also be assigned to layers.
- The display Line weights feature can be turned on/off on the status bar to show or not show lineweights in the drawing, thus making regenerations faster.
- Line weights are displayed using a pixel width in proportion to the real-world unit value at which they plot. If you are using a high-resolution monitor, you can adjust the line weight display scale to better display different line weight widths.

Fig 1




ALPHABET OF LINEWEIGHTS

SUN153381

his graphic depicts a sample set of line weights for various types of entities in a drawing. The actual line widths are being approximated in this image due to the conversion to a raster image. See sample drawing for a more accurate depiction of the lineweights.

### Object Properties

1 Choose Modify, Properties.

Or

2 Click the Properties icon. 

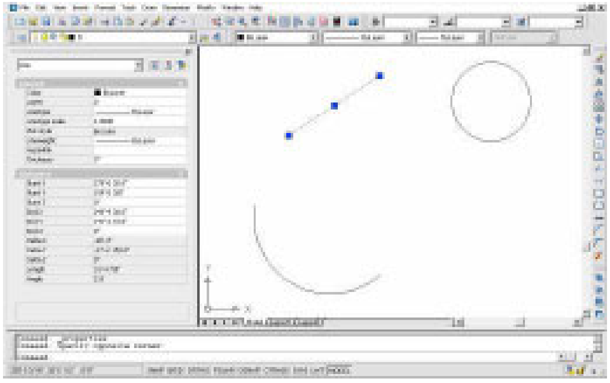
Or

3 Type DDCHPROP or DDMODIFY at the com mand prompt.

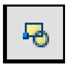
Command: DDCHPROP (CH) or

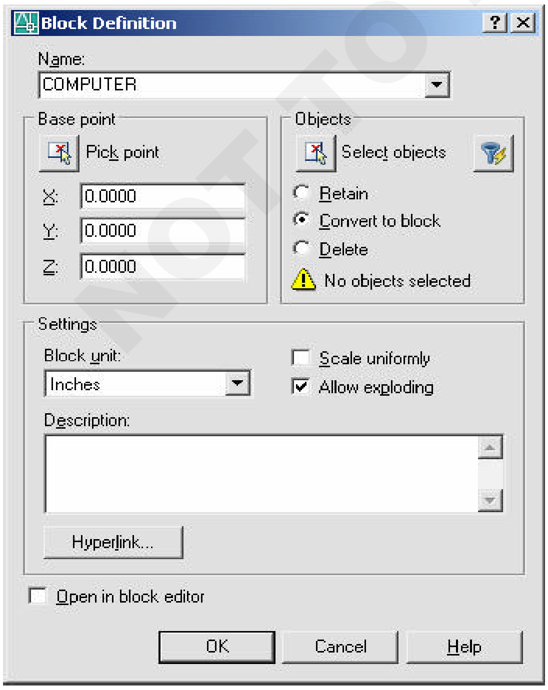
DDMODIFY (MO)

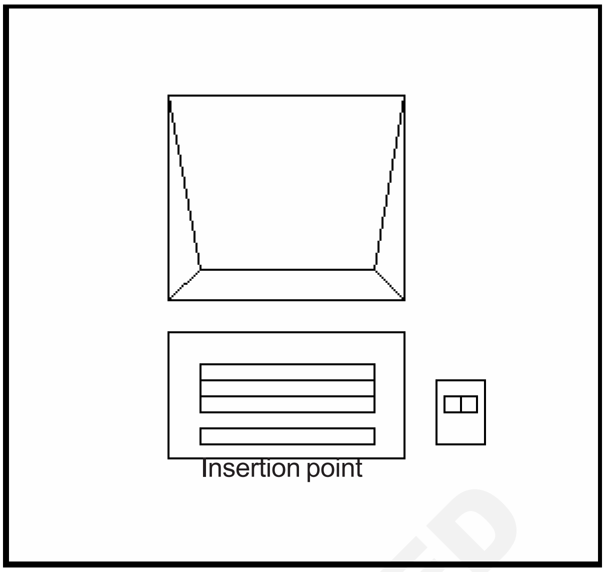
| | | |
|---|---|---|
| 4 | Pick | Objects whose properties you want to change Pick a window for DDMODIFY. |
| | | Select objects: (select) |
| 5 | Press | ENTER to accept objects. |
| | | Select objects: (press enter) |
| 6 | Choose | One of the following properties to change. |



### Creating Local Blocks (BMAKE)

| | | |
|---|---|---|
| 1 | Choose | Draw, Block, Make. |
| | | Or |
| 2 | Click | the make block icon.  |
| | | Or |
| 3 | Type | BMAKE at the command prompt. |
| | | Command: BMAKE or BLOCK |
| 4 | Type | the name of the block. |
| 5 | Pick | an insertion point. |
| 6 | Select | objects to be included in the block definition. |
| 7 | Click | OK. |

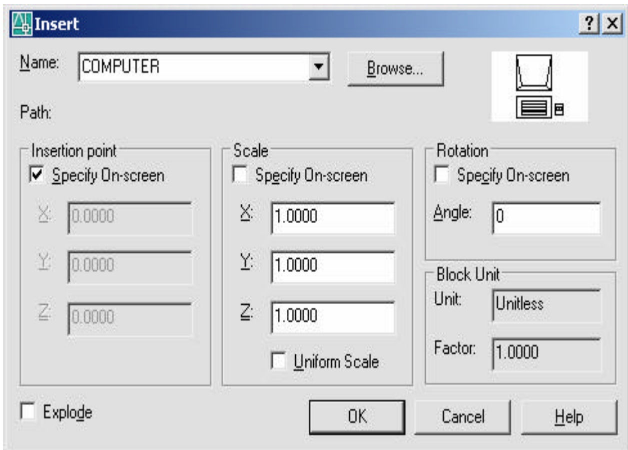



**You cannot use DIRECT, LIGHT, AVE_RENDER,RM_SDB, SH_SPOT, and OVERHEAD as valid block names.**

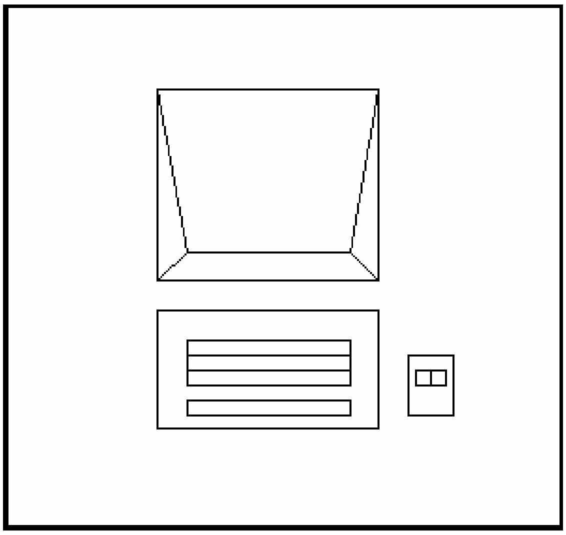
### Inserting Blocks

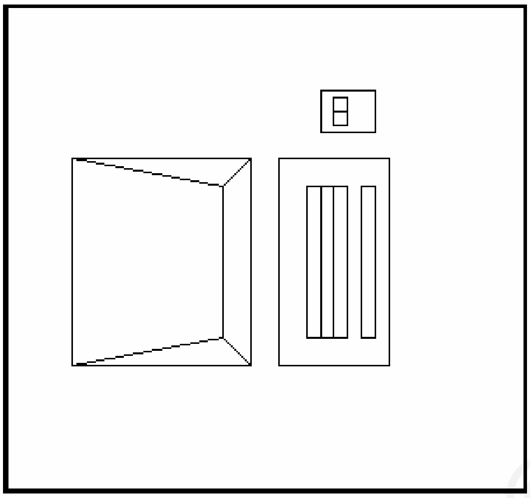
| | | |
|---|---|---|
| 1 | Choose | Insert, Insert Block |
| | | Or |
| 2 | Click | the insert icon from the INSERT toolbar. |
| 3 | Type | INSERT at the command prompt. |
| | | Command: INSERT |
| 4 | Choose | the insertion point, scale, and rotation of the block. |
| 5 | Choose | the insertion point, scale, and rotation of the block |




Block Inserted with a zero degree rotation angle

Block Inserted with a ninety degree rotation angle.





**Typing Insert (-INSERT)**

1 Type -INSERT at the command prompt. Com mand:-INSERT

2 Type Block name to insert.
Insert block name or (?) type name

3 Pick An insertion point. Insertion point: pick point

4 Press ENTER to keep the same x scale factor as the original block. X scale factor <1> Corner /XYZ:

5 Press ENTER to keep the same x scale factor as the original block.
Y scale factor (default= X):

6 Press ENTER to keep a rotation angle or zero. Rotation angle <0>:

7 Pick A rotation angle.

**Control the Colour and Line type of Blocks**

The objects in an inserted block can retain their original properties, can inherit properties from the layer on which they are inserted, or can inherit the properties set as current in the drawing.

You have three choices for how the colour, linetype, and lineweight properties of objects are treated when a block reference is inserted.

- Objects in the block do not inherit colour, linetype, and lineweight properties from the current settings. The properties of objects in the block do not change regardless of the current settings.

- For this choice, it is recommended that you set the color, linetype, and lineweight properties individually for each object in the block definition: do not use BYBLOCK or BYLAYER color, linetype, and lineweight settings when creating these objects.

- Objects in the block inherit color, linetype, and lineweight properties from the color, linetype, and lineweight assigned to the current layer only.

- For this choice, before you create objects to be included in the block definition, set the current layer to 0, and set the current color, linetype, and lineweight to BYLAYER.

- Objects inherit color, linetype, and lineweight properties from the current color, linetype, and lineweight that you have set explicitly, that is, that you have set to override the color, linetype, or lineweight assigned to the current layer. If you have not explicitly set them, then these properties are inherited from the color, linetype, and lineweight assigned to the current layer.

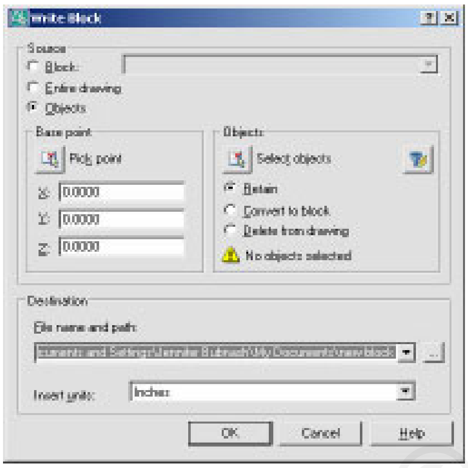
- For this choice, before you create objects to be included in the block definition, set the current color or linetype to BYBLOCK.

| **If you want objects in a block to** | **Create objects on these layers** | **Create objects with these properties** |
|---|---|---|
| Retain original properties | Any but 0 (zero) | Any but BYBLOCK or BYLAYER |
| Inherit properties from the current layer | 0 (zero) | BYLAYER |
| Inherit individual properties first, then layer properties | Any | BYBLOCK |

## Wblock Command

Writes objects to a new drawing file.

| | | |
|---|---|---|
| 1 | Type | WBLOCK at the command prompt Com mand: WBLOCK |
| 2 | Type | A drawing name (and location). |
| 3 | Type | A block name if a local block already exists. Block name: name or |
| 4 | Press | ENTER to create a block. |
| 5 | Pick | An insertion point on the object |
| | | Insertion base point: pick a point |
| 6 | Pick | Objects to create the block. |
| | | Select objects: pick objects |
| 7 | Press | ENTER to end the selection set. |




## Running Object Snaps

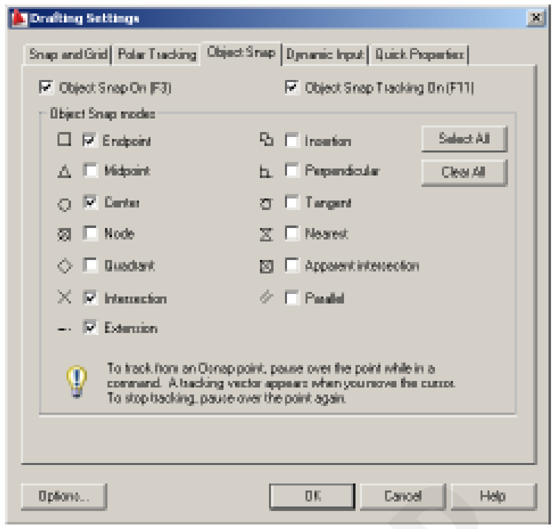
An object snap mode specifies a snap point at an exact location on an object. OSNAP specifies running object snap modes, which remain active until you turn them off.

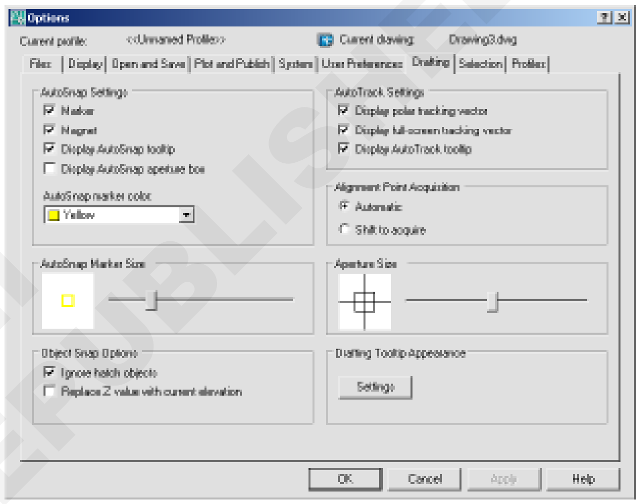
| | | |
|---|---|---|
| 1 | Choose | Tools, Drafting Settings.... |
| | | Or |
| 2 | Type | DDOSNAP at the command prompt command: DDOSNAP |
| | | Or |
| 3 | Click | OSNAP on the Status Bar. |
| 4 | Right Click | The Object Snap TAB. |
| 5 | Choose | an object snap to turn ON/OFF from the dialog box. |

## Osnap Settings

When you use any of the object snap settings, AutoSnap displays a marker and a Snap tip when you move the cursor over a snap point.

| | | |
|---|---|---|
| 1 | Choose | Tools, Options... |
| 2 | Select | the Drafting tab in the Options dialog box. |
| 3 | Change | settings and Choose OK. |




The following are object snap modes:

| | |
|---|---|
| CENter | Center of Arc or Circle |
| ENDpoint | Closest endpoint of Line/Arc |
| INSertion tribute | Insertion point of Text/Block/Shape/At- |
| INTersection | Intersection of Lines/Arcs/Circles |
| MIDpoint | Midpoint of a line/Arc or midpoint |
| NEAerst | Nearest point on a Line/Arc/Circle/Point |
| APParent Int | Finds where two entities would intersect |
| NODe tion point) | Nearest point entity (or Dimension defini- |
| PERpendicular | Perpendicular to a Line/Arc/Circle |
| QUAdrant | Quadrant point on an Arc/Circle |
| QUIck | Quick mode (first find, not closest). |
| TANgent | Tangent to Arc or Circle |

## 5.3 Redraw and Regen

Redraw refreshes the current view.

1 Type Redraw at the command prompt

Command: Redraw or R

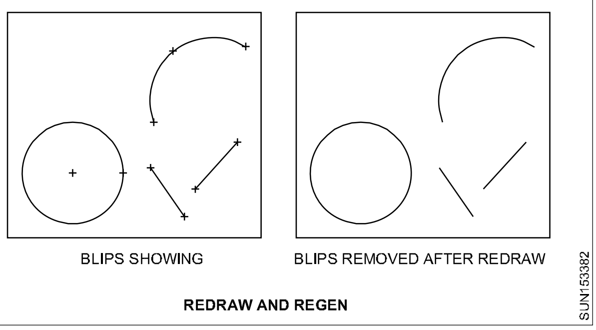
REGEN regenerates the entire drawing and recomputes the screen coordinates for all objects. It also re-indexes the drawing database for optimum display and object selection performance.

1. Type REGEN at the common prompt.

Command: REGEN or RE

**TIP:** When BLIPMODE is on, marker blips left by editing commands are removed from the current viewport

Fig 2




### Measuring Distances

1 Choose Tools, Inquiry, and Distance.

Or

2 Click the Distance icon from the Inquiry Toolbar.

Or

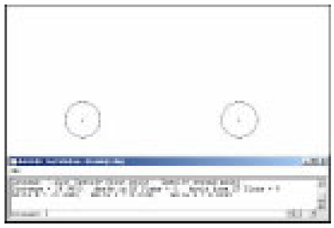
3 Type DIST at the command prompt

Command: DIST

4 Pick The first point to measure from First point: Pick point

5 Pick The second point to measure to Second point: pick point

Distance Between Circle Centers



**TIP**

Be sure to use Object Snaps with the MEASURE command.

**Divide**

1 Choose Draw, Point, and Divide.

Or

2 Type DIVIDE at the command prompt

Command: DIVIDE

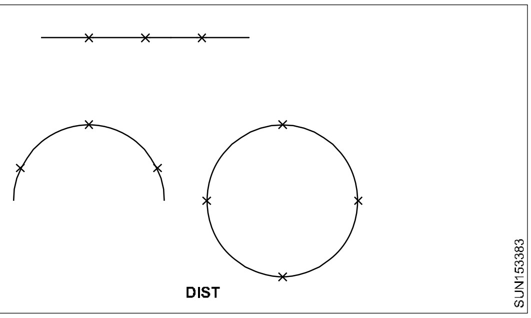
3 Pick Object to divide

Select object to divide: (pick one object) You can select a single Line, Arc, Circle, or polyline. If you enter a segment count between 2 and 32,767, Point entities will be placed along the object to divide it into that number of equal segments.

4 Type The number of equal segments to divide the object into <Number of segments>/ Block: (number)

Objects divided using points

Fig 3



# Setting up of plane table and instrument used in plane tabling

**Objectives:** At the end of this lesson you shall be able to
- **state plane tabling**
- **name the Instruments and Accessories used in plane tabling**
- **state the construction and uses of Instruments and Accessories of plane tabling**
- **explain about the setting up of plane table over a station**
- **explain about Levelling, centering and orientation in plane tabling**
- **explain the methods of plane tabling.**

**Plane tabling:** Plane tabling is a graphical method of surveying in which field observations and plotting are done simultaneously on a plane table.

It is most suitable for filling in the various details between the stations previously fixed by Triangulation.

It is commonly used for preparing small scale mapping or medium size mapping. This type of survey is employed when great accuracy is not required such as Topographical surveys.

Instruments used in plane tabling

– Plane table with Tripod

– Alidade

Accessories used in plane Tabling

– Spirit level

– Trough compass

– Plumbing fork with plumb-bob & water proofing cover

**Plane table with Tripod etc. :** Plane table is made of well seasoned good quality teak or pine wood is available in sizes.

– small : 50cm x 40cm x 1.5cm

– medium : 50cm x 50cm x 1.5cm

– Large : 75cm x 60cm x 1.5cm

It is mounted on a Tripod in such a way that it can be levelled, rotated about a vertical axis and clamped in any position. The upper surface of the board must be perfectly plane. The tripod is generally of the open frame type and can be folded (Fig 1) for convenience of transportation

**Qualities of a good plane table**

– The butterfly nuts which clamp the legs to the clamping head should not be free.

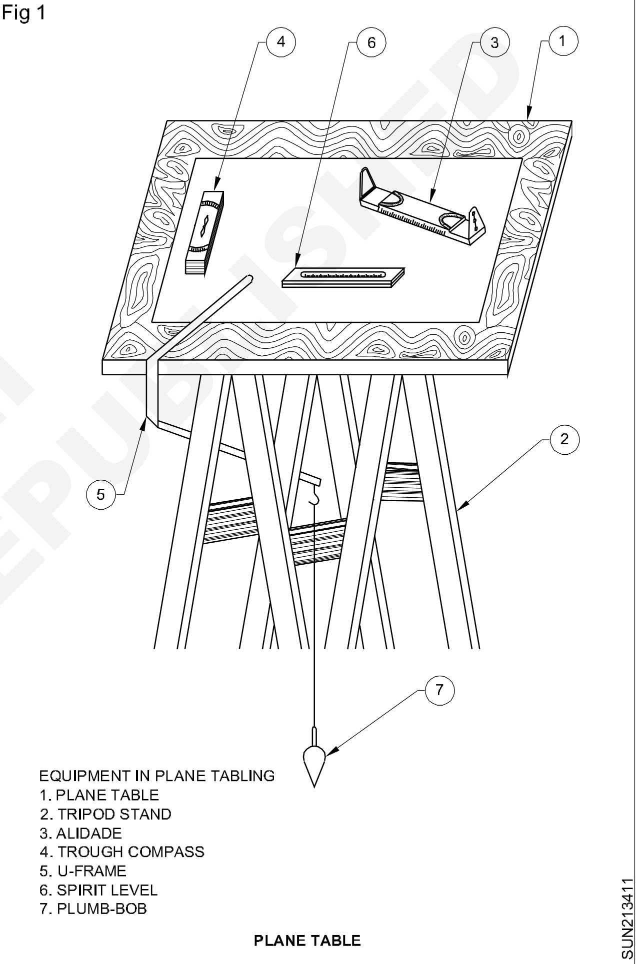
– The clamping assembly should fit the plate at the bottom of the plane table.

**The Alidade:** The Alidade is a straight edge with some form of sighting device. Two types of alidades are generally used.

– Plain alidade

– Telescopic alidade

Fig 1




PLANE TABLE

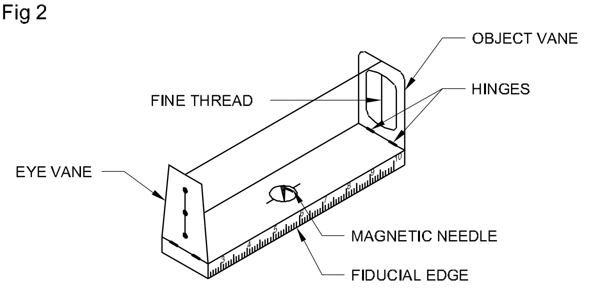
**Plain alidade:** It consists of a metal or wooden rule with two vanes at the ends. Vanes are hinged and can be folded on the rule when the alidade is not in use (Fig 2).

One of the vanes known as sight vane is provided with a narrow slit with three holes, one at the top, one at the bottom and one in the middle.

The other vane which is known as Object vane is open and carries a hair stretched between the top and bottom of the slit. With the help of the slit, a definite line of sight may be established parallel to the ruling edge of the alidade. The alidade can be rotated about the point which represents the location of the instrument station on the sheet so that the line of sight passes through the station sighted. The two vanes should be perpendicular to the ruler as well as surface of the plane table. The working edge of the alidade is called Fiducial edge.

The plain alidade can be used when the elevations or depressions of the objects are low

Fig 2

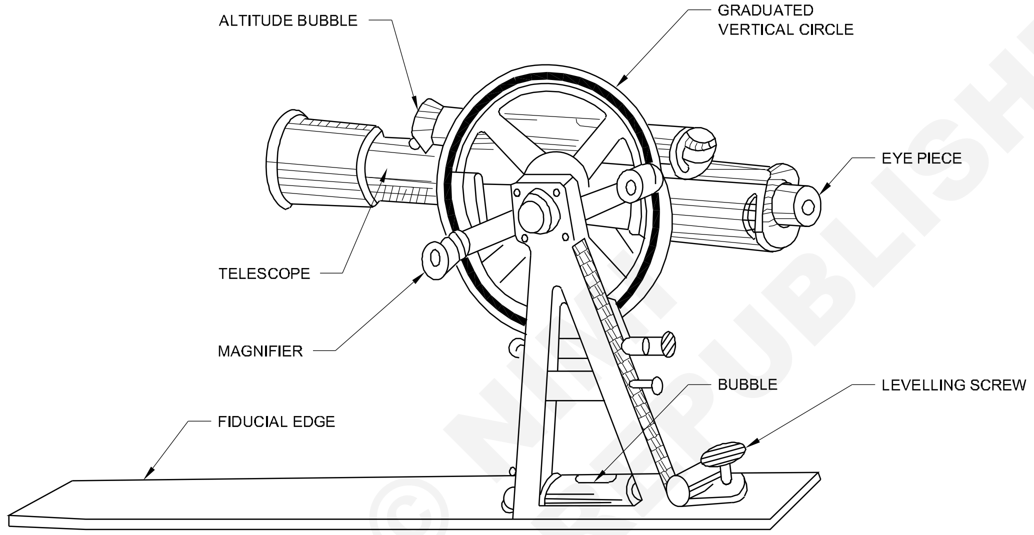



A PLAIN ALIDADE

**Telescopic Alidade:** It is generally used when it is required to take inclined sights. Telescope increases the range and accuracy of the sights. It consists of a small telescope with a level tube. A graduated scale is mounted on a horizontal axis. The horizontal axis rest on a A-frame which is supported on a heavy metal ruler. One side of the ruler is used as working edge (Fiducial edge) along which lines may be drawn. The angles both elevation and depression can be read on the vertical circle.(Fig 3)

**Spirit level:** A spirit level consists of a small metal tube which contains a small bubble at centre. The Base of spirit level must be flat so that it can be laid on the table. When bubble remains central, the table is truly level.(Fig.4)

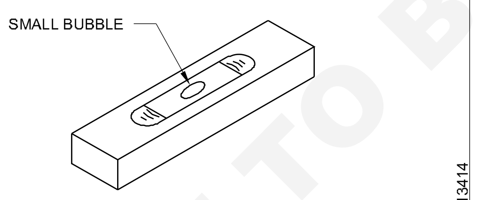
Fig 3




A TELESCOPIC ALIDADE

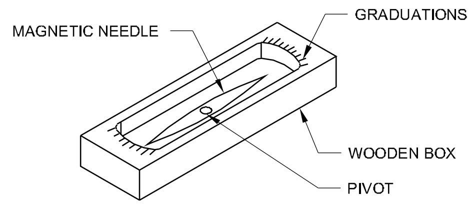


Fig 4




SPIRIT LEVEL

Fig 5



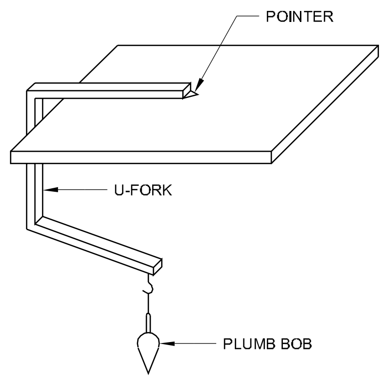

TROUGH COMPASS

**Trough compass or magnetic compass:** A box compass consists of a magnetic needle pivoted at its centre freely. It is used for marking the direction of the magnetic meridian on the sheet. So it is also used for orienting the plane table to magnetic north. Both the edges of a compass are straight, and bottom surface is flat. The magnetic needle should be fairly sensitive and play freely.(Fig 5)

**Plumbing fork with bob:** The fork consists of a hair pin shaped light metal frame having two arms of equal length, in which a plumb-bob is suspended from the end of the lower arm. (Fig 6)

The fitting can be places with the upper arm lying on the top of the table and the lower arm below it, the table being centred when the plumb-bob hangs freely over the ground

Fig 6




PLUMBING FORK WITH PLUMB BOB

mark and the pointed end of the upper arm coincides with the equivalent point on the plan.

It is used for centering the table over the point or station occupied by the plane table when the plotted position of that point is already known on the sheet. In the beginning of the work it is meant for transferring the ground point on to the sheet so that the plotted point and the ground station are in the same vertical line.

**Setting up the plane Table**

The setting up the plane table involves three operations.

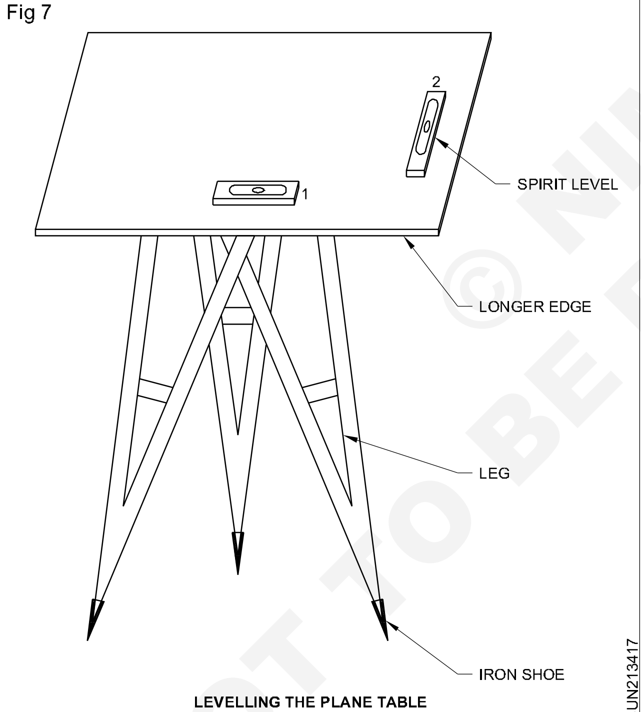
1 Levelling the plane Table

2 Centering the plane Table

3 Orienting the plane Table.

**Levelling the plane Table:** In this operation, the table top is made truly horizontal. For rough and small scale works, levelling of table can be done by eye estimation, and for large scale works levelling of table can be done by using spirit level. The levelling is specially important in hilly terrain where some of the control points are situated at higher level and some other at lower level. (Fig 7)

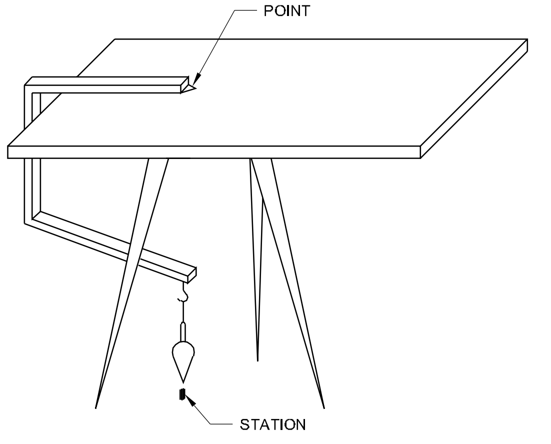
Fig 7




LEVELLING THE PLANE TABLE

**Centering the plane Table:** In this operation, the location of the plane table station, on the paper is brought exactly vertically above the ground station position. For rough works exact centering of the station is not necessary but for large scale maps and accurate works exact centering is required. (Fig 8)

Fig 8



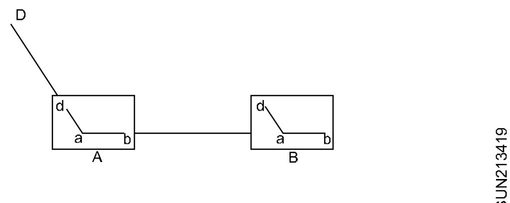

CENTERING THE STATION

**Orienting the plane table:** It is the process of putting the plane table in to some fixed direction so that the line representing a particular direction on the plan is parallel to that direction on the ground. Orientation is necessary when more than one instrument station is to be used. If orientation is not done, the table will not be parallel to itself at different positions resulting in an overall distortion of the map. The process of centering and orientation are dependent on each other. For orientation, the table will have to be rotated about its vertical axis, thus disturbing the centering.

**Orientation by back sighting (Fig. 9)**

The table is set up on the station B and it is represented as 'b' on the paper which is plotted by means of a line ab from the back station A. Now, the orientation is bringing ba on the paper over BA on the ground. Placing of alidade on ba, turn the table till the station 'A' is bisected. Then clamp the board in this position.

Fig 9




**Orientation by magnetic needle**

For oriented the table at any station other than the first station, but the trough compass on the meridian already drawn on the paper at the first station and turn the table till the ends of the needle are opposite the zeros of the scale towards north - south direction. At this position clamp the board. This is the quick method but unsuitable for magnetic area.

## Methods of plane table survey

**Objectives:** At the end of this lesson you shall be able to
- **methods of plane table survey**
- **radiation method of plane table survey**
- **intersection method of plane table survey.**

The following are the four methods of plane table survey.

- Radiation
- Intersection
- Traversing
- Resection

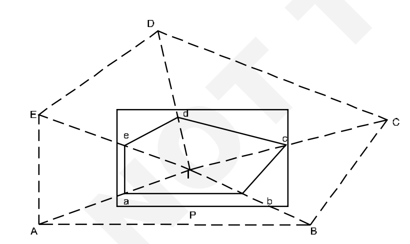
### Radiation method

The plane table is set up at only one station and various points are located by radiating lines drawn from the instrument station to each of the points and plotting to scale along the ray drawn with the distance measured from the station to the point sighted.

**(Fig1)**

- Select a point P such that all the points to be located are visible from this point.
- Set up and level the table at P and clamp it.
- Select a point 'p' on the sheet and make it vertically above 'P' on the ground by the use of 'U' frame.
- The point 'p' is represents on the sheet as the station 'P' on the ground.
- Mark the direction of the magnetic meridian with the trough compass in the top corner of the sheet.
- With the alidade touching 'p' sight the various points A,B,C,D and E etc to be located and draw radial lines towards them along the fiducial edge of the alidade.

Fig 1



RADIATION

- Measure the radial distance PA, PB, PC, PD and PE with the tape.
- Plot the distance to scale along the corresponding rays. Join the points a,b,c,d,e on the sheet.

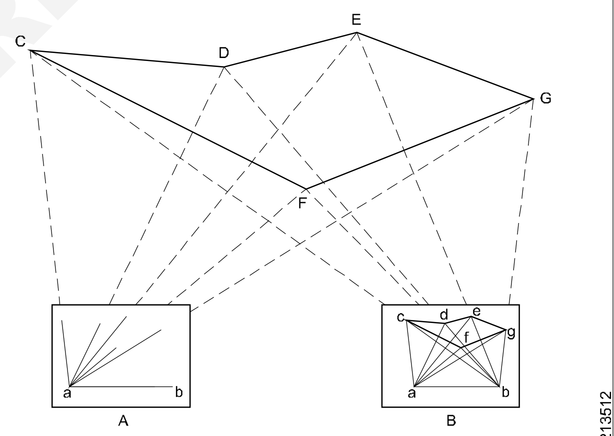
**Note: This method is suitable for the survey of small areas which can be commanded from single station.**

- It is also useful in combination with other methods for surveying detail within a tape length from the station.

### Intersection Method

- In this method the positions of the points are fixed on the sheet by the intersection of the rays drawn from two instrument stations.
- The line joining these two stations are termed as base line.
- This is the only linear measurement taken in the field.
- It is largely employed for locating detail and for locating the points to be used subsequently as instrument stations.
- It is also used for plotting the distant and inaccessible objects, broken boundaries, river etc.
- It is more suitable for surveying hilly country where it is not possible to measure the horizontal distances. difficult to measure the horizontal distances.

Fig 2



INTERSECTION

### Procedure (Fig 2)

- Select two points A and B on the ground, so that all points to be plotted are visible from both the station.
- Set up and level the plane table at station A and mark a suitable point 'a' on the paper, so that it is vertically above the instrument station A on the ground.
- Mark the direction of magnetic meridian on the top corner of the sheet by means of a trough compass.
- With the alidade touches on the point 'a', sight the station B and other points 1,2,3 etc to be located and draw rays towards them.

- Mark the respective lines by letter b, 1,2,3 etc to avoid confusion.
- Measure the base line AB with a steel tape or chain, cut off distance 'ab' to scale along the ray from 'a' to 'B'
- This is the position 'b' on the sheet of the station 'B' on the ground.
- Shift the instrument and set it up and level at 'B' such that the point 'b' is exactly above the point B on the ground.
- Orient the table by placing the alidade along 'ba', turning the table till the line of sight stricks 'A' and clamp it.
- With the alidade pivoted on 'b' draw rays sighting towards the same objects. (i.e) 1,2,3,4 etc.
- The intersections of these rays with the respective rays from 'a' determine the positions of the object 1,2,3,4 on the sheets.

## Traversing method of plane table survey

**Objectives:** At the end of this lesson you shall be able to
- **state traverse method of plane table survey**
- **conduct traverse method of plane table survey.**

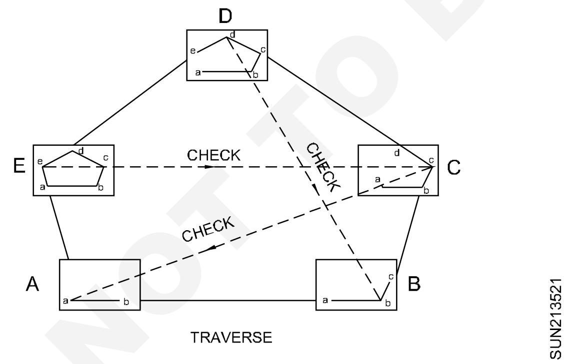
### Traversing

- This is main method of plane tabling and similar to that of compass or Theodolite traversing.
- It is used for running survey lines of a closed traverse or open traverse.
- The details may be located by offsets taken in the usual manner (i.e.) by the radiation or by inter section method of plane tabling.

### Procedure

- Select the traverse stations A,B,C, D etc. on the ground. (Fig 1)
- Set up the table over one of them say "A'. select a point 'a' suitably on the sheet. Level and centre the table over 'A'.
- Mark the direction of the magnetic meridian on the top corner to the sheet by means of the trough compass.
- With the alidade touching 'a' sight 'B' and draw a ray.

Fig 1




- Measure the distance AB and scale off 'ab'. Thus fixing of the position of 'b' on the sheet which represents the station 'B' on the ground.
- Locate the near by details by offsets taken in the usual manner or by radiation and distant objects by intersection method.
- Shift the table and set it up at 'B' with 'b' over 'B' and orient it by placing the alidade along ba, turning the table till the line of sight strikes 'A' and then clamp it.
- With the alidade touching 'b' sight 'C', draw a ray.
- Measure the line BC and cut off 'bc' to scale.
- Locate the surrounding details as taken before in station 'b'.
- Proceed similarly to the other stations, in each case orienting by a back sight before taking the forward sight until all the remaining stations are plotted.

### Check

- Intermediate checks should be taken wherever possible. If 'A' is visible from C, the work done, up to 'C' can be checked by sighting 'A' with the alidade touching 'C' and noting if the edge touches 'a' similarly other check lines DB, EC etc can be used to the check the work.
- When no other stations are visible from the station occupied, take some well defined object such as corner of a building which has been previously fixed on the sheet and it should be used to check the work.

## Resection method of plane table survey

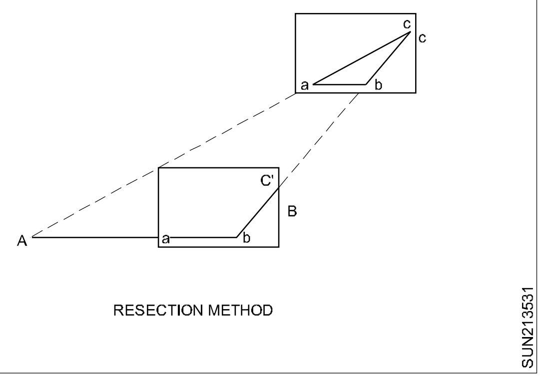
**Objective :** At the end of this lesson you shall be able to
- **state the resection method of plane table survey.**

### Resection Method

- It is used for locating the station points only.
- The main feature of resection is that the point plotted on the sheet is the station occupied by the plane table.
- After stations are fixed the details are taken by radiation or intersection, or sometimes both.
- Select a base line AB on the ground. (Fig 1)
- Measure the distance accurately and then plot 'ab' in a convenient position.

- Set up and level the table at 'B'. so that 'b' lies vertically above B and orient the table by placing the alidade along 'ab' and turning the table till 'A' is bisected and then clamp it.
- With the alidade touching 'b' sight the station 'C' which is to be plotted by resection and draw a ray.

Fig 1



RESECTION METHOD

- Estimate the distance BC by judgement only and move the point 'C' and along a ray to represent the approximate position of 'C'.
- Shift the table and set it up with c, on the ground point 'C'.
- Orient the table by taking back sight on 'B' and clamp it.
- With the alidade pivoted on 'a' sight the station 'A' and draw a ray.
- The point of intersection of this ray and that previously drawn from 'b' gives the required point 'c'. (i.e.) true position of 'C'.
- It necessary locate the other station in the above manner. It is also know as back ray method.



## Locate and plot new station point by two point and three point problem

**Objectives:** At the end of this lesson you shall be able to
- **define about resection**
- **state two and three point problem**
- **describe Lehman's rule**
- **list out the errors in plane tabling**
- **describe the advantages and disadvantages.**

**Resection method**

The process of determining the location of the station points occupied by the plane table, by means of drawing back rays from the stations whose locations have already been plotted on the sheet is called resection.

This method consists of drawing rays from known points whose locations are already available on the sheet. The intersection of these rays will be at a point if the orientation of the table was correct before rays are drawn. The problem, therefore, lies in orienting the table at the unknown occupied station.

It may be solved by any one of the following methods.

1 Two point problem

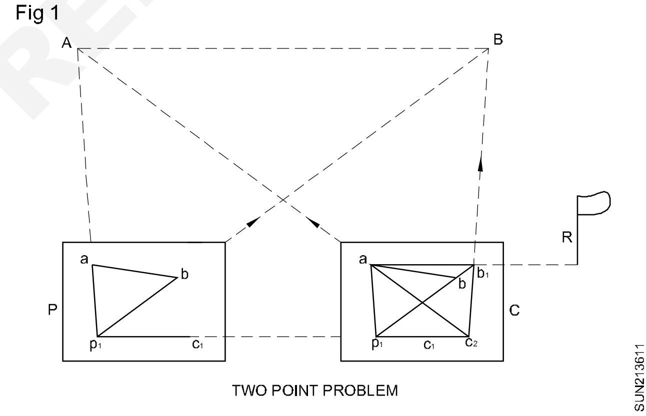
2 Three point problem

**Two point problem:** The two point problem consists in establishing the position of the instrument station on the plan by making sights towards two well defined objects which are visible from the instrument station and whose positions have already been plotted on the plan.

In Fig 1, A and B are the well defined objects, 'a' and 'b' their plotted positions on the plan.

'C' is the instrument station and 'c' is its required position on the plan. 'P' is the helping station to find out the instrument station which is to be occupied by the plane table. 'R' is the position of Ranging rod.

Fig 1



TWO POINT PROBLEM

**Three point problem:** Three point problem consists in establishing the position of the instrument station on the plan by making sights towards three well defined objects which are visible from the instrument station and whose positions have already been plotted on the plan.

Fig 2 shows A, B and C are three well defined objects a,b and c their plotted positions on the plan. P is the instrument station and 'p' is its required position on the plan.

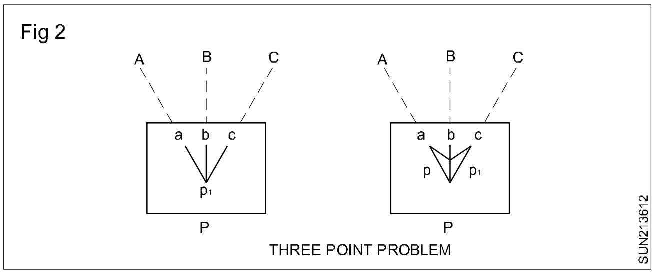
The three point problem may be solved

1 By mechanical method (Tracing paper method)

2 By graphical method (Bessel's method)

3 By Trial and Error method.

Fig 2



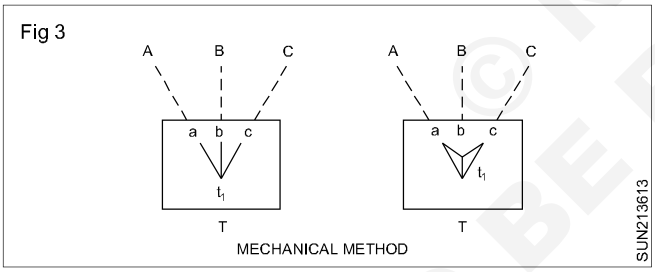

1 **Mechanical or Tracing paper method:** In this method a tracing paper is used over the drawing sheet in which the plotted positions of (a,b and c) the known objects (A,B and C) are drawn. The back rays are drawn on the tracing paper by sighting the known objects. The intersection of the above three rays will give instrument position on the tracing sheet. By unfastening and adjusting the tracing paper over the plotted positions of the object on the drawing sheet will give the new instrument position of the station occupied by the plane table.

**Mechanical method**

It is also called as tracing paper method.

- Set up the plane lable at ‘T’.
- Orient the table as nearly in its proper position using by trough compass and clamp the board.
- Put the tracing paper over the plane table sheet and select a point ‘$t_1$’ on the tracing paper approximately representing the station point ‘T’. (Fig 3)

Fig 3




- With the help of alidade touching on t1 (pivoted on t1) sight the station points A, B and C and draw rays towards them.
- Unfasten the tracing paper and move it over on the plane table sheet, till the three rays are simultaneously pass through a, b and c. Prick the point t1 on the drawing sheet with fine needle point. The obtained point is the required point ‘T’ (Fig 3)
- Remove the tracing paper.
- Unclamp the plane table and orient by placing the alidade ta and turning the board till the station ‘A’ is bisected.
- For a check, sight the station points B and C with the help of alidade centered on b and c, and draw the rays.

These rays must pass through T if the work is correct.

If not, a small triangle error is formed and this may be eliminated by trial and error method.

2 **Graphical or Bessel’s method :** In this method any two of three known object points and its plotted positions on the drawing sheet are taken for solving the problem.

**Bessel’s method**

It is the simplest graphical method and is commonly used.

Set up and level the plane table at the instrument station at ‘T’.

Turn the table till the station ‘P’ is sighted. i.e (P is towards P).

Clamp the plane table.

The alidade is touching r and sight $\phi$ and draw a ray r$\phi$. (Fig 4, a)

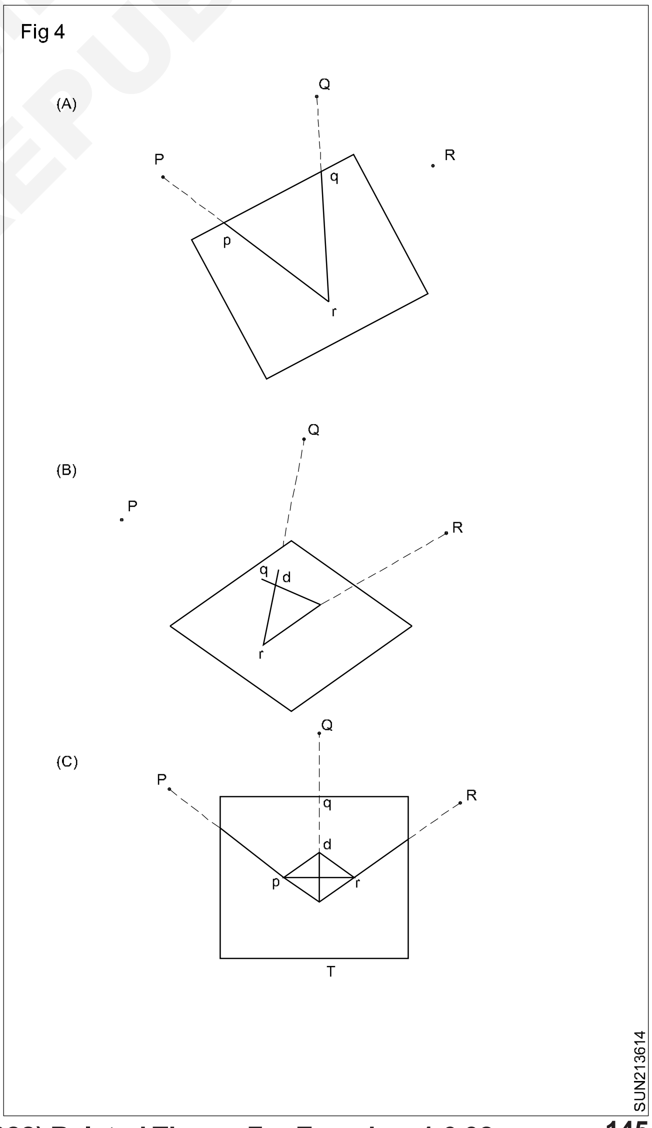
**Fig 4.b**

Unclamp the plane table. Put the alidade along rp and turn the plane table till R station R is bisected. i.e (r is towards R).

Then clamp the table. The alidade touching on P and sight Q and draw a ray PQ intersecting the previous ray rQ in the point at d.

**Fig (4,c)**

Fig 4



Put the alidade along dq, turn the plane table till Q is sighted and clamp the table. This is the correct orientation e.e (P must lie on dq and also PQ and Rr.

Put the alidade on P sight P and draw a ray. This ray will intersecting the ray dq in p which is the instrument station P.

As for the checking purpose, centre the alidade on r and bisect 'R' and draw ray. This ray Rr should pass through P if the work is correct.

3 **By trial and error method:** From the above three methods trial and error method is quick and accurate method. It is also known as triangle of error method. The position of the instrument station occupied by the plane table on the drawing sheet is found by Trial and Error method.

In this method the plane table is set up infront of the known object positions A, B and C with the plotted positions as 'a', 'b' and 'c' on the sheet. The table is roughly oriented by using compass or by eye judgement. Using the alidade and sight the objects through the plotted points respectively and draw back rays. Because of rough orientation the rays will not pass through a single point but will form a small triangle known as triangle of error.

By repeated trials, this triangle is eliminated so that the three rays Aa,Bb and Cc pass through one point, which is the required point (p). The position of point (p) is estimated from the triangle of error by the application of Lehmann's Rules.

**The triangle formed by joining the ground points A,B andC is called the great triangle. The circle passing through these points is called as the great circle.**

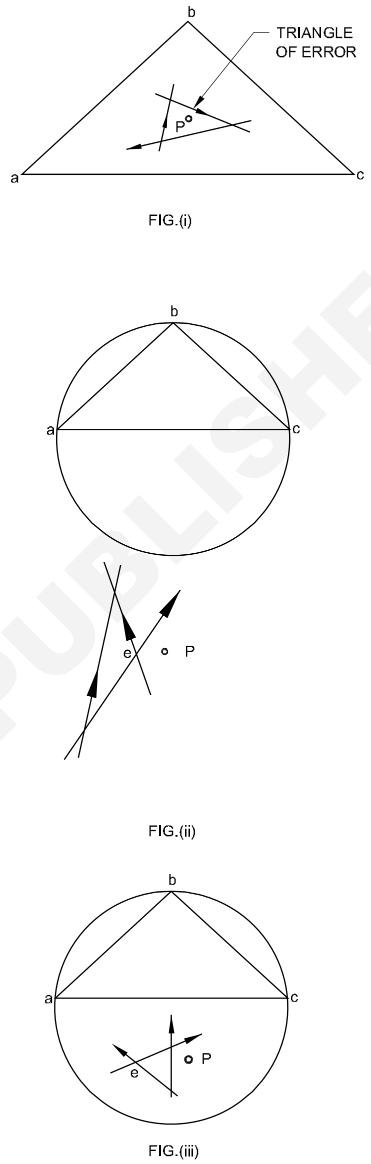
**Lehmann's Rules:**

- The distance of the point 'P' from each of the rays Aa, Bb and Cc is in proportion to the distance of A,B and C from 'p' respectively.
- When looking in the direction of each of the distant points A,B and C the point 'p' will be found on the same side of the three rays Aa, Bb and Cc i.e. it is either to the left or to the right of each of the three rays. (Fig 5(ii) and (iii))
- It follows from the above two rules that if the instrument station 'P' lies outside the great triangle 'ABC', the triangle of error falls outside 'abc' and the required point 'p' is outside the triangle of error. (Fig 5(ii) and (iii))
- Similarly if the station P lies with in the great triangle 'ABC', the triangle of error falls inside the triangle 'abc' and the point 'p' must within the triangle of error (Fig 5(i))

The above rules suffice for the solution of the problem, yet two more rules are given for assistance;-

- When the station-point 'p' is outside the great circle, the point 'p' is always on the same side of the ray drawn to the most distant point as the intersection (e) of other two rays (Fig 5(ii))
- When the station point 'P' is outside the great triangle 'ABC', but inside the great circle ie. within one of the three segments of the great circle, formed by the sides of the great triangles, the ray drawn towards the middle point lies between the point p and the intersection (e) of the other two rays (Fig 5(iii))

Fig 5

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**Errors in plane tabling**

The common sources of error in plane tabling are,

1 Instrumental error

2 Errors of manipulation and sighting

3 Errors of plotting.

**Instrumental Error**

- The top surface of the board not being a perfect plane
- The edge of the alidade not being a straight line.
- The sights of the alidade not being perpendicular to its base.

- The fittings of table and tripod being loose.
- Error due to defective trough compass

**Errors of manipulation and sighting**

- the board not being horizontal
- the table not being accurately centered
- the table not being properly clamped
- the objects not being correctly sighted.
- the alidade not being correctly centered on the station point on the sheet.
- the rays not being accurately drawn through the station point
- the table not being correctly oriented.

**Errors of plotting**

- by using the good quality of paper and stretching it correctly on the board.
- by taking care in drawing and in the use of scales.

**Advantages and disadvantages of plane table surveying**

**Advantages**

- It is the most rapid method.
- Field notes are not required, hence the mistakes in booking is eliminated.
- The angles and linear measurement are not observed since they are obtained graphically.
- As plotting is done directly in the field, there is no chances of omitting necessary measurements.
- The amount of office work is less.
- Checking of plotted details can be done easily on the spot itself.
- the principles of intersection and resection are conveniently used to avoid computation.
- It is less costly than other types of surveys.
- No great skill is required.

**Disadvantages**

- The absence of field notes is sometimes inconvenient, if the survey is to be replotted to a different scale.
- It is not used for large scale surveys and accurate work.
- The instrument is heavy and having many accessories, being loose are likely to be lost.
- In rainy season and cold wind affect the progress of survey.
- This survey cannot be done in dense wooded areas.
- Only day time can be availed for field and plotting works when comparing other types of surveying.

**Testing and adjustment of plane table**

**i The board**

The upper surface of the board should a perfect plane

**Test and adjustment**

- Check the straight edge in all the directions.
- If the surface of the board is not perfectly plane, remove the parts by sand papering or by planning.

**ii The surface of the board should be perpendicular to the vertical axis of the instrument.**

**Test**

- Set up and level the plane table over a station.
- Bringing the bubble in the central position by placing of a spirit level on the table.
- Turn the table through 180$^o$ and check the bubble in central or not.
- Then place the spirit level at 90$^o$ to the previous position and check the bubble in central and repeat.
- If the bubble in central on reverse to the vertical axis of the instrument. Therefore the adjustment is correct.

**Adjustment**

- If the bubble is not central position, the apparent error (half of the error) by packing between the underside of the board.
- Repeat the same process till the bubble in central after reversal in each case.

**iii The fiducial edge (or) ruling edge of the alidade should be a straight line.**

**Test**

- Select any two points on the drawing sheet at a distance equal to length of the alidade.
- Join these two points along the edge of the with fine line.
- Reverse the alidade. (End for end)
- Place the alidade at the end points and draw a line.
- If the two lines are in inner line the alidade is a corrected one.

**Adjustment**

If not, correct the edge by filing and again testing.

**(iv)The axes of the spirit levels mounted on the alidade should be parallel to the base of the alidade.**

**Test**

- Place the alidade on the table.
- Bring the bubble of one of the levels of the alidade in central by means of foot screws of the table.
- Mark this position of the alidade.

- Lift and reverse the alidade into 180° and replace it within the mark.
- If the bubble is in central the adjustment is correct.

**Adjustment**

- If the bubble is not in central, bring the bubble in central by adjusting the half the error by means of level tube and other half by foot screws.
- Repeat the same procedure till the bubble is in centre.
- The same way test and adjust the second level tube.

**(v) The sight vanes of the alidade should be perpendicular to the base of the alidade.**

**Test**

**In case of plain alidade**

- Suspend a plumb line at a distance from the instrument.
- Place the alidade on the levelled table. Observe the sighting silt and vertical hair of the object vane appear parallel to the plumb line.

**Adjustment**

- If they are not in parallel to the plumb line, adjust by tilting of the base of the sights. (some times packing of the base of the sights also)

**Incase of telescopic alidade**

**Adjustment**

1 The line of collimation should be perpendicular to the horizontal axis of the telescope.

2 The horizontal axis must be parallel to the base of the alidade.

3 The vertical circle must zero when the line of sight is horizontal.

4 The axis of the telescope level should be parallel to the line of sight.

**General instructions while surveying plane table**

The following points are kept in mind while plane table

- The stations on the ground should be marked A,B,C, D etc to be denoted by corresponding small letters a, b, c, d etc. when plotting on the sheet.
- The plane table should be turned, only on orientation. After orientation the board is clamped in position.
- While sighting objects, the table should be clamped in position. Only the alidade should be moved on the table to bisect the objects.
- The working edge of the alidade (fiducially edge) must touching the plotted station point on the sheet while sights are observed.
- It is advisable their the alidade should be centred on the same side of the station pin throughout the survey. Keep the alidade on the left of station pin is more idled.
- The drawing should be cleaned as for as possible.

**The plane table is always placed in every station which is parallel to the position occupied at the first station, which is called as the principle of plane table.**

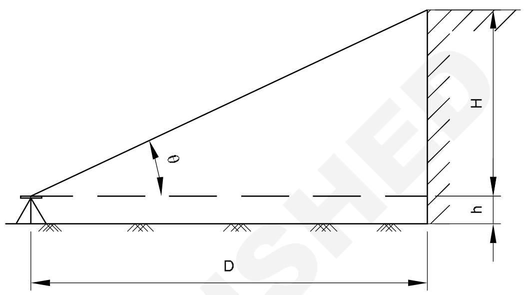
**Always orientation by back sighting is preferred it is most reliable than magnetic needle method.**

## Determination of height by telescopic alidade

**Objectives:** At the end of this lesson you shall be able to
- **state about the construction & use of telescopic alidade**
- **explain the method of use of telescopic alidade in ranging & to read lier measurement**
- **calculation of trigonometrical values.**

- The plane table is setup at end convenient station point in front of the target's height to the find.
- Select a point 'P' such that the target height say a building / (Electric grid post) can be visible clearly
- Setup and level the plane table over the station point & clamp it.
- Select a point on the drawing sheet 'P' by transferring the ground station to sheet
- The telescopic alidade is carefully placed on the table.
- Make the telescope axis is parallel to the plane table or horizontal axis
- keep the telescopic, alidade just adjacent to the station point
- Note that when the horizontal position of telescope should be consider in the 'O' degree of graduated vertical circle of telescopic alidade.
- If not make the mirror adjustment & make the telescope horizontal & 0 degree co-incidence
- Range the target (building) just foot of the target
- Take the levelling staff reading (Horizontal)
- The without shifting the alidade raise the telescopic alidade telescope only and view the apex point.

Fig 1

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- Note down the graduated vertical circle reading in degrees left it be 'Q'
- Note down the distance between the station point to foot of the building where the horizontal reading is taken out.
- Let it be 'D' meters.

Then-Distance in known 'D'

- Angle of elevation is known $\theta$
- Height of building is = H = Tan$\theta$ D
- Tan$\theta$ D+H)

## Introduction to theodolite

**Objectives:** At the end of this lesson you shall be able to
- **enumerate uses of theodolite**
- **classify theodolite**
- **designate theodolite.**

**Introduction**

Theodolite is primarily used for measuring horizontal and vertical angles. Later further additions were made to make possible of several uses such as

- prolonging a line
- establishing line
- levelling

It is sometimes referred to as Universal Instrument. Theodolite is a very useful instrument for engineers.

**Classifications of theodolite**

Theodolite may be classified into

1 Transit or engineer's theodolite and

2 Non-transit theodolite

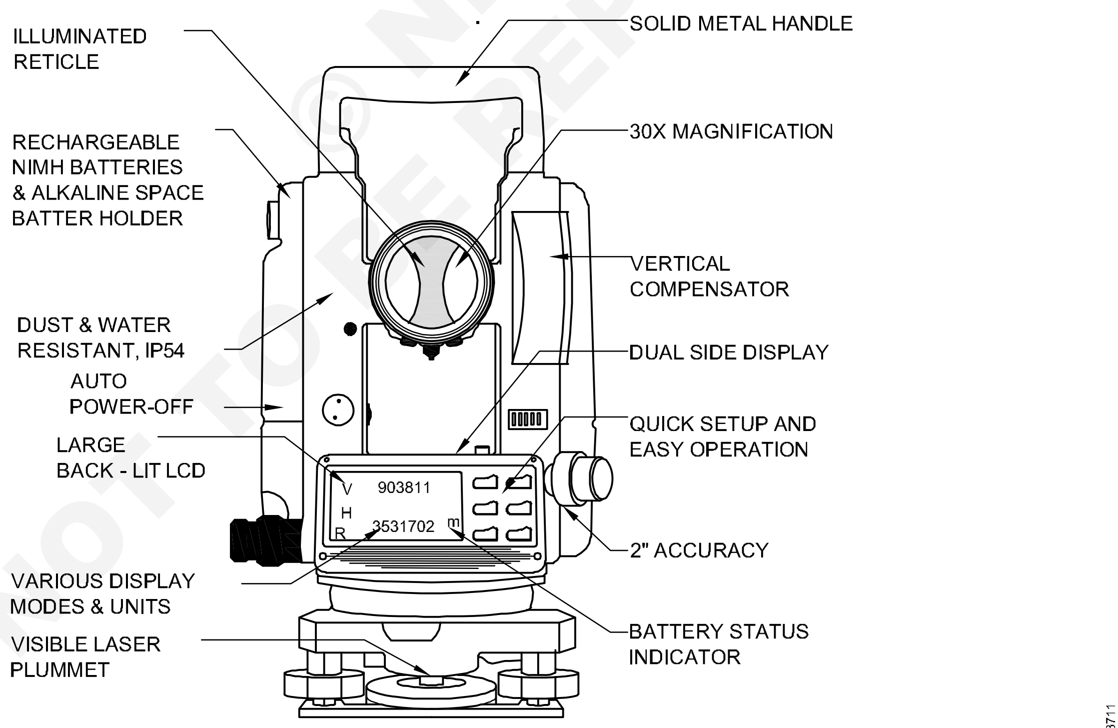
A Theodolite is said to be transit one, when its telescope can be revolved through 180° in a vertical plane about its horizontal axis, thus turning the telescope in exactly opposite direction. All modern theodolites are transit type.

A theodolite is said to be non-transit one, if its telescope cannot be revolved through 180° in a vertical plane about its horizontal axis. Non-transit theodolites are obsolete now-a-days. Digital theodolite with higher precision are available. It is used where higher accuracy is needed.

**Designation of theodolite**

The size of a theodolite is defined by its diameter of the graduate circle of the lower plate. For example, a 25 cm theodolite means the diameter of the lower graduated circle is 25 cm

Fig 1



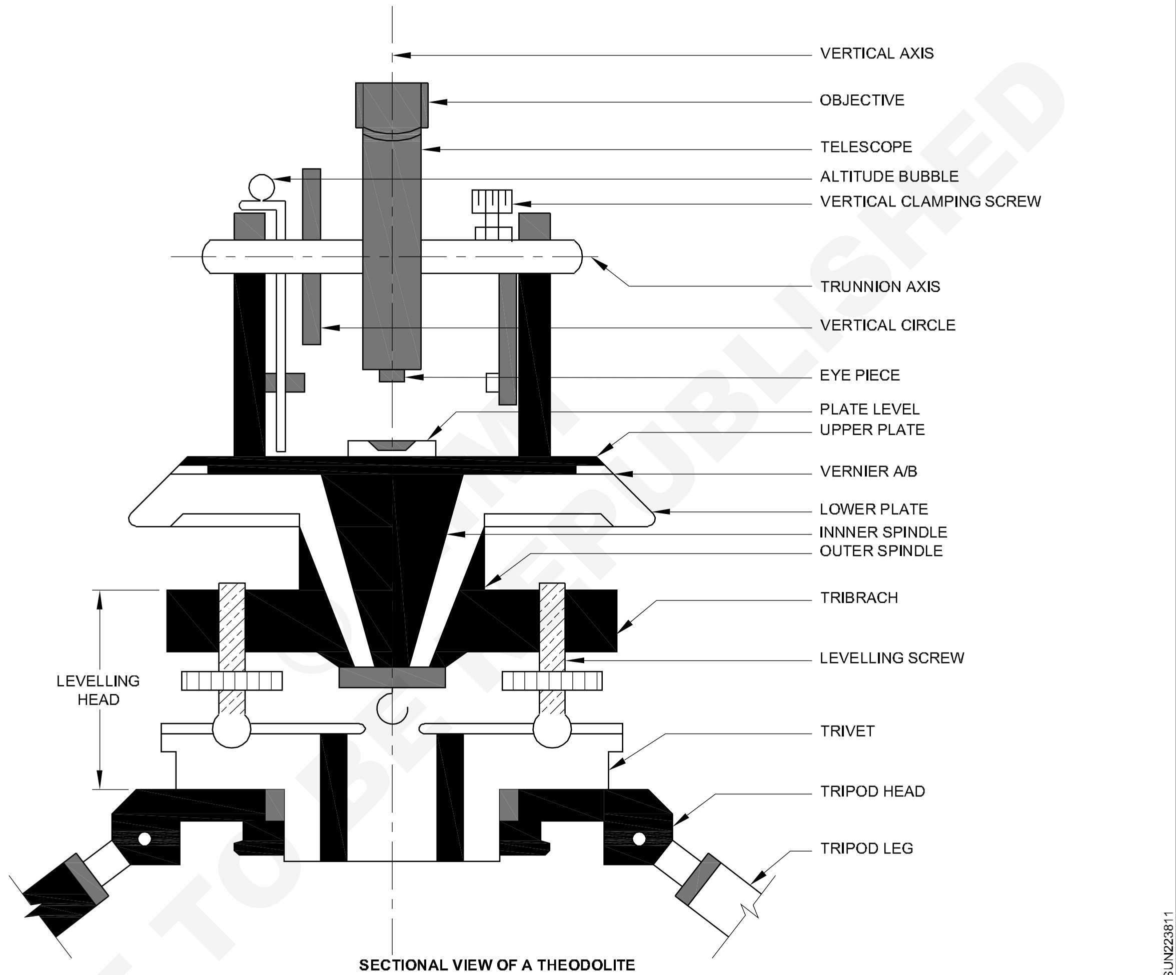

THEODOLITE

## Main parts of a vernier theodolite

**Objectives:** At the end of this lesson you shall be able to
- **sketch sectional views of a theodolite**
- **explain the main parts of theodolite**
- **state the fundamental operations of theodolite.**

### Vernier theodolite

Fig 1




SECTIONAL VIEW OF A THEODOLITE



### Levelling head

Levelling head is used to level the instrument horizontal. It consists of two plates

1 Upper tribrach plate and

2 Trivet or Lower tribrach plate

The upper plate carries three levelling screws. The lower plate also known as foot plate is provided with a large central hole with thread for fits into the top of the tripod. A plumb bob can be suspended from a hook at the lower end of the inner spindle for centering purpose.

**Shifting head:** This device helps in exactly centering the instrument over the station. When it is unlocked, the instrument can be moved slightly and independently of the levelling head. Therefore the instrument is first approximately centered over the station and exact centering is done using the shifting head.

### Lower plate and upper plate

It carries a circular scale which is graduated to 0° to 360°. It is attached to the outer spindle.

Upper plate is also called vernier plate. Two diametrically opposite verniers (A and B) provided with magnifiers are fixed to the upper plate. It is attached tonner spindle which rotates in the outer spindle.

### Clamp and tangents

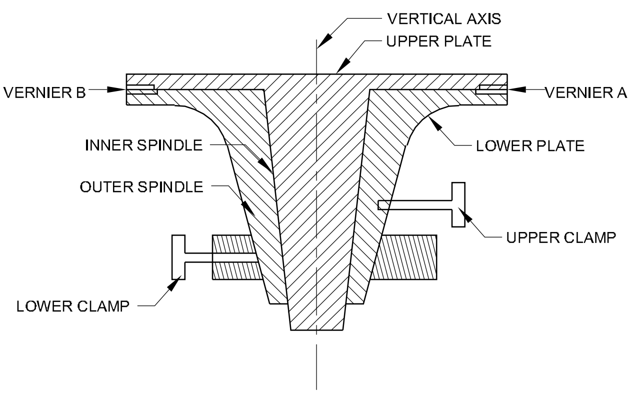
Two clamp screws and tangents (Fig.2) are provided on the horizontal circle and one clamp screw and tangent screw is provided on the vertical circle. They are called, 1 Upper clamping screw and its tangent

2 Lower clamping screw and its tangent

3 Vertical circle clamping screw and its tangent.

Lower plate can be clamped to outer spindle at any desired position using lower clamps. The upper plate can be clamped to the lower plate using upper clamp screws. If the upper clamp is locked and lower clamp is loosened the two plates rotate together on outer spindle without causing any change in the reading. If the upper clamp is loosened and the lower clamp is clamped, the upper plate rotates on its inner spindle with relative motion between two plates. This properly is used for measuring horizontal angles.

Fig 2




CLAMP AND TANGENTS

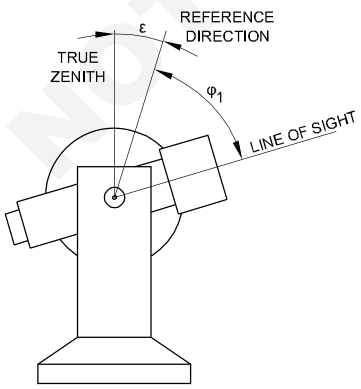
## Level tubes

There are two level tubes. One on the horizontal upper plate and another attached to the vertical vernier. Sometimes, it carries two plate levels. If two plate levels are provided they will be at right angles to each other. A level tube is also known as a bubble tube or spirit level or level.

## Telescope (Fig 3)

Function of telescope is to provide the line of sight. Telescope is mounted on horizontal axis (placed at right angles to the line of collimation). Vertical circle is also connected with telescope. It has,

Fig 3




TELESCOPE - DIRECT POSITION

i an eye piece (held to the eye when sighting through telescope).

ii a diaphragm and

iii an object glass or objective (towards object sighted)

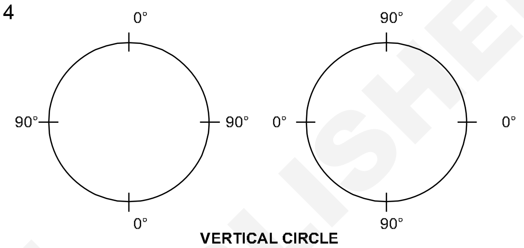
## Vertical circle (Fig 4)

Vertical circle is connected to telescope and its moves with telescope when telescope is rotated in vertical plane. The following graduations are in common use.

1 The vertical circle is divided into four quadrants from 0° to 90° in both directions. The 0° - 0° line is a horizontal line.

2 The vertical circle is divided into four quadrants from 0° to 90° in both directions, the 0° - 0° line is a vertical line.

Fig 4




VERTICAL CIRCLE

## Index frame (or) 'T' frame (or) Vernier frame (Fig 5)

It resembles the English letter 'T' is centered on the horizontal axis of the instrument. It consists of a vertical arm and a horizontal arm. The vertical arm is called clipping and a horizontal arm is called an index arm.

Clipping arm is provided with a form and two clipping screws at its lower extremity. At the top of the frame is attached a bubble tube called the altitude bubble tube. At the two ends of index arm verniers 'C' and 'D' are fitted.

## The standards (or) 'A' frame (Fig 6)

Two standards resembling english letter 'A' are fixed on the upper plate. These frames support the telescope. They are known as standards or 'A' frame. The horizontal axis of the telescope is supported on these 'A' frames. The 'T' frame and vertical circle clamp are attached to this frame.

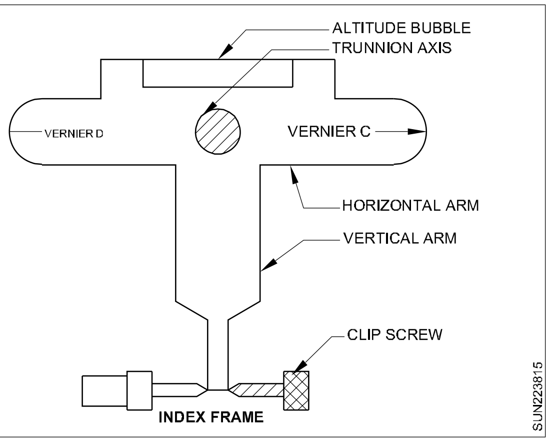
## Tripod

Theodolite is used by mounting it on a tripod when being used in the field. It consists of three legs which are provided with pointed steel shoes to get good grip on the ground. External screw is provided on top of the tripod to facilitate screwing of theodolite.

## Plumb bob

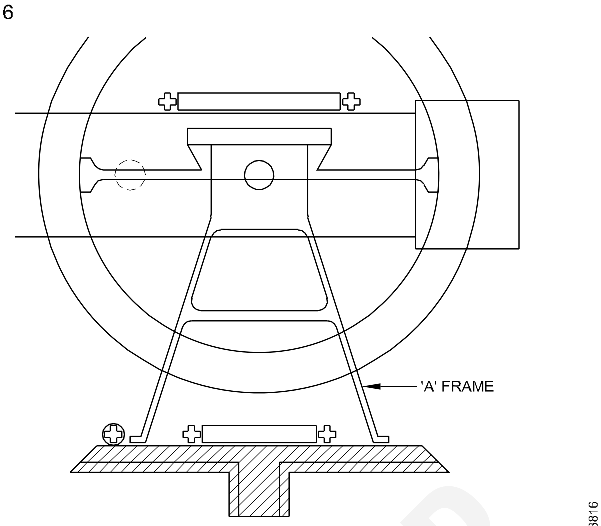
A hook is provided at the lower end of the inner spindle from which a plumb bob can be suspended. It facilitates exact centering of the theodolite over the station.

Fig 5




INDEX FRAME

Fig 6




THE STANDARDS OR ( 'A' FRAME)

# Fundamental axis and geometry of theodolite

**Objectives:** At the end of this lesson you shall be able to
- **explain the fundamental axis of theodolite**
- **state geometry of the theodolite.**

## Fundamental axis of theodolite

### Vertical axis

The axis about which a theodolite is rotated in a horizontal plane is the vertical axis.

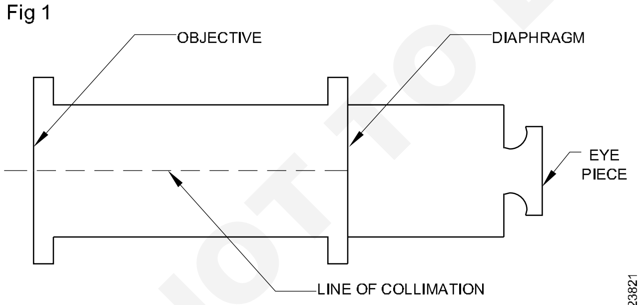
### Horizontal axis (Trunnion axis)

The axis about which the telescope rotates is a vertical plane is called horizontal axis or trunnion axis.

### Line of collimation or line of sight (Fig 1)

It is an imaginary line joining the intersection of the cross hairs with the optical centre of the object glass and its continuation.

Fig 1




LINE OF COLLIMATION OR LINE OF SIGHT

### Axis of telescope

It is an imaginary line joining the centre of the eye piece and the optical centre of the object glass. (Fig 2)

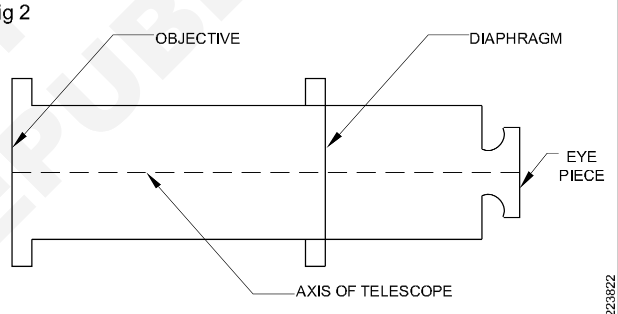
### Axis of plate level bubble

An imaginary straight line tangential to the longitudinal curve of plate level at its centre.

### Axis of the altitude level tube

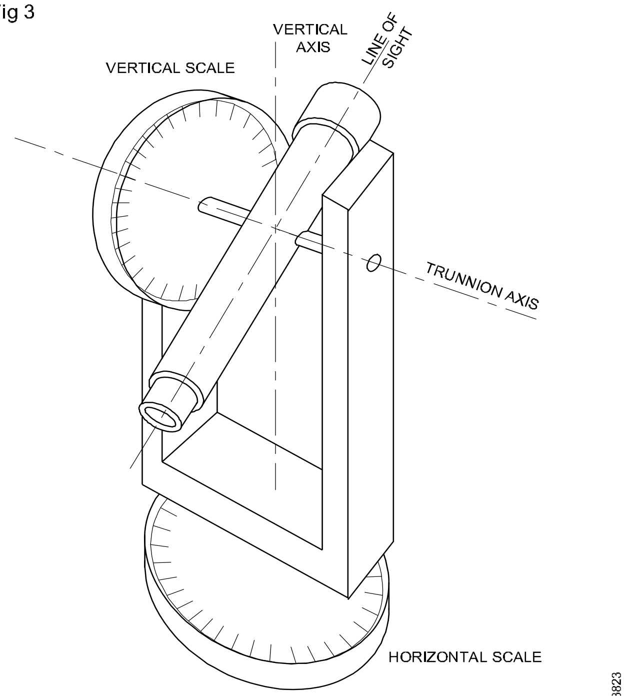
An imaginary straight line tangential to the longitudinal curve of altitude level at its centre. (Fig 3)

Fig 2




AXIS OF TELESCOPE

Fig 3




AXIS OF THE ALTITUDE LEVEL TUBE

**Geometry of the theodolite**

In a perfectly constructed theodolite following relations between axis of the instrument should exist:

1 The vertical axis of the instrument should be perpendicular to the axis of the plate bubble.

2 Line of sight should be perpendicular to the horizontal axis.

3 The horizontal axis should be perpendicular to the vertical axis.

4 The axis of the altitude bubble tube should be parallel to the line of sight.

## Theodolite - definitions and terms

**Objectives:** At the end of this lesson you shall be able to
- **define the terms used in theodolite surveying**
- **state the difference between face left and face right observations**
- **explain least count.**

**Definitions and other technical terms**

**Centering**

The process of bringing the vertical axis of theodolite immediately over a mark or station is known as centering. This is achieved by suspending plumb bob along vertical axis of theodolite and shifting the head.

**Transiting (or) reversing (or) plunging (Fig.1)**

The process of turning the telescope in vertical plane, about its horizontal axis through 180° is known as transiting. the terms reversing or plunging are also used sometimes for transiting.

**Swing (Fig.1)**

Rotating telescope in horizontal plane, about its vertical axis is called swing. According to the direction of rotation there are two swings.

When the telescope is rotated clockwise it is called right swing.

When the telescope is rotated anti-clockwise it is called left swing.

**Telescope normal**

When the vertical circle is on the left of the telescope and the target on telescope is up then it is called telescope normal.

**Telescope inverted**

When the vertical circle is on the right of the telescope and the target on the telescope is down then it is called telescope inverted.

**Face left and face right observations (Fig 2)**

The observations made keeping the vertical circle of the instrument on the left side of the telescope is known as face left observations.

The observations made keeping the vertical circle of the instrument on the right side of the telescope is known as face right observations.

**Changing face**

Process of changing face left to right or vice versa is known as changing face.

Fig 1

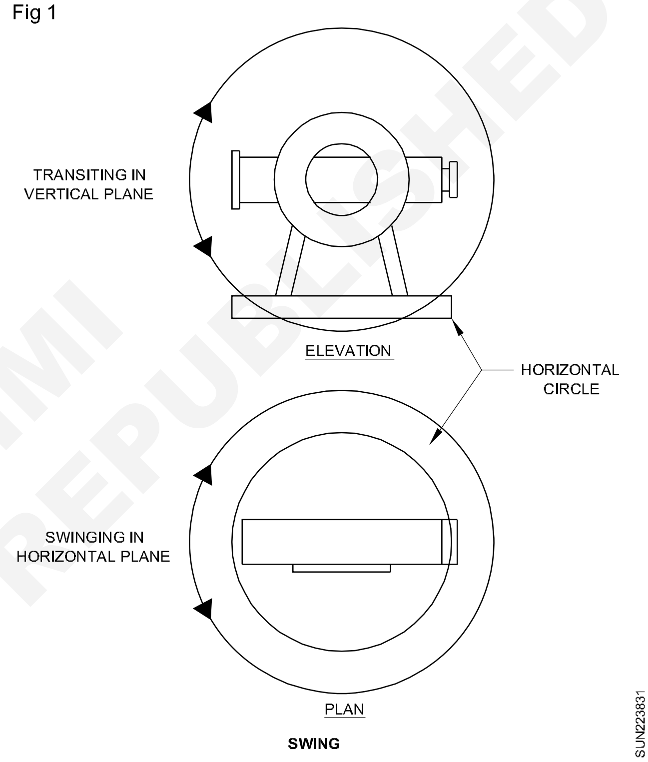
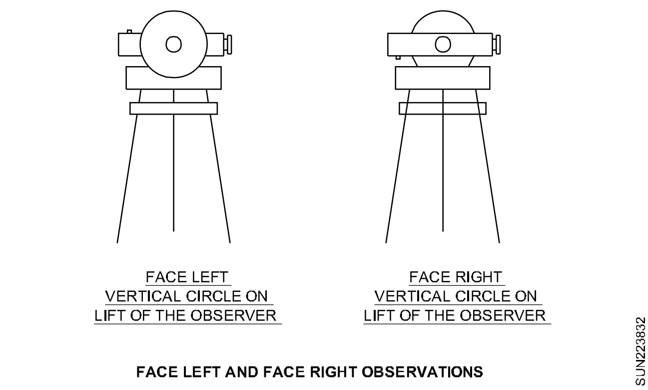



Fig 2

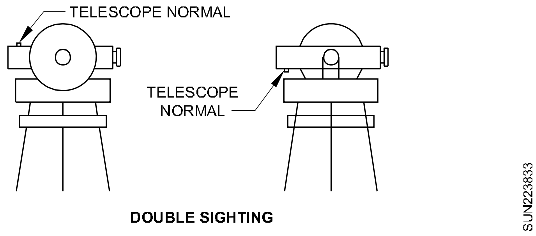



**A set of observation:** It consists of two horizontal observations; that is one face left and one face right observations.

**Double sighting (Fig 3)**

Operating theodolite twice, once with telescope in the normal condition and another with telescope in the reverse condition.

Fig 3




DOUBLE SIGHTING

**Least count (L.C.)**

The smallest measurable unit is called Least Count.

**Lining in**

The process of establishing intermediate points with a theodolite on a given straight line, whose both ends are intervisible is called lining in.

**Balancing in**

The process of establishing intermediate points with a theodolite on a given straight line, whose both ends are not intervisible (e.g. forest) is called balancing in.

## Unplacing and placing of theodolite

**Objectives:** At the end of this lesson you shall be able to
- **take out theodolite from the box**
- **place theodolite in the box.**

**Taking out theodolite from the box**

Open the box carefully. Ensure the correct seating of the telescpe in the box. The trainee may prepare a rough sketch and stick it to the inner cover or mark the position of seating position of theodolite in the box. Hold the upper body of the theodolite with the left hand and put the middle finger of the right hand below the foot screw and gently lift it out of the box.

**Placing theodolite in the box**

Unscrew the theodolite from the stand and place the theodolite carefully inside the box.

When placing theodolite in the box, ensure the following

1 Loosen all the clamps

2 Cover the objective glass

3 Vertical circle on left side of the surveyor.

4 One foot screw on the top, facing the surveyor and the other two rest on supports provided in the box.

Fig 1


DIGITAL THEODOLITE BOX

## Temporary adjustments of theodolite

**Objectives:** At the end of this lesson you shall be able to
- **set up and centre the instrument**
- **level up the theodolite**
- **eliminate parallax.**

**Temporary adjustments of a theodolite**

Temporary adjustments are those adjustments required at every new set up of the theodolite. Following temporary adjustments are required for a new set up of a theodolite before starting the work they are,

1 Setting up

2 Centering

3 Levelling up

4 Focussing

  a Focussing the eyepiece

  b Focussing the objectives

**1 Setting up**

Initially tripod is set up at a convenient height over the station spreading and fixing three legs firmly on the ground. Fix the instrument over the tripod. Bring the levelling screw at the middle of the run. Then the instrument is approximately levelled by eye judgement. Some instruments are provided with a small circular bubble on the tribrach to check the horizontal level.

**Centering will disturb if there is considerable dislevelment.**

**2 Centering**

Centering is achieved by suspending plumb bob with a string attached to the hook fitted to the bottom end of the vertical axis. Approximate centering is done by moving the legs radially and circumferentially. Accurate centering by finer movement is done by shifting the head, unlocking the shifting head clamp.

**Centering is done to place the vertical axis exactly over the station.**

**3 Levelling up**

Levelling operation to make the vertical axis of the instrument truly vertical and pass through the station.

**4 Focussing**

Focussing is done to eliminate parallax error.

**5 Focussing the eye piece**

This is done by holding a white paper 15 cm in front of the objective and turning the eye piece in or out until the cross hairs are seen sharp and distinct.

**6 Focussing the objective**

Object to be sighted is focussed to bring the image in the plane of the cross hairs.

Move the eye up and down or sideways to check whether the cross hairs have any relative movement with respect to the object sighted.

Parallax is condition that there exists relative movement between the cross hairs and the object sighted. This condition arises when the focussing lens is not in its proper position. Parallax can be eliminated by refocussing lens improper position.

## Permanent adjustments of theodolite

**Objectives:** At the end of this lesson you shall be able to
- **list the permanent adjustments**
- **explain relationship satisfied by adjustments**
- **explain tests and adjustments.**

**Permanent adjustments**

The fundamental lines of theodolite have inter-relationships amongst each other. Manufacturers of theodolite take care of itself while manufacturing theodolite.

The relationships between fundamental lines are explained in the geometry of theodolite. However the prolonged use of theodolite and mishandling of instrument in field will make the fundamental lines relations altered, there by observations erroneous.

So the instrument has to be checked for these relations and if found erroneous, the instrument should be correctly adjusted before using it for recording the observations. Such adjustments are called permanent adjustment.

The tests and permanent adjustments are done in the following order.

1 **Plate level test:** To make the plate bubbles central to their run when the vertical axis of the theodolite is truly vertical.

2 **Cross hair ring test:** To make the vertical and horizontal cross hairs lie in a plane perpendicular to the horizontal axis.

3 **Collimation test:** To make the line of sight perpendicular to the horizontal axis.

4 **Spire test:** To make the horizontal axis perpendicular to the vertical axis.

5 **Bubble tube adjustment:** To make the telescope bubble central when the line of sight is horizontal.

6 **Vertical ARC test:** To make the vertical circle indicate zero when the line of sight is perpendicular to the vertical axis.

### 1) Plate lever test

**Relation established:** Axis of the plate level tube should be perpendicular to the vertical axis of the instrument.

Bubble must remain at the centre of its run during complete revolution if the instrument is in perfect adjustment. This test is used to check whether the plate level axis perpendicular to the vertical axis of the instrument.

**Test:** To test, the instrument is levelled and the telescope is rotated through 180°. If the bubble runs out of the centre, the adjustment is out of order. If the bubble is out of the centre, count the number of graduations of on the bubble tube.

**Adjustment:** Correct half the error by means of pair of levelling screws and the remaining correction is made by means of capstan headed screw provided at the end of the level tube.

### 2) Cross-hair ring test

Relation established: The vertical cross-hair should be in a plane perpendicular to the horizontal axis.

**Test:** Instrument is levelled. The telescope is directed towards a plumb bob string at rest. The string is bisected and telescope is rotated slightly in a vertical plane. If the relation is in perfect condition, the image of the string will coincide with the vertical cross hair. If the image moves off the cross hair, it means the relation is not in adjustment.

**Adjustment:** To adjust the vertical cross hair, loosen all four capstan screws on the cross-hair ring. Rotate the ring carefully, so that the image of the string and the vertical cross hair coincide. The screws are then tightened.

**If the vertical cross hair is set perpendicular to the horizontal axis, the horizontal axis is automatically made horizontal.**

### 3) Collimation in azimuth test

**Relation established:** The line of sight should be perpendicular to the horizontal axis. If this relation is in adjustment the line of collimation will generate a plane when the telescope is revolved in vertical plane. If the relation is not in adjustment, the line of collimation will generate a cone with the horizontal axis as its axis.(Fig.1)

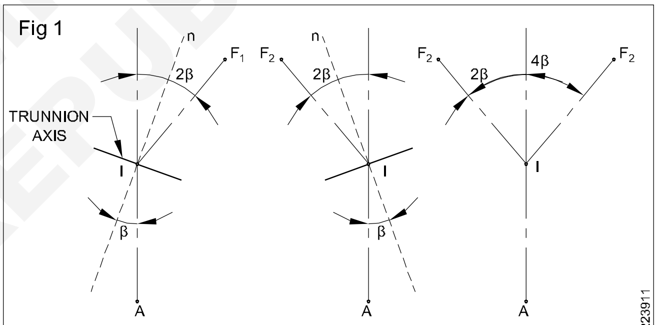
**Test:** The instrument is setup and levelled at a point in an open field so as to have an unobstructed view for about 60 m on either side of the instrument. Set up the instrument at midway, telescope in normal condition, sight a point. Transit the telescope and fix another point on the same line.

Change face of the instrument and bisect the first point. Transit the telescope. If the line of sight passes through the already fixed point, then the line of sight is perpendicular to the horizontal axis. If the line of sight does not pass through the point, the adjustment is done as follows:

**Adjustments:** Fix the new point. Measure the distance between points. Measure a quarter of the distance from the last point. Adjust the vertical hair by means of two opposite capstan headed screws so that the line of sight passes through the quarter distance. Repeat the test till line of sight passes through the same point in both face observations. The instrument is at point I, the backsight is point A and point F1 is set at the foresight. Line n is perpendicular to the trunnion axis, as the line of sight should be the line of sight is deflected from line n by an angle β. The error in the backsight reverses direction in the foresight. The foresight direction is in error by two times the deflection error 2β.

Turn to the same backsight in inverted position. Plunge the scope again, and in direct position, set another mark at the foresight, F2, as shown in the figure. The angle between the two foresight marks is four times the deflection error. It is corrected by moving the crosshair horizontally.

Fig 1




COLLIMATION IN AZIMUTH TEST

### 4) Spire test

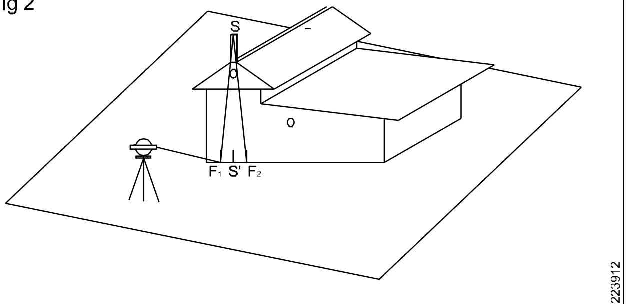
**Relation established:** The horizontal axis should be perpendicular to the vertical axis. This adjustment ensures that the line of sight revolves in a vertical plane perpendicular to the horizontal axis when the instrument is levelled.

**Test:** Set up the instrument near any tall object which has a well defined point available at 60° to 70° vertical angle. With face left sight the well defined point. Lower the telescope after arresting the horizontal movement of telescope and find foot of the point of the ground. Change face of the instrument and repeat above procedure. If foot of the point sighted is same in both face observations then the horizontal axis is perpendicular to the vertical axis and if not the instrument needs adjustment.

**Adjustment:** Distance between foot distance is measured and mark the midway between the distance. Centre point is bisected and raise the telescope to sight the point, but it is in an error by half the distance between foot of the point.

One end of the horizontal axis is moved with the adjusting screw until the line of sight bisects the point. Repeat the test and check the adjustment. (Fig 2)

Fig 2




COLLIMATION IN SPIRE TEST

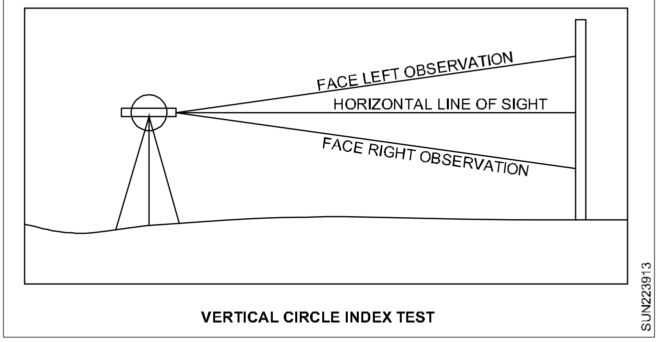
#### 5) Bubble tube adjustment test

**Relation established:** The axis of the bubble tube attached to the telescope should be parallel to the line of sight. This done so that the vertical circle reads zero when the telescope is horizontal.

**Test:** Set the vertical vernier to zero. A staff is held vertical at about 60 m from the instrument and the reading is taken by face left observation. Then the face is changed and the staff is read again. If there is an error, the face readings will be different.

**Adjustment:** The telescope is to read the mean of the two staff readings. Then the vertical circle should be brought back to read zero using the clip screws.

Fig 3




VERTICAL CIRCLE INDEX TEST

#### 6) Vertical ARC test

**Desired relation:** When the line of sight is perpendicular to the vertical axis, the vertical circle should read zero.

**Test:** Centre the altitude bubble on the telescope. The zero of the vernier of the vertical circle should coincide with the zero on the main scale of the vertical circle. If it doesn't coincide, it needs adjustment.

**Adjustment:** The capstan head screws are loosened and the vernier is moved till the zero coincides with that of the main scale.

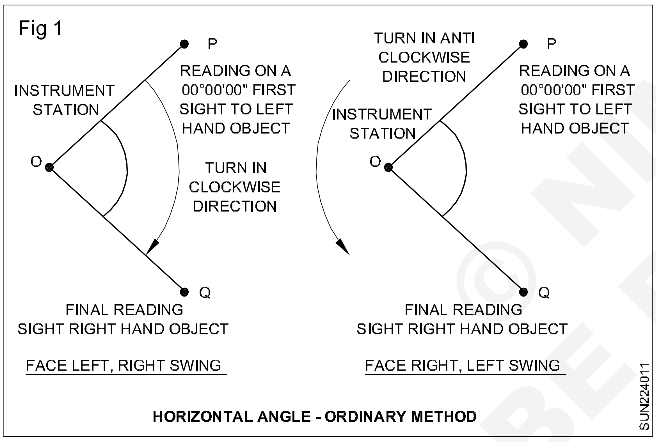
## Theodolite - measuring horizontal angle - ordinary method

**Objectives:** At the end of this lesson you shall be able to
- **explain ordinary method**
- **state advantages of ordinary method**
- **point out things to remember while working.**

### Ordinary method

A single set of observations are made for measuring a horizontal angle between any two points at a station in this method (Fig.1).

Fix two station, P and Q on the ground and set up the instrument at the point, "O'. Perform all temporary adjustments. Set vernier A 00° 00' 00". Sight the left hand station. Loosen the lower clamp, sight the right hand station and observe reading. Change face of the instrument and take another set of readings. The mean of the face left and face right observations is the final required angle. Procedure explained in the given figure and a table is also given to show how to tabulate.



HORIZONTAL ANGLE - ORDINARY METHOD

### Advantages of ordinary method

1 Errors due to eccentricity of the spindles are eliminated by reading both the verniers.

2 Errors due to eccentricity of the verniers are eliminated by reading both the verniers.

### Point to remember

1 Carefully clamp and unclamp screws and tangents.

2 Utmost care should be taken to avoid errors and mistakes while operating theodolite.

3 Usually degrees, minutes and seconds are measured at vernier A and Minutes and Seconds in Vernier B.

4 Theodolite should swing in clockwise direction (Right swing) for face lit observation and swing in anticlockwise direction (Left swing) for face right observation.

5 Telescope cannot move relative to graduated circle when upper screw is clamped and lower screw is unclamped but can rotate in horizontal plane.

6 Telescope moves relative to graduated circle and can rotate in horizontal plane also when upper screw is unclamped and lower screw is clamped.



## Theodolite - measuring horizontal angle - repetition method

**Objectives:** At the end of this lesson you shall be able to
- **explain repetition method**
- **state advantages of repetition method**
- **state errors which are not eliminated.**

### Repetition method

This method is used to measure a horizontal angle accurately. In this method same angle is measured repeatedly in both face observations instead of single observations. Mean of the face left and face right readings after doing by the number of repetitions, is the final measured value of the angle.

Fix two stations, P and Q, on the ground and set up the instrument (Fig 1) at the point, 'O'. Perform all temporary adjustments. Set vernier A 00° 00' 00". Sight the left hand station (Fig.1). Choose the upper clamp, sight the right hand station and observer reading. Without changing the reading observed, turn the telescope and sight 'P'. Measure the angle again, which will read twice the first angle. Repeat the process for required number of repetitions.

Change face of the instrument and repeat above steps (Fig.2). The mean of the face left and face right observations is the final required angle.

Suppose that, for measuring a horizontal angle 'θ', 'n' times repetitions are done. Then angle $\theta = (n \times \theta) \div n$.

### Advantages of repetition method

1 Errors due to imperfect graduations are minimized by reading on different parts of the graduated circle.

2 Errors, due to eccentricity of the spindles are eliminated by reading both the verniers.

3 Errors due to eccentricity of the verniers are eliminated by reading both the verniers

4 Error due to line of collimation not being perpendicular to the horizontal axis is eliminated by taking both the face left and face right observations.

5 Error due to inaccurate bisection is compensated because many observations are taken.

6 Possible to obtain values lesser than least count of the instrument.

**Errors which are not eliminated by this method**

1 Slip

2 Displacement of signal

3 Vertically of vertical axis

**Points to remember**

1 For ordinary works, 3 repetitions are sufficient.

2 For precise work, 5 or 6 repetitions are done.

3 Care should be taken if reading exceeds 360°.

4 Carefully clamp and unclamp screws and tangents.

5 Utmost care should be taken to avoid errors and mistakes while operating theodolite.

**Face left, right swing observation**

**Example**

Mean of two readings (Fig.1)

$$\angle POQ = \frac{147^\circ\ 56'50"}{3} = \angle 49^\circ\ 18'56"$$

No. of repetitions = 3.

∠147° 56’ 50” is the angle after 3 repetitions.

**Face right, left swing observation (Fig 2)**

Mean of two readings

$$\angle POQ = \frac{147^\circ\ 56'50"}{3} = \angle 49^\circ\ 18'56"$$

No. of repetitions = 3.

∠147° 56’ 50” is the angle after 3 repetitions.

Means of two observations is the final angle =

$$\frac{\angle 49^\circ\ 18'56 + \angle 49^\circ\ 18'56"}{2} = \angle 49^\circ\ 18'56"$$

$$\angle POQ = \angle 49^\circ\ 18'56"$$

Fig 1

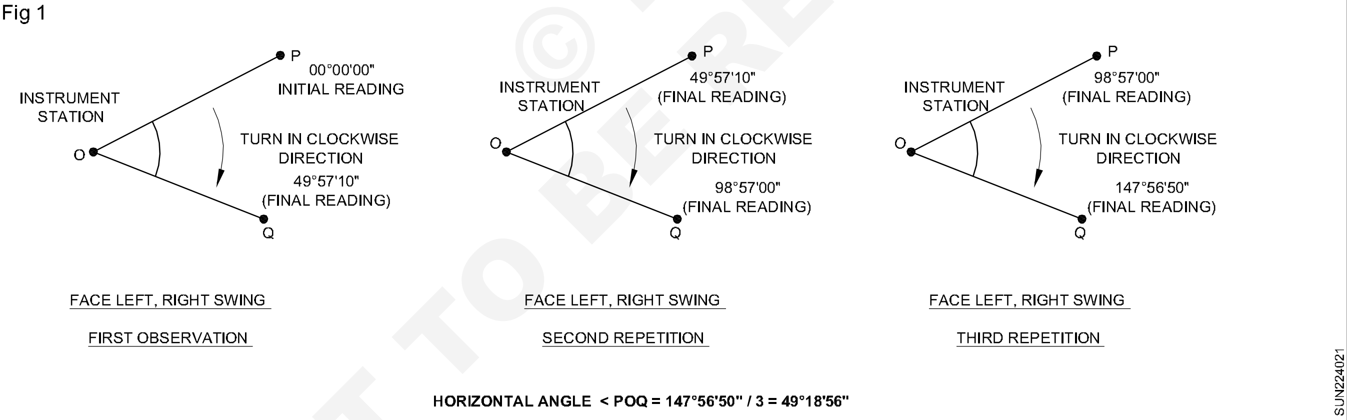
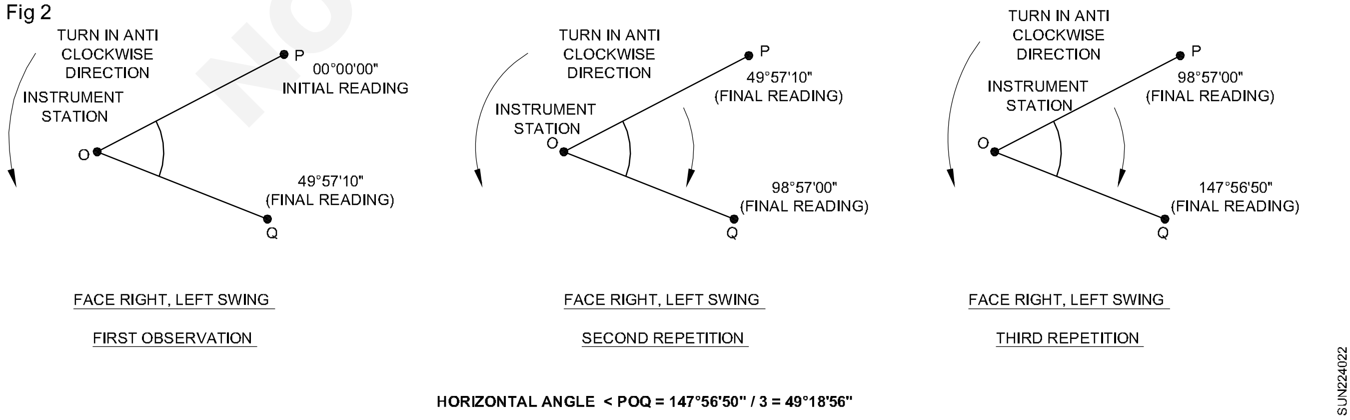



Fig 2



## Theodolite - measuring horizontal angle - reiteration method

**Objectives:** At the end of this lesson you shall be able to
- **explain reiteration method**
- **point out things to remember**
- **check and adjust closing the horizon error.**

**Reiteration method**

This method is useful for measuring precisely a number of horizontal angles from a single station point. Suppose from a station 'O', angle's POQ, QOR ROS and SOP are to be measured. After setting the vernier A, 00° 00' 00", sight the initial station P. Unlock the upper clamp and swing telescope clockwise (left swing) and successively bisect the stations Q, R, and S and measure angles accurately. Tabulate it correctly. Finally close the horizon by sighting initial station P. When closing horizon (the angle between the last station and first station), the final reading should be same as initial reading. If large discrepancy is found, the whole work should be repeated.

Change face of the instrument and swing telescope anticlockwise (right swing) and bisect the stations. Measures angels accurately and tabulate it.

Determine ∠QOR by deducting ∠POQ from ∠POR. Thus determine the remaining three angles separately for both face observations. Average of the two face observations is required angle. Sum of all the four angles to check whether the sum is 360°. If the error is small it is distributed equally among all the angles and the corrected angles are obtained.

More precision can be obtained by taking 'n' set of readings and averaging the observations.

**Points to remember**

1 While bisecting stations after sighting initial station use only upper clamp screw and its tangent.

2 For face left observation, turn telescope clockwise and for face right observation, turn telescope anticlockwise.

3 Carefully tabulate face right observation because last station will bisect first.

4 Mean angles are checked for closing the horizon.

5 Angles are corrected angles after checking and adjusting for horizon closing (if found any discrepancy).

## Theodolite - errors

**Objectives:** At the end of this lesson you shall be able to
- **classify errors**
- **state instrumental error**
- **state how to eliminate or minimize errors.**

**Errors**

The sources which cause error in the measurements are classified as

1 Instrumental

2 Natural

3 Personal

**1 Instrumental errors:** Instrumental errors are caused due to fundamental axis going out of the adjustments. It is caused due to

i Wear and tear of components due to prolonged use of the instrument.

ii Manufacturing defects.

**a Plate level axis not being perpendicular to vertical axis:** If this fundamental relation is out of order, the actual measurement we are observing is in the vertical plane instead of horizontal plane. It will affect seriously in vertical angle measurements and calculation of elevation.

**Elimination:** Correcting by permanent adjustment.

**b Trunnion axis not being perpendicular to vertical axis:** Horizontal angles and vertical angles will be erroneous if this relation is out of order.

**Elimination:** Taking the average of observations on face left and face right.

**c Line of collimation not being perpendicular to trunnion axis:** Line of collimation will not revolve in a vertical plane when the telescope is raised or lowered if line of collimation is not being perpendicular to the trunnion axis.

**Elimination:** Taking the average of observations on face left and face right.

**d Eccentricity of inner and outer plate axis :** Vertical axis of the inner spindle (carries vernier) and outer spindle (carries horizontal circle) should coincide, otherwise errors will occur.

**Elimination:** Reading both verniers and taking mean of both the vernier readings.

**e Eccentricity of vernier :** If verniers are not exactly diametrically opposite, i.e. 180° to each other, the two vernier readings will not differ by 180°. However, since the difference is constant, both the vernier readings will give same angle. Hence, this manufacturing defect has no effect on the observations.

**f Imperfect vertical circle vernier:** When the line of sight is not horizontal, vertical circle vernier will not show zero reading and will make the vertical angle error.

**Elimination:** Readings are taken on both faces.

**g Imperfect graduations:** If graduations on the horizontal circle are not uniformly spaced or if the scale is not properly centred, the horizontal angle readings will not be correct. Error is greatest when observations are taken on different vertical angles and different lengths.

Minimizing error: Taking observations at different portions of the horizontal scale and taking mean of the observations and measuring angles by repetition method.

**2 Natural errors:** These errors are caused due to natural elements such as wind, temperature and atmospheric conditions.

**a Temperature effect:** Exposure of instrument to the sun may cause expansion of different parts of the instrument. Unequal expansion of the instrument parts will result in erroneous observations. Bubble will move to the heated portion of the theodolite.

**Minimizing error**

i Exposure of instrument is avoided by using surveyor's umbrella.

ii Shelter the instrument from the rays of the sun.

**b Wind effect:** Exposurre of the instrument to the heavy wind will cause vibrations of different parts of the theodolite causing error in observations.

**Avoiding error**

i Suspend the work when the wind is strong

ii Shelter the instrument from the wind

**c Refraction effect:** Refraction causes difficulty in sighting the object.

**Avoiding error**

Avoid line of sight passing close to structures such as buildings, smoke stacks, bitumen surfaces and surfaces which radiate heat.

**d Unequal settlement of tripod:** If the ground is soft, tripod will settle and errors will creep on the observations.

**Avoiding error**

i Fix tripod on firm ground

ii Press the tripod legs sufficiently into the ground

iii Use triangular frame

iv Driving stakes on soft ground to receive tripod legs

**3 Personal errors:** Personal errors arise from limitations of human eye in setting up the instrument and taking observations. Sometimes surveyor overlooks some of his limitations resulting in personal errors.

**a Error due to inaccurate centering:** If the instrument is not set up exactly over the station, it will produce error when measuring horizontal angles. The magnitude of the error is directly proportional to the direction of instrument and inversely proportional to the length of the sight. Angular error is about 1' when the error of centring is 1 cm for a length of sight 35m.

Error may be kept in negligible limit by taking reasonable care. Time should not be wasted in setting up of the instrument when the sights are long.

**b Error due to inaccurate levelling:** This error is small when the sights are nearly level, but may be large for steep inclined sights. Error may be eliminated or minimized by frequent checking of the position of the bubble centre and if necessary it should be recentered.

**c Slip in screws:** Slip may occur if the clamp screws are not properly tightened or shifting head is not properly tightened or when the instrument is not properly fixed to the tripod head. Slip causes error.

The error due to slip is avoided by tightening all the screws.

**d Improper use of screws and tangents:** This error is introduced by improper use of the screws and tangents. For sighting right hand object, use upper clamp screw and its tangent.

For sighting an object after setting pre-determined angle, use lower screw and is tangent. For measuring horizontal angle, use upper screw and its tangent.

Final bisection of the object should be achieved using slow motion screw.

| |
|---|
| **No slow motion screws work until corresponding clamp screws have been tightened.** |

**e Improper setting and reading of the verniers:** An error in reading vernier occurs.

- if the observer does not use a magnifying glass.
- if the observer does not look radially along the graduations when reading the verniers.
- if the observer does not know how to read the vernier.
- if legibility of the vernier divisions and lines is less.

Proper care should be taken to minimize these types of errors.

**f. Inaccurate sighting:** Great care should be taken to bisect accurately, if the station to be observed is closer. Usually sights are taken on the upper portion which is visible from the instrument.

Error can be minimized by bisecting the lower portion of the object and accurately centering the vertical cross hair.

**g Level bubble not centered:** The position of the bubble centre should be checked frequently and if necessary should be centered once again.

**h Parallax:** Parallax exists due to imperfect focusing of the eyepiece and objective glass. Take reasonable care while focusing to minimize the error due to parallax.

**Mistakes**

The common mistakes or blunders which the surveyors generally make due to carelessness are:

1 Misreading the vernier.

2. Reading the wrong vernier.

3 Sighting the wrong signal.

4 Turning the wrong tangent screws.

5 Setting up the instrument over the wrong station.

6 Booking wrong values of the readings.

7 Missing to mention right or left deflection angle.

8 Forgetting to deduct the observation from 360° in left deflection angle. Utmost care should be taken in the field to avoid the above mistakes.

# Laying off a horizontal angle

**Objectives:** At the end of this lesson you shall be able to
- **explain laying off a horizontal angle by ordinary method**
- **explain laying off a horizontal angle by repetition method**
- **find equivalent liner distance for an angular value.**

**Laying off a horizontal angle**

**Ordinary method**

Sometimes surveyor has to lay off per- determined horizontal angles on the field. Laying off a horizontal angle is explained below.

To lay off an angle POQ equal to say 60°35’40”, as shown in the figure. 1

Set up the instrument at O and set the vernier A to read 00” 00’00”. Tighten upper clamp and loosen lower clamp. Turn the telescope and sight the station P. Clamp the lower plate and unlock the upper plate. Turn the upper plate until the vernier A reads the given angle 60° 35’40”. Upper tangent screw is used to set the given angle accurately. Fix the station Q along the line of sight of the required angle.

Fig 1

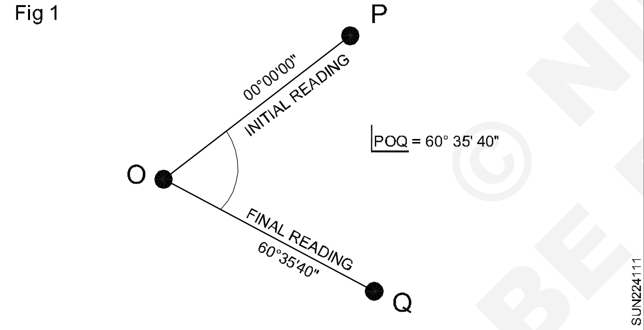



Fig 1 Laying off horizontal angle by ordinary method.

Repetition method

This method is used where angles to be laid off need more accuracy. The method of laying off the by repetition method is explained below. First, set out stations P, O and $Q_1$ as per the given angle using the ordinary method. Q is designated as $Q_1$ because Q located may not be the exact position. Then, measure the angle POQ by six repetitions (three face left observations and three face right observations) and get the average value. Let the average value of the angle is 60°35’45”. Difference between the set out angle value and the required angle value is, 60°35’45. Difference between the set out angle value and the required angle value is, 60°35’40” = 05”.

Since the value is very small, it cannot be set out by means of an angular measurement. But this angular measurement is converted to linear distance, if the length of the side of the angle is known. Say it is 100 m.

The arc equivalent to angular value 05” for a line of length 100m is given by the formula,

= radius x angular value in radian measure.

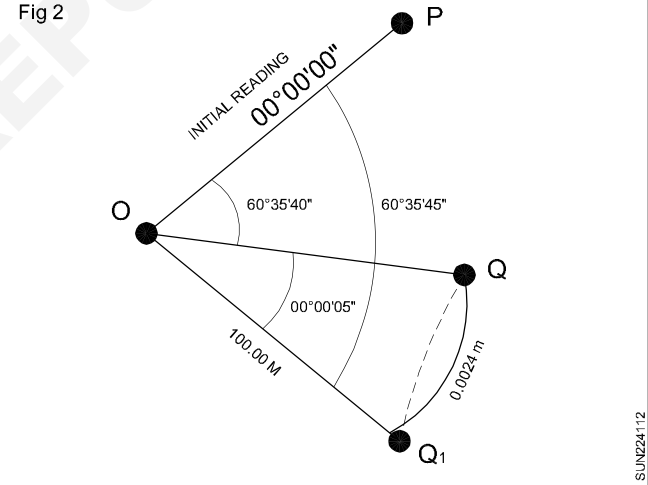
**So the arc or linear distance = (since arc is approximately equal to linear distance)**

**= 100 x [ (05 / 3600) x ( π/ 180)]**

**= 0.0024 m**

Set 0.0024 m either inwards or outwards at right angle to the line $QQ_1$ at $Q_1$. In the above case, set out value is greater than required value, so 0.0024 m has to shift inwards.

Fig 2




**Difference between arc and linear distance is negligible**.

Fig.2. Laying off horizontal angle by repetition method.

# Theodolite - measuring vertical angle

**Objectives:** At the end of this lesson you shall be able to
- **define vertical angle**
- **differentiate angle of elevation and angle of depression**
- **explain how to measure vertical angle.**

### Measurement of vertical angle (Fig 1 and 2)

A vertical angel is defined as the angle between the line of sight and a horizontal line at a station in a vertical plane.

If the angle measured is above the horizontal line, then it is called angle of depression. Angle of depression is a positive angle (+).

If the angle measured is below the horizontal line, then it is called angle of depression. Angle of depression is a negative angle (-).

The method of measuring vertical angle varies according to the type of the instrument used. Engineer's transit measures vertical angle with respect to horizontal line. Electronic theodolites can measure vertical angles with respect to horizontal line or with respect to zenith.

Set up the instrument at the station. Perform all the temporary adjustments. The altitude bubble is set to its centre of run for all positions of the telescope. To do this follow the given steps.

1 Turn the instrument so that the altitude bubble is parallel to the line joining any two parallel screws.

2 Bring the bubble to its centre of its run by turning both the levelling screws either inwards or outwards.

3 Turn the telescope through 90° so that the altitude bubble is perpendicular to the line joining the above two levelling screws i.e. bubble tube over the third foot screw.

4 Bring the bubble of the altitude level again to the centre of its run by turning the third screw.

5 Turn back the telescope through 90° so that the altitude level is parallel to the two foot screws.

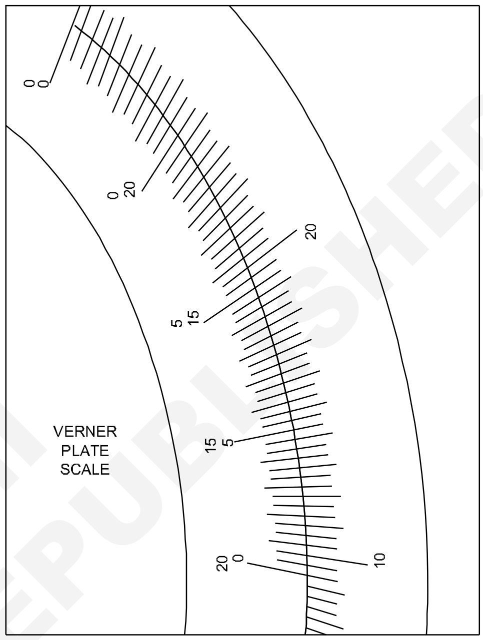
6 Repeat above steps until the altitude bubble remains central in both the positions.

7 Swing the telescope through 180° so that the altitude level is paralledl to the two levelling screws so that the eyepiece and the objective ends are reversed.

8 Bubble will remain central if the instrument is in permanent adjustments.

The object to which the vertical angle is required to bisect using the vertical clamping screw and its tangent screw. The reading on the vertical circle is now read. Change face of the instrument and take another reading. Mean of the readings is the vertical angle.

Fig 1




MEASURING VERTICAL ANGLE

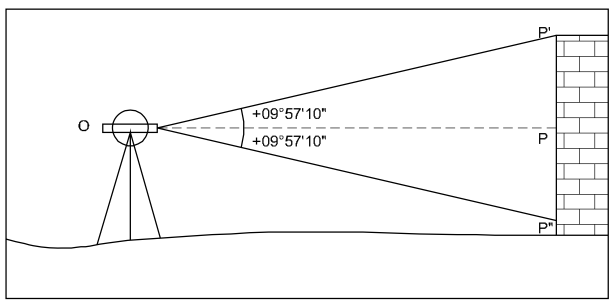
### Points to remember

1 Carefully read vernier 'C' and vernier 'D'

2 Signs of angles should be noted down very carefully.

3 To eliminate or minimize errors due to improper adjustments of the instrument, both face readings should be taken.

Fig 2




MEASUREMENT OF VERTICAL ANGLE

# Theodolite - deflection angle and direct angle

**Objectives:** At the end of this lesson you shall be able to
- **state deflection angle**
- **differentiate right deflection angle and left deflection angle**
- **state direct angle**
- **differentiate deflection angles and direct angles.**

Theodolite is used for various kinds of operations in the field measuring deflection angle, direct angle, prolonging a line and running a straight line are some of them. Operations using theodolite are explained in forthcoming chapters.

Horizontal angle can be measured by any of the 3 methods explained earlier, depending upon the conditions.

**Deflection angle**

Angle between the preceding line and the succeeding line is called deflection angle. The deflection angles vary between 0° to 180°. This angle is very useful in open traversing, such as alignment of highways, railways, canals etc.

**Right deflection and left deflection angle**

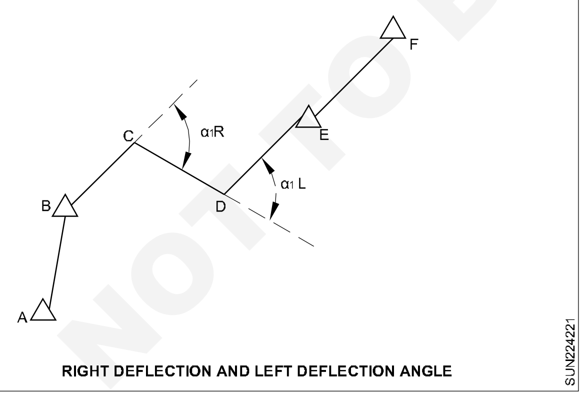
The angle measured in clockwise direction is called right deflection angle and right (Fig.1).

The angle measured in anticlockwise direction is called left deflection angle and left (Fig.1)

The measurement of deflection angles is done by taking a backsight on the previous station with zero reading on one of the verniers. Then the telescope is transited and turned clockwise or anticlockwise as the case may be.

Accuracy of the values can be improved by taking repeated readings. The angular closure is checked by calculating azimuths from known lines (AB and EF in the figure 1).

Fig 1




RIGHT DEFLECTION AND LEFT DEFLECTION ANGLE

**Points to remember**

1 Right deflection angle is the value of the angle measured itself.

2 The angle observed on scale deducted from 360° is the value of the left deflection angle.

3 The numerical value of the deflection angle must always be followed by 'R' or 'L'. 'R' for right deflection angle and 'L' is for left deflection angle.

4 Measure bearing of a traverse line if there are no known coordinates for the traverse.

**Direct angles**

Angles measured clockwise from a backsight to the previous line are called angles to the right or direct angles. The direct angles vary 0° to 360°. The angle is very useful both in open traverse and closed traverse.

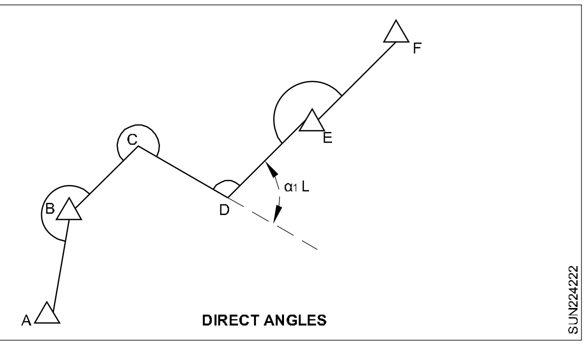
Accuracy of the values can be improved by taking repeated readings. The angular closure is checked by calculating azimuths from known lines (AB and EF) in the following figure 2).

**Points to remember**

1 Rotation should always be clockwise from the back sight.

2 Measure bearing of a traverse line if there are no known coordinates for the traverse.

Fig 2




DIRECT ANGLES

**Table for entering reading to measuring vertical angle**

| Instrument at | Sight to | Face Left C | | | D | | Mean | | | Right Swing Number of Repetitions | Vertical Angle | | | Face Left C | | | D | | Mean | | | Right Swing Number of Repetitions | Vertical Angle | | | Average Vertical Angle | Rough Sketch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | – | – | – | – | 0 | – | – | | 0 | – | – | 0 | – | – | – | – | 0 | – | – | | 0 | – | – | | |

| Instrument at | Sight to | Face Left C | | | D | | Mean | | | Right Swing No. of Repetitions | Vertical Angle | | | Face Left C | | | D | | Mean | | | Right Swing No. of Repetitions | Vertical Angle | | | Aveerage Vertical Angle | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | ‘ | “ | ‘ | “ | 0 | ‘ | “ | | 0 | ‘ | “ | 0 | ‘ | “ | ‘ | “ | 0 | ‘ | “ | | 0 | ‘ | “ | 0 | ‘ | “ |
| o | P | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | | 00 | 00 | 00 | 00 | 00 | 00 |
| o | P’ | +09 | 57 | 20 | 57 | 00 | +09 | 57 | 10 | 1 | +09 | 57 | 10 | +09 | 57 | 00 | 56 | 40 | +09 | 56 | 50 | 1 | +09 | 56 | 50 | +09 | 57 | 00 |
| o | P” | +09 | 57 | 20 | 57 | 00 | +09 | 57 | 10 | | -09 | 57 | 10 | -09 | 57 | 00 | 56 | 40 | -09 | 56 | 50 | | -09 | 56 | 50 | -09 | 57 | 00 |

Eg. Angle of elevation ∠POP’ = + 09° 57’ 10” R.T. 2.2.42 Fig.2

Angle of elevation ∠POP’ = + 09° 57’ 10”

Include vertical angle ∠P’ OP” = ∠POP’ + ∟POP” = 19° 54’ 20”

# Theodolite - prolonging a line

**Objectives:** At the end of this lesson you shall be able to
- **state methods for prolonging a line**
- **compare methods for prolonging a line**
- **state most suitable method for prolonging a line.**

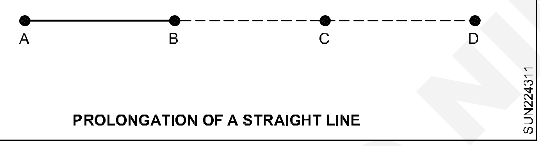
**Prolongation of a straight line**

Sometimes a survey line has to extend or prolong to considerable distance. There are three methods for prolonging a line. The methods are explained below.

**1 Method I:** Set up the instrument over the end 'A', and sight the end 'B' of line 'AB'. Arrest the horizontal motion of the instrument and locate another point 'C' at a considerable distance from 'B' on the prolongation of line. Shift the theodolite to 'B'. Following above steps locate another point 'D'. The process is repeated until the line is prolonged to the desired distance. (Fig 1)

This method will result in cumulative errors if the insturment is not in adjustment.

Fig 1

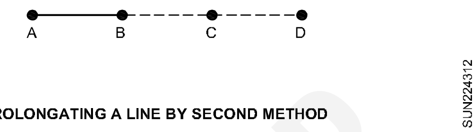



PROLONGATION OF A STRAIGHT LINE

**2 Method II:** First fix a line 'AB'. Set up the instrument over the end 'B', instead of 'A' as in the above method. Shift the instrument to 'C' and backsight 'B'. Transit the telescope and locate 'D'. The process is repeated until the line is prolonged to the desired distance. (Fig 2)

This process is more accurate than the first method because the error is not carried over to other spans.

Fig 2

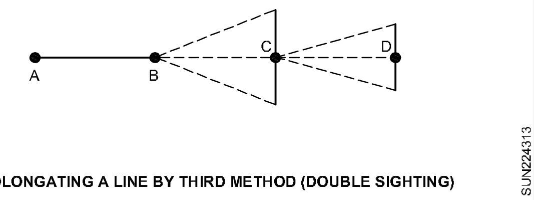



PROLONGATING A LINE BY SECOND METHOD

**3 Method III (Double sighting):** This method is also called double sighting. First, fix a line 'AB'. Set up the instrument over the end 'B'. Backsight 'A' with face left. Plunge the telescope and locate $C_1$. Change face of the instrument. Backsight 'A' again, plunge the telescope and locate $C_2$. We get two points $C_1$ and $C_2$ as the instrument is out of adjustments. The mean of the locations C1 and $C_2$ is the desired point C. The process is repeated until the line is prolonged to the desired distance. (Fig 3)

This method is used when the instrument is suspected with improper adjustments. The error is doubled on reversal of the telescope and the mean of the two locations becomes the desired location of point.

Fig 3




PROLONGATING A LINE BY THIRD METHOD (DOUBLE SIGHTING)

# Trigonometric levelling (Indirect levelling)

**Objectives:** At the end of this lesson you shall be able to
- **state advantages of indirect levelling**
- **determine height of in accessible objects**
- **explain various cases of trigonometric levelling**
- **deduce the reduced level the appropriate formula.**

This is an indirect method of levelling in which the difference in elevation of the points is determined from the observed vertical angles and the measured distances.

The vertical angles are generally measured by theodolite and the horizontal distances are either measured or computed.

Trigonometric levelling is commonly used in topographical works because of it is very advantages in mountainous terrain.

Depending upon the field conditions, different cases may arrive. Some of the cases are discussed below.

Case1. Base of the object accessible

Case 2. Base of the object inaccessible, instrument stations in the same vertical plane as the elevated object.

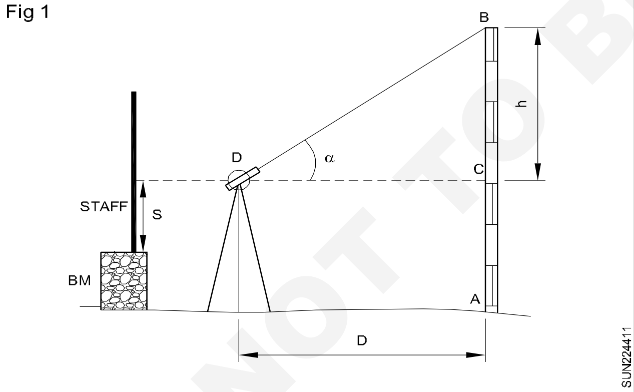
Case3. Base of the object inaccessible, instrument stations not in the same vertical plane as the elevated object.

**Case 1 (a) (Fig 1)**

**Base of the object accessible - the object vertical**

Let AB is the vertical object,

Fig 1




D is the horizontal distance between the object and the instrument,

S is the staff reading on the levelling staff held vertical on the B.M,

h is the height of the object above vertical axis.

$\alpha$ is the angle of elevation to the top of the object.

From triangle BCD,

BC = CD x tan $\alpha$

h = D x tan $\alpha$

R.L. of B = R.L. of B.M. + S + h

= R.L. of B.M. + S+D tan $\alpha$

**Exercise**

In instrument was set up at point O. With horizontal sight when staff held at a bench mark of 100.000 m, reading was 0.745 m. The horizontal distance between a point, A from O is 19.950 m and A was observed at an angle of elevation 19°44′45″. Determine the RL of A.

**Solution (Fig 2)**

$\alpha$ = 19°44′45″

D = 19.950 m

S = 0.745 m

h = D x tan $\alpha$

= 19.950 x tan 19°44′45″

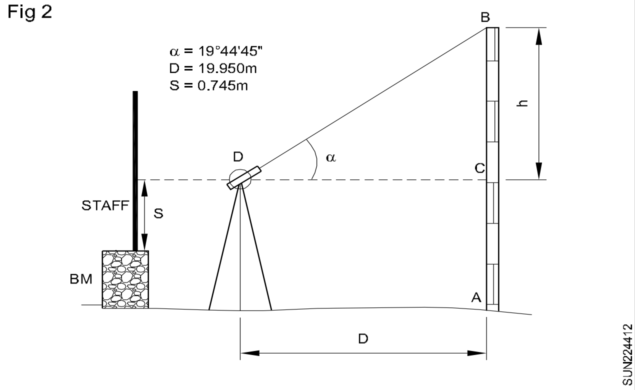
= 7.160 m

R.L. of A = R.L. of B.M. + S + h

= 100.00 + 0.745 + 7.160

= 107.905 m

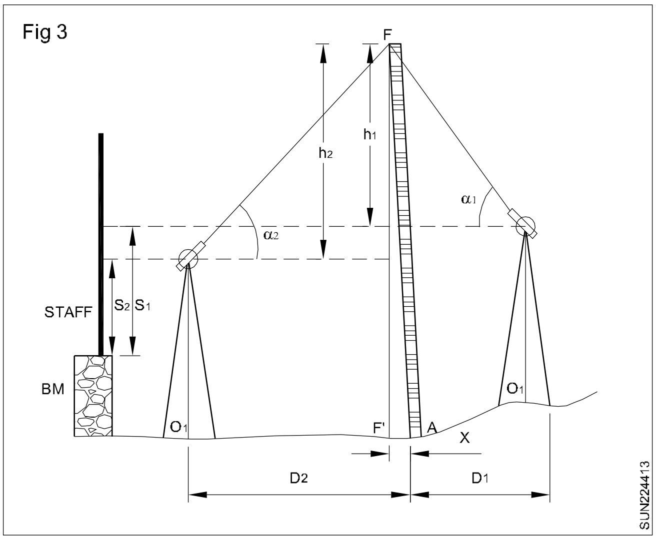
Fig 2




**Case 1 (b) (Fig 3)**

**Base of the object accessible - the object inclined**

In figure AF is the inclined object, x is the distance between the foot of the object and the projection F′of the top. $O_1$ and $O_2$ and A are in the same vertical plane, $D_1$ and $D_2$ are the distances of the foot of the object from the instrument stations $O_1$ and $O_2$, respectively. S1 and S2 are the staff reading on B.M. from instrument positions at $O_1$ and $O_2$, respectively and $\alpha_1$ and $\alpha_2$ are the angles of elevation from $O_1$ and $O_2$ respectively.




R.L. of F as per set up of instrument at $O_1$ = R.L. of B.M + $S_1$ + $h_1$

= R.L of B.M. + $S_1$ + ($D_1$ + x) tan $\alpha_1$ → Eq (1)

R.L of F as per set up of instrument at $O_2$ = R.L of B.M + $S_2$ + $h_2$

= R.L. of B.M. + $S_2$ + ($D_2$ - x) tan $\alpha_2$ → Eq (2)

From Eq (1) and Eq (2)

$$x = \frac{(S_1 - S_2) + D_1 \tan\alpha_1 - D_2 \tan\alpha_2}{\tan\alpha_1 + \tan\alpha_2}$$

R.L. of F can be calculated after computing the value of x.

R.L. of F = R.L. of B.M. + $S_1$ + ($D_1$ + x) tan $\alpha_1$

R.L. of F = R.L. of B.M. + $S_2$ + ($D_2$ - x) tan $\alpha_2$

**Case 2**

**Base of the object inaccessible - instrument stations and the elevated object in the same vertical plane (single plane method) (Fig 4)**

If the horizontal distance between the instrument and the elevated object is inaccessible, the observations are made from two instrument stations. Assuming the two instrument stations and the object to be in the same vertical plane there may be two cases.

Height of instrument are same,

Heights of instrument are at different levels.

**Heights of instrument are same,**

h is the vertical distance PQ′

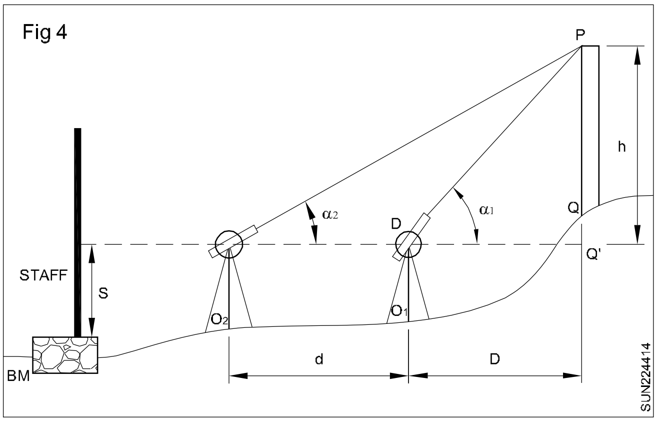
S is the staff reading on the B.M,

$\alpha_1$ and $\alpha_1$ are the angles of elevation measured at instrument station $O_1$, and the object

d is the horizontal distance between the two stations.

**Fig 4. Single plane, 'H' Bottom & 'S' Top are at same level**

From triangle $O_1Q'P$, h = D tan $\alpha_1$ → Eq (1)




From triangle $O_2Q'P$, h = (D + d) tan $\alpha_2$ → Eq (2)

Equating both equations

$$D = \frac{d \tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$$

$$h = \frac{d \tan\alpha_1 \tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$$

R.L. of P = R.L. of B.M. + S + h

**Heights of instrument are at different levels.**

There are three cases

Instrument axis at $O_1$ higher than that at $O_2$

Instrument axis at $O_2$ higher than that at $O_1$

Instrument axis at different levels

Instrument axis at $O_1$ higher than that at $O_2$

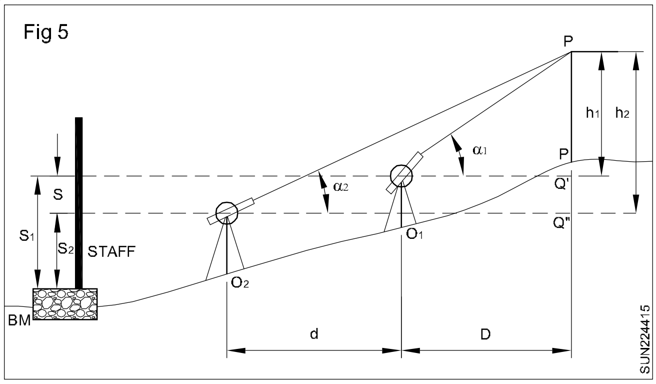



**Fig 5. Single plane: $O_1$ higher than $O_2$**

$h_1$ - $h_2$ = Q′Q″ = $S_1$ - $S_2$ = S

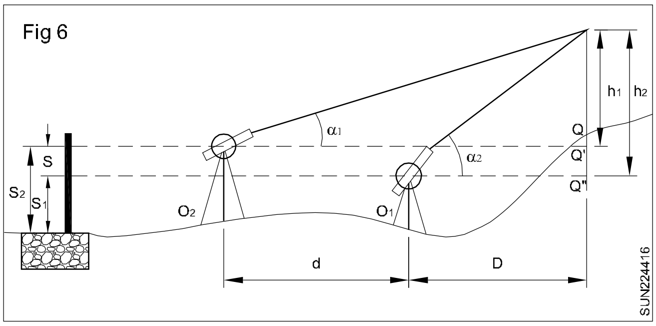
From triangle $O_1Q''P$, $h_1$ = D tan $\alpha_1$ → Eq (1)

From triangle $O_2Q''P$, $h_2$ = (D + d) tan $\alpha_2$ → Eq (2)

From equations 1 and 2

$$D = \frac{(d \tan\alpha_2 - S)}{(\tan\alpha_1 - \tan\alpha_2)}$$

Therefore $h = \dfrac{d \tan\alpha_1 \tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$




R.L. of P = R.L. of B.M. + $S_1$ + $h_1$ or

R.L. of P = R.L. of B.M. + $S_2$ + $h_2$

Instrument axis at $O_2$ higher than that at $O_1$

**Fig 6. Single plane method. $O_2$ higher than $O_1$**

$h_1 - h_2 = Q'Q'' = S_2 - S_1 = S$

From triangle $Q_1Q''P$, $h_1 = D \tan \alpha_1 \rightarrow$ Eq (1)

From triangle $Q_2Q''P$, $h_2 = (D + d) \tan \alpha_2 \rightarrow$ Eq (2)

From equations 1 and 2

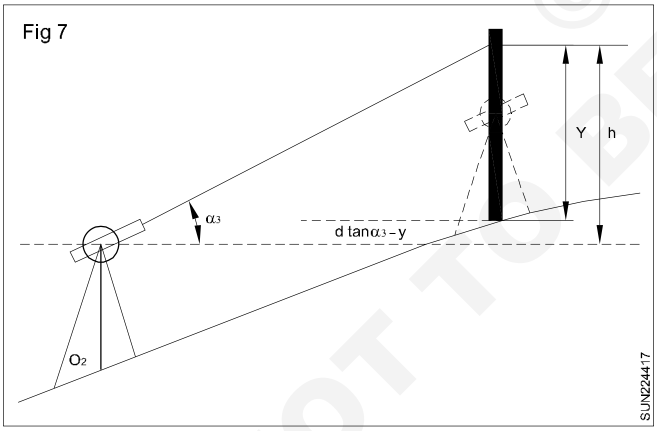
$$D = \frac{S + d\ \tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$$

$$h_1 = \frac{(S + d\tan\alpha_2)\tan\alpha_1}{(\tan\alpha_1 - \tan\alpha_2)}$$

R.L. of P = R.L. of B.M. + $S_1$ + $h_1$ or

R.L. of P = R.L. of B.M. + $S_2$ + $h_2$

**Instrument axes at different levels**




If the difference in elevation ($S_2$ - $S_1$) between the two instrument stations is too large and cannot be measured on a staff at the B.M. then the following procedure is adopted.

**Fig 7 Single plane method: Level difference between two stations is greater**

Set up the instrument at $O_1$ and measure the vertical angle at the point P.

Transit the telescope and establish a point $O_2$.

Shift the instrument to $O_2$ and measure the vertical angle at the point P.

Observe the staff reading Y on the staff at $O_1$.

Let S be the difference in level between the two axes at $O_1$ and $O_2$.

Therefore $S = h_2 - h_1$

$$D = \frac{(d\tan\alpha_2 - S)}{(\tan\alpha_1 - \tan\alpha_2)}$$

$$h_1 = \frac{(d\tan\alpha_2 - S)}{(\tan\alpha_1 - \tan\alpha_2)}$$

Height of station $O_1$ at above the axis at $O_2$ = h - v

= d tan $\alpha_3$ - y

S = d tan $\alpha_3$ - r + h′

Hence R.L. of P = R.L. of B.M. + $S_1$ +S+$h_1$

= R.L. of B.M. + $S_1$ + d tan $\alpha_3$ - y + h′+ $h_1$

**Exercise**

The following observations were made on a chimney top to ascertain its elevation:

| Instrument station | Staff reading on BM | Angle of elevation |
|---|---|---|
| $O_1$ | 1.035 | 20°00'00" |
| $O_2$ | 0.915 | 13°00'00" |

Reduced level of BM was 100.000 m. The instrument stations were 20.00 m apart and were in line with the chimney top, A. Find the RL of the A.

**Solution**

$S_1$ = 1.035 m, $\alpha_1 = 20°00'00''$

$S_2$ = 0.915 m, $\alpha_2 = 13°00'00''$

RL of BM = 100.000 m

d = 20.00 m

S = 1.035 -0.915 = 0.120 m

From staff reading we know that observations taken from near to the point A is lower than the other observation.

i.e. $O_1$ is higher than $O_2$ (single plane method, instrument axes at different levels). (Fig 8)

So D = (d tan$\alpha_2$- S)/ (tan $\alpha_1$- tan $\alpha_2$)

= (20 x tan 13°00′00″– 0.120)/(tan 20°00′00″ – tan 13°00′00″)

= (4.61 - 0.120)/(0.3639 - 0.2308)

= 33.78m

Therefore $h_1$= D tan $\alpha_1$

= 33.78 x tan 20°00′00″ = 12.297 m

RL of A = RL of BM + $S_1$ ÷ $h_1$

= 100.000 + 1.035 + 12.297 = 113.332 m

or, RL of A = RL of BM + $S_2$ + $h_2$

$h_2 = (D+d) \times \tan \alpha_2 = (33.78+20) \times \tan 13°00'00$

Therefore RL of A = 100.000 + 0.915 + ((33.78 + 20) x tan 13°00′00

Let P and R be the two instrument stations in the same vertical plane as that of Q

1 Set the instrument at P and level at accurately with respect to the attitude bubble. Measure the angle of elevation $\alpha_1$ to Q

2 Sight the point R with reading on horizontal circle as zero and measure the angle $RPQ_1$ i.e, the horizontal angle $O_1$ at P.

3 Take a back sight ‘S’ on the staff kept at B.M.

4 Shift the instrument to and measure $\alpha_2$ and $\theta_1$ there.

In fig AQ as the horizontal line through A, Q’ being the vertical projection of Q

From triangle AQQ’, QQ’=h1 = D tan$\alpha_1$

From triangle $PRQ_1$, $PQ_1R = 180° - (\theta_1+\theta_2)$

by sine rule,

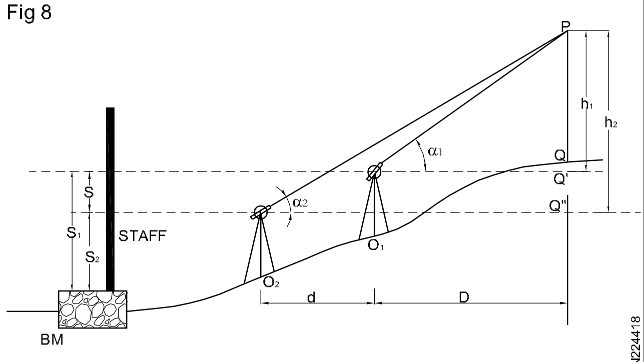
$$\frac{PQ1}{\sin\theta_2} = \frac{RQ1}{\sin\theta_1} = \frac{RP}{\sin[180-(\theta_1+\theta_2)]} = \frac{b}{\sin(\theta_1+\theta_2)}$$

$$PQ_1 = D = \frac{b \sin\theta_2}{\sin(\theta_1+\theta_2)}$$

$$RQ_1 = \frac{b \sin}{\sin(\theta_1+\theta_2)}$$

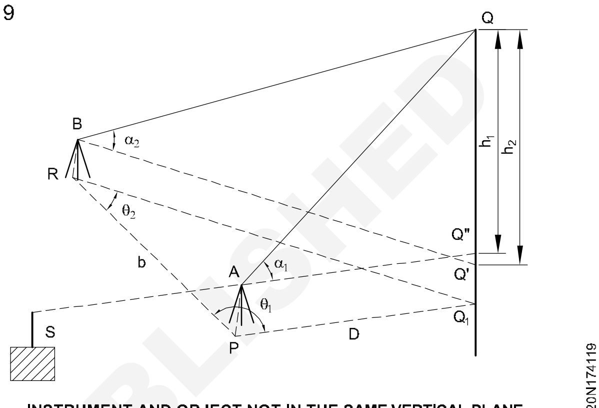
$$h1 = D \tan = \frac{b \sin\theta_2 \times \tan\alpha_1}{b \sin\theta_1+\theta_2}$$

Fig 8




SINGLE PLANE METHOD

Fig 9




INSTRUMENT AND OBJECT NOT IN THE SAME VERTICAL PLANE

# Traverse survey (Closed and open)

**Objectives:** At the end of this lesson you shall be able to
- **state uses of traverse surveying**
- **state types of traverse**
- **differentiate open and closed traverse.**

### Traverse

Thorough knowledge of traverse surveying is required for surveying using theodolite. In subsequent lessons, traverse and theodolite traverse will be explained.

A traverse is a series of connected lines whose lengths and directions are known.

The lengths of the lines are determined either

- by direct measurement, or
- by EDM equipment, or
- by indirect measurement (tachometry).

The angles are measured with

- Theodolite, or
- Magnetic compass

When the extent of survey is not large and desired accuracy is not high, angles are not measured but directions of lines are fixed by chain angles.

### Use of traverse surveying

- To establish the positions of boundary lines.
- To determine the positions of existing boundary lines.
- To calculate area within a boundary.
- To establish ground controls for photogrammetric work.
- To establish ground controls for calculating earth work quantities.
- To establish control for locating highways, railways and other construction works.
- To establish control for mapping.

### Types of traverse

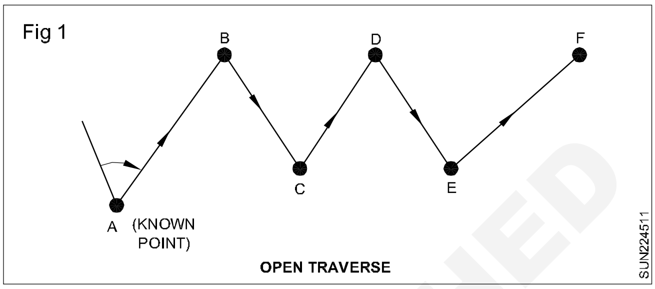
Two general classes of traverse are:

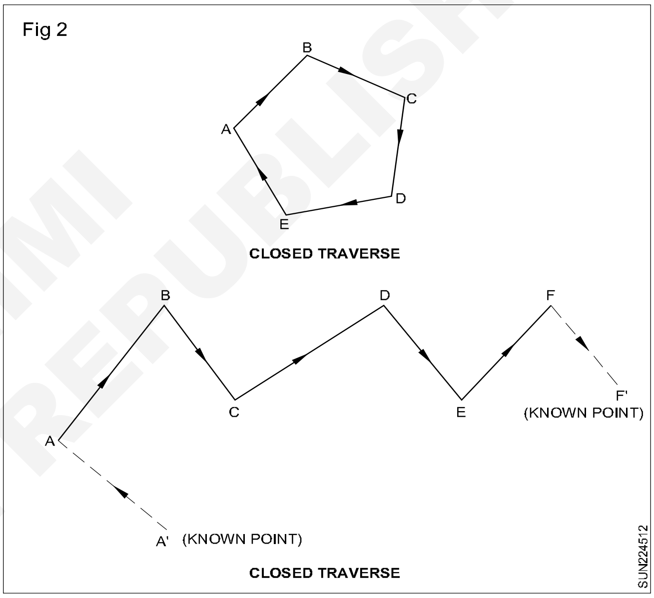
- Open traverse.
- Closed traverse

### Open traverse

Open traverse (Fig 1) is that type of traverse in which origin point starts at known location and terminate point ends at unknown location.

There is no opportunity for checking the accuracy of the ongoing work in open traverse. So all survey measurements are carefully repeated at the time of the work. The major disadvantages of open traverse are,




1 There is no check on summation of angles.

2 There is no check on positions of intermediate points.

Steps to minimize errors in open traverse are,

1 Each distance should be measured twice in both directions and also should be roughly checked by tachometry method.

2 Angles should be measured by method of repetition and also should be checked by magnetic bearings.

An open traverse is usually run for establishing control in preliminary surveys and construction surveys such as roads, pipelines, etc., because the results are always open to doubt.

Distances are measured usually by tape or EDM equipment and usually deflection angles are measured at the traverse stations.

Fig 1 Open Traverse

**Closed traverse.**

Closed traverse (Figure 2 (a) and (b)) is that type of traverse in which origin point and terminate point are known locations. In such traverse, sum of all internal angles should be equal to (2n-4) times right angles, where n is the number of sides.

This mathematical condition provides computational checks which gives indication of the accuracy of measurements,

Closed traverse provides check for both linear and angular measurements and therefore preferred to all other types of traverse.

Figure 2 (a) shows a closed traverse ABCDEA. The traverse originates and terminates at the same point. From the figure it is clear that this traverse is mathematically and geometrically closed. It is called closed-loop traverse.

Figure 2 (b) shows a closed traverse ABCDEF. The traverse originates and terminates at different points. From the figure it is clear that this traverse is mathematically closed and geometrically open.

## Classification of traverse

**Objectives:** At the end of this lesson you shall be able to
- **classify traverse based on the instruments used**
- **explain method of traversing**
- **explain how to measure traverse length in theodolite traversing**
- **explain how to measure traverse angle in theodolite traversing.**

**Classification of traverse based upon the instruments used.**

Classification of traverse based upon the instruments employed are:

- Chain traversing
- Compass traversing
- Plane table traversing
- Theodolite traversing

**Methods of traversing**

A traverse can be run by several methods depending upon the instrument. The classification of traverse based upon the instruments employed and the methods of running the traverses are explained below.

**Chain traversing**

In this method, the entire work is done with a chain or tape and no angle measuring instrument is employed. The directions of lines are fixed by linear measurements only. Directions of lines are fixed by taking chain angles.

Chain angles are generally liable to errors as the accuracy of measurement of the angles, is proportional to the accuracy achieved in measuring the tie distances.

**Compass traversing**

When a compass is used to fix directions, the traverse is called compass traversing. Method is already explained in compass surveying module.

**Plane table traversing**

Traversing using plane table is called plane table traversing. Method is already explained in plane table surveying module.

**Theodolite traversing**

In the method of traverse, theodolite is commonly used for providing horizontal control systems.

**Measurement of theodolite traverse lengths**

Depending on accuracy required, the length can be measured by:

- chaining,
- taping,
- tachometry or,
- EDM equipment.

For greater accuracy, lengths are measured in both directions and average value is taken.

**Measurement of theodolite traverse angels**

Traverse angles can be:

- interior angles,
- deflection angles,
- direct angles,
- azimuth angles or
- magnetic bearings.



## Theodolite traversing methods - I

**Objectives:** At the end of this lesson you shall be able to
- **state methods of theodolite traversing**
- **explain loose needle method**
- **explain fast needle methods**
- **compare loose needle and fast needle methods.**

**Theodolite traversing**

Any one of the following methods may be used for fixing direction in theodolite traversing:

- Loosing needle method.
- Fast needle method.
- Included angle method.
- Direct angle method.
- Deflection angle method.
- Azimuth method.

**Loose needle method**

In this method, a theodolite fitted with a magnetic compass is used to determine the bearings of the lines. From bearings included angles are determined and checked for theoretical sum of interior angles. If any error is found, correction is distributed equally among the angles and corrected bearings are computed.

Loose needle method is rarely used as it is prone to local attraction.

### Fast needle method

In this method, the magnetic bearing of only the first line is measured. The magnetic bearings of all other lines are determined indirectly. This method is more accurate than the loose needle method and is generally preferred because only single magnetic bearing is measured.

There are three methods of traversing by fast needle method:

- Direct method with transiting
- Direct method without transiting
- Back bearing method

### Direct method with transiting

In this method, instrument is set up at the starting station A and the rearing is set to zero. By releasing the magnetic needle, the telescope is brought in magnetic meridian using lower plate clamp. Unclamp the upper plate and the telescope is directed towards B and the reading is taken. It is the bearing of the line AB.

Instrument is shifted to B with both the clamp in tightened position. Set up the instrument at B. Unclamp lower clamp, direct the telescope to A. Plunge the telescope. Now, the telescope is in the line of sight of AB. Releasing upper clamp, telescope is directed towards C. Now, reading is the bearing of the line BC.

Shift the instrument to the next station and repeat the above steps at each station and measure the bearing of the line.

### Direct method without transiting

Follow the steps described in the first paragraph of the direct method with transiting. Shift the instrument to B. Now, without plunging the telescope, direct the telescope to sight C and measure the reading. To obtain the magnetic bearing a correction has to be applied to the readings. Add 180°00'00" if the reading measured is less than 180°00'00" and subtract 180°00'00" if the measured reading is more than 180°00'00".

### Back bearing method

Follow the steps described in the first paragraph of the direct method with transiting. Shift the instrument to station B. Sight the station A as in the direct method with transiting. Calculate the back bearing of the AB from the fore bearing measured. Set the vernier to the backbearing of AB. Tighten the upper clamp. Using lower clamp bisect A. Release upper clamp, rotate telescope in clockwise direction and bisect C. Now, the reading is forebearing of BC. The above process is repeated at each station of the traverse to obtain the bearings of the lines.

Direct method with transiting is quite easy method but direct method without transiting gives the best results even when the instrument is not in perfect adjustment. Back bearing method is seldom used.



## Theodolite traversing methods - II

**Objectives:** At the end of this lesson you shall be able to
- **explain included angle method**
- **explain direct angle method**
- **explain deflection angle method**
- **expalin azimuth method.**

### Included angle method

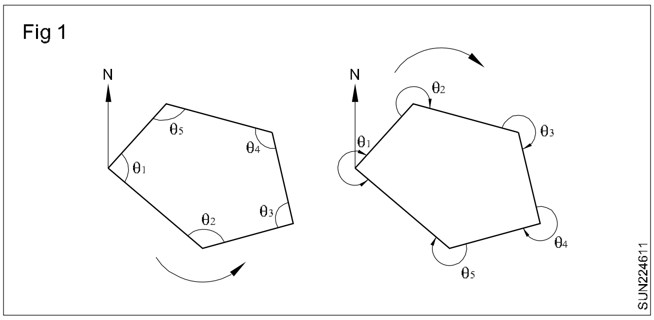
This method is suitable for closed traverse. In this method magnetic bearing of first line only is taken. At first station, say A, instrument is set up and levelled. If instrument is fitted with magnetic compass, take fore bearing of the line AB. If instrument is not fitted with magnetic compass, take a fore bearing using prismatic compass and record it. Set vernier A zero and bisect the last station, say E. Tighten lower clamp and loose upper clamp; turn the telescope in clockwise direction to sight the station B. Bisect it accurately and measure the included angle at A. All interior angles are measured twice, one by face left and another by face right. To measure angle more accurately, measure the angle by repetition method. Measure the length of the closed loop and record it.

Check the measured angles to the theoretical sum of the interior angles. If small error is found, distribute the error equally and if error is large, repeat the work.

Angles measured are interior angles if traverse is run in anticlockwise direction and theoretical sum is equal to (2n-4) x 90°.

Angels measured are exterior angles if traverse is run in clockwise direction and theoretical sum is equal to (2n+4)x90°.

Fig 1. Included angle method.




### Direct angle method

(Refer the lesson deflection angle, direct angle and its measurement.)

This method may be used for open traverse or closed traverse. In this method magnetic bearing of first line only is taken. At first station, say A, instrument is set up and levelled. If instrument is fitted with magnetic compass, take fore bearing of the lien AB. If instrument is not fitted with magnetic compass, take a fore bearing using prismatic compass and record it. Shift instrument to the next station, say B. Set vernier A zero and bisect the previous station, A. Tighten lower clamp and loosen upper clamp, turn the telescope in clockwise direction to sight the station C. Bisect it accurately and measure the direct angle. Accuracy can be improved by taking repeated readings.

Rotation of telescope for measuring direct angle at each station should be clockwise

**Deflection angle method**

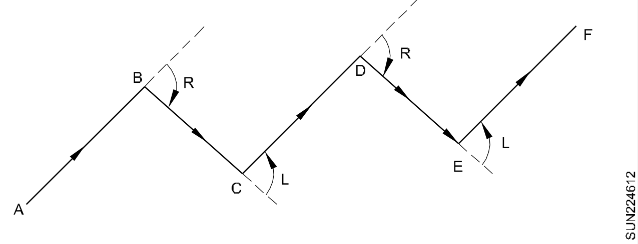
(Refer the lesson deflection angle, direct angle and its measurement.)

This method is suitable for open traverse where only a few details are located as the traverse is run. In this method, magnetic bearing of first line is taken. At first station, say A, instrument is set up and levelled. If instrument is fitted with magnetic compass, take fore bearing of the line AB. If instrument is not fitted with magnetic compass, take a fore bearing using prismatic compass and record it. Shift instrument to the next station, say B. Set vernier A zero and bisect the previous station, A. Tighten lower clamp, transit the telescope and loosening the upper clamp, turn the telescope either left or right to sight the next station C. Record the angle with deflection direction. Similarly measure deflection angles at the traverse stations.

Magnetic bearings are also observed from each traverse station. The angular closure is checked by calculating bearing from known line bearings.

Fig.2 Deflection angle method

Fig 2

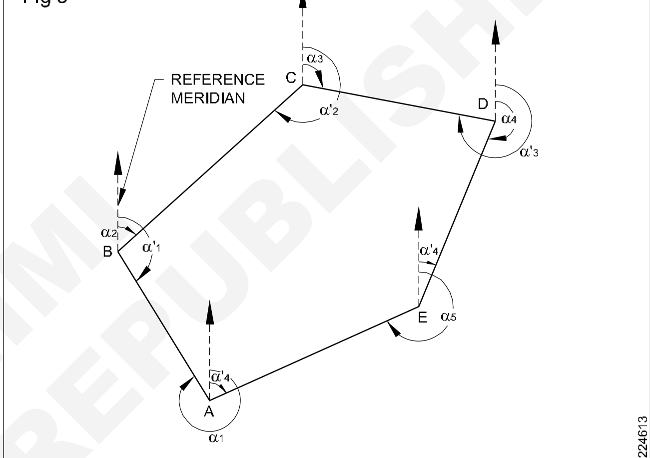



**Azimuth method**

The angle between a line and the meridian measured in clockwise direction, usually from the north of the meridian is called azimuth of the line. Azimuths may be true, magnetic or assumed, depending upon the reference meridian adopted. Azimuth and bearing are similar and azimuth is mostly used in geodetic and astronomical surveying, whereas the term bearing is commonly used in plane table surveying.

In this method, at each traverse station, the back azimuth of the preceding line and the azimuth of the forward line are measured using a transit. This method is used extensively for topographic and other surveys. Method is illustrated in the following figure 3.

Fig 3




AZIMUTH METHOD



## Theodolite traversing phases

**Objective:** At the end of this lesson you shall be able to
- **explain theodolite traversing phases.**

**Traverse phases**

- Reconnaissance
- Selection of traverse stations
- Marking of stations
- Measuring linear and angular measurements.
- Locating details
- Plotting and adjusting closing error

**Reconnaissance**

Preliminary field inspection of the entire area to be surveyed is known as reconnaissance.

**Selection of traverse stations**

As far as possible the survey work should be based upon the basic principle of surveying, number of stations should be minimum, stations should be inter visible, stations should be selected on firm and level ground etc.

**Marking of stations**

After finalizing the locations of the traverse stations, their positions are marked on the ground. The station mark should be permanent in nature as far as possible so that the stations can be used in future if required.

**Measuring linear and angular measurements**

Already discussed.

**Locating details**

As per field conditions, adopting any of the methods of principle of surveying, locate details. The angles and distances should preferably be measured from the traverse stations to avoid the errors in measurement of distances along the traverse lines.

**Plotting and adjusting closing error**

The method of plotting a traverse is already explained in the previous module. Closing error will be dealt in the next lesson.

# Closing error

**Objectives:** At the end of this lesson you shall be able to
- **define closing error**
- **find magnitude and direction of closing error.**

### Closing error

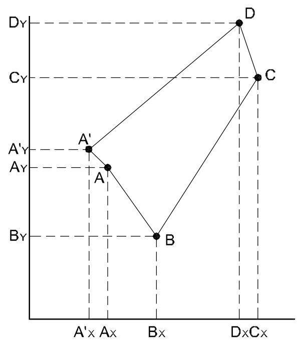
Sometimes a geometrically closed traverse fails to close. "Then there is closing error:

Closing error is the distance by which the end of a traverse falls short in coinciding with the starting point of the traverse.

As explained earlier, if a closed traverse work is correct, the algebraic sum of the latitudes should be equal to zero, and the algebraic sum of the departures should be equal to zero, i.e. $\sum L = 0$ and $\sum D = 0$.

Following figures shows a closed traverse ABCDA, in which starting point and end point not coinciding.

Fig 1




CLOSING ERROR OF A CLOSED TRAVERSE

Fig.1 Closing error of a closed traverse

The Distance A'A is the closing error.

From the figures it is understood that horizontal component and vertical component of A'A is A' x Ax and A'yAy respectively.

Algebraic sum of the horizontal components of the length of the sides, $\sum D$ = AxBx+BxCx-CxDx-DxA'x=A'xAx.

Algebraic sum of the horizontal components of the lengths of the sides, $\sum L$ =(ByCy+CyDy)-(AyBy+DyA'y) = A'yAy.

Let A'xAx is Ox and A'yAy is Oy, then from the right angled triangle , AA'Z,

$$AA' = \text{Closing error} = e = \sqrt{(Ox)^2 + (Oy)^2}$$

$$= \sqrt{\sum L^2 + \sum D^2}$$

The direction of the closing error is determined from tan $\theta$= opposite side adjacent side = $\Sigma D / \Sigma L$.

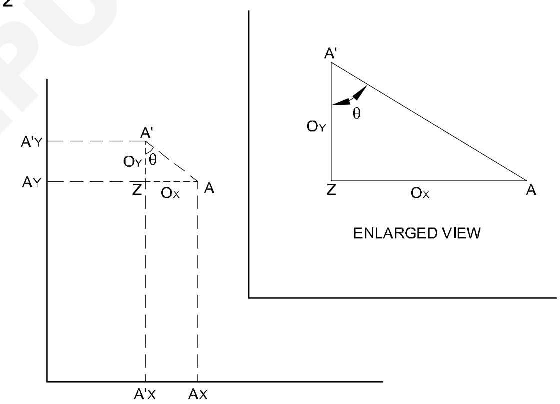
The sign of and thus define the quadrant in which the closing error lies.

Sometimes the term relative error of closure is also used to express precision of the survey.

Relative error of closure = (Closure error) ÷ (Perimeter of the traverse)

Fig 2 Enlarged view of closing error.

Fig 2




ENLARGED VIEW OF CLOSING ERROR



# Latitudes and departures

**Objectives:** At the end of this lesson you shall be able to
- **determine latitudes**
- **determine departures**
- **balance the traverse using transit method**
- **balance the traverse using Bowditch's (mathematical) method.**

### Latitudes and departures

The latitude of a line is its projection on to the north - south meridian.

The distance measured towards the north (upward) is called northing whereas the distance measured towards the south (downward) is called southing.

The departure of a line is its projection on to the east-west meridian.

The distance measured towards the east (right ward) is called easting whereas the distance measured towards the west (leftward) is called westing.

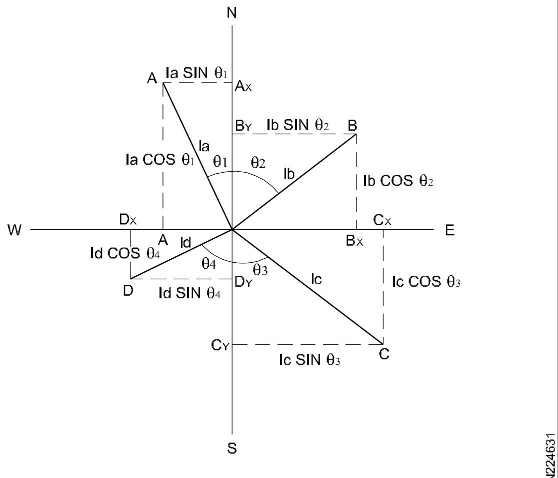
From the reduced bearing or WCB and lengths of the lines, the latitudes and departures of the lines can be calculated.

Latitude of OA is northing = Ia $\cos\varnothing^1$ (+)

Departure of OA is westing = Ia $\sin\varnothing^1$(-)

Latitude of OB is northing = Ib $\cos\varnothing^2$(+)

Fig 1




LATITUDE & DEPARTURE VALUE OF LINES IN DIFFERENT QUADRANTS

Departure of OA is easting = Ib Sin$\varnothing^2$ (+)

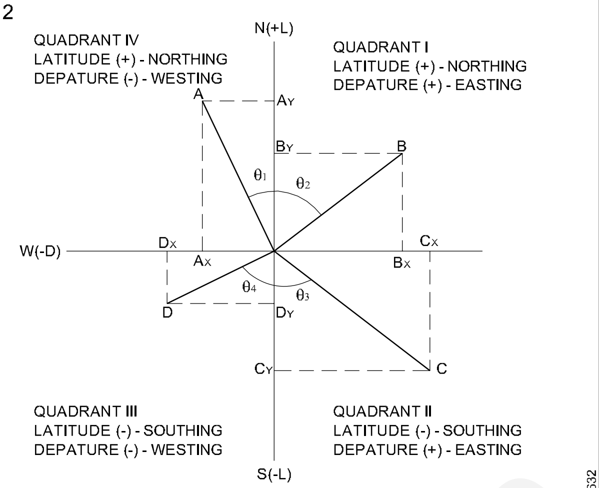
Latitude of OC is northing - Ic Cos$\varnothing^3$ (-)

Departure of OC is easting - Ic Sin$\varnothing^3$ (+)

Latitude of OD is southing = Id cos$\varnothing^3$ (-)

Departure of OD is westing = Id sin$\varnothing^3$ (-)

Fig 2




LATITUDE & DEPARTURE OF POINTS IN DIFFERENT QUADRANTS

Here l is the length of the line and $\varnothing$ is the reduced bearing of the respective line.

Find coordinates of a line AB observed radially from a station A using magnetic compass, whose W.C.B are <45°00'00", <135°00'00", <225°00'00" and <315°00'00".

**Solution**

| Line | Length (m) | W.C.B. | R.B. | Coordinates |
|---|---|---|---|---|
| AB | 100 | 45°00'00" | N45°00'00"E | Latitude = 100 x cos 45°00'00" = +70.71 m<br>Departure = 100 x sin 45°00'00" = + 70.71 m |
| | | 135°00'00" | S45°00'00"E | Latitude = 100 x cos 45°00'00" = -70.71 m<br>Departure = 100 x sin 45°00'00" = + 70.71 m |
| | | 225°00'00" | S45°00'00"W | Latitude = 100 x cos 45°00'00" = -70.71 m<br>Departure = 100 x sin 45°00'00" = - 70.71 m |
| | | 315°00'00" | N45°00'00"W | Latitude = 100 x cos 45°00'00" = +70.71 m<br>Departure = 100 x sin 45°00'00" = - 70.71 m |

| Line | Length(m) | W.C.B | R.B | Coordinates (m) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Latitude | | Departure | |
| | | | | Northing | Southing | Easting | Westing |
| | | | | + | - | + | - |
| AB | 100 | 45°00'00" | N45°00'00E" | 70.71 | | 70.71 | |
| | | 135°00'00" | S45°00'00"E | | 70.71 | 70.71 | |
| | | 225°00'00" | S45°00'00"W | | 70.71 | | 70.71 |
| | | 315°00'00" | N45°00'00"W | 70.71 | | | 70.71 |

# Checking balancing the traverse

**Objectives:** At the end of this lesson you shall be able to
- **explain balancing the traverse**
- **describe various mathematical and graphical methods of balancing the traverse.**

**Balancing the traverse**

The term balancing is generally applied to the operation of applying corrections to latitudes and departures to satisfy the conditions, $\Sigma D = 0$, $\Sigma L = 0$ for a closed traverse.

For a traverse work we can have the following three conditions:

1 Angular accuracy is higher than the linear accuracy. E.g. A hilly terrain.

2 Angular accuracy is lower than the linear accuracy. E.g Angles measured with compass and distances with an EDM equipment.

3 Angular accuracy is same as the linear accuracy. E.g. Angles measured with theodolite and linear distances measured with an EDM equipment.

Depending upon the above conditions traverse is balanced. Traverse balancing can be done both mathematically and graphically. There are many methods for balancing traverse, but commonly used mathematical methods and graphical methods are,

**Mathematical methods**

1 Bowditch's or compass rule method

2 Transit rule method

**Graphical methods**

1 Graphical method

2 Axis method

**Bowditch's method**

This method was suggested by C.F Bowditch. He made some assumptions for developing this method.

According to this method the errors in linear measurement are proportional to  and that the errors is angular measurements are inversely proportional to , where 'l' is the length of the line.

**Correction to latitude = Total error in latitude x (Length of that traverse line) ÷ (total length of traverse)**

**Correction to departure = Total error in departure x (length of that traverse line) ÷ (total length of traverse)**

**The sign of the above corrections depends upon the algebraic sum of latitudes and departures.**

**If $\Sigma N > \Sigma S$, the sign of corrections for northings is negative and for southings positive and vice versa.**

**If $\Sigma E > \Sigma W$, the sign of corrections for eastings is negative and for westings positive and vice versa.**

Bowditch's rule is also known as compass rule because this method is most suitable for compass survey. However this method is most commonly used for an average engineering survey because it is easy to apply and the corrections do not alter the plotting.

**2 Transit rule method**

When the angular measurements are more precise than the linear measurements, balancing the traverse is done by employing transit rule. According to this rule, the total error in latitude and departure is distributed in proportion to the latitude and departure of the traverse line.

**Correction to latitude = Total error in latitude x (Latitude of that traverse line ) ÷ (arithmetic sum of latitudes)**

**Correction to departure = Total error in departure x (Departure of that traverse line) ÷ (arithmetic sum of departures)**

**The sign of the above corrections depends upon the algebraic sum of latitudes and departures.**

**If $\Sigma N > \Sigma S$, the sign of corrections for northings is negative and for southings positive and vice versa.**

**If $\Sigma E > \Sigma W$, the sign of corrections for eastings is negative and for westings positive and vice versa.**

**Plotting a traverse survey**

After balancing the traverse, the traverse is plotted by rectangular coordinates.

**Exercise**

A first hand group of surveyors conducted a closed traverse with a theodolite. The lengths and observations of a closed traverse ABCDA are given below. Prepare a Gale's traverse table.

| Line | Length(m) | Included angle | W.C.B |
|---|---|---|---|
| AB | 250 | <A=95°00'00” | 140°00'00'' |
| BC | 650 | <B = 75°00'00” | - |
| CD | 120 | <C = 125°00'00” | - |
| DA | 700 | <D = 70°00'00” | - |

**Solution**

Sum of the observed included angles of the traverse =95°00'00” + 75°00'00” + 125°00'00” + 70°00'00” = 365°00'00”

Theoretical sum of the included angles = (2n-4) x 90° = (2x4-4) x 90° = 360°00'00”.

Error = 365°00'00” - 360°00'00” = +05°00'00”

Therefore a correction of - (05°00'00”/4) should be applied to each angle, i.e -01°15'00” correction.

Hence corrected included angles at each stations are

<A = 95°00'00” - 01°15'00” - 93°45'00”

<B = 75°00'00” - 01°15'00” - 73°45'00”

<C = 125°00'00” - 01°15'00” - 123°45'00”

<D = 70°00'00” - 01°15'00” - 68°45'00”

**Calculation of Bearings**

Bearing of BC =

Bearing of line AB + <B -180°00'00” = 140°00'00” +73°45'00” -180°00'00” = 33°45'00”

Bearing of CD =

Bearing of line BC+<C -180°00'00” = 33°45'00” +123°45'00” -180°00'00” = 337°30'00”

Bearing of DA =

Bearing of line CD+<D -180°00'00” = 337°30'00” +68°45'00” -180°00'00” = 226°15'00”

Bearing of AB =

Bearing of line DA+<A -180°00'00” = 226°15'00” +93°45'00” -180°00'00” = 140°00'00” (check)

| Line | Length(m) | W.C.B | R.B |
|---|---|---|---|
| AB | 250 | 140°00'00” | S40°00'00''E |
| BC | 650 | 33°45'00” | N33°45'00”E |
| CD | 120 | 337°30'00” | N22°30'00”W |
| DA | 700 | 226°15'00” | S46°15'00”W |

**Consecutive coordinates**

Coordinates of B

Latitude = 250 x Cos 40°00'00” = -191.5111 m

Departure =250 x Sin 40°00'00” = +160.6969 m

Coordinates of C

Latitude = 650 x Cos 33°45'00” = +540.4552 m

Departure =250 x Sin 33°45'00” = +361.1206 m

Coordinates of D

Latitude = 120 x Cos 22°30'00” = +110.8655 m

Depature =120 x Sin 22°30'00” = -45.9220 m

Coordinates of A

Latitude = 700 x Cos 46°15'00” = -484.0591 m

Depature =700 x Sin 46°15'00” = -505.6547 m

| | Latitude | | Depature | |
|---|---|---|---|---|
| B | | -191.511 | 160.6969 | |
| C | 540.4552 | | 361.1206 | |
| D | 110.8655 | | | -45.922 |
| A | | 484.0591 | | -5056547 |
| total | 6513207 | -6755702 | 5218175 | -5515767 |
| Σ | | -24.2495 | | -29.7592 |

Since, ΣL = -191.5111+540.4552+110.8655- 484.0591 = -24.2495 m

ΣD = +160.6969+361.1206 - 45.9220 - 505.6547 = -29.7592m

Hence there is closing error,

Closing error, e = $\sqrt{\left(\sum L^2\right)+\left(\sum D^2\right)}$

$= \sqrt{(-24.2495)^2+(-29.7592)}$

= 38.4168 m

Reduced bearing of the closing error = $\tan^{-1}$(ΣD/ΣL)

= $\tan^{-1}$(29.7592/24.2495)

= 50°49'30” (SW quadrant, since ΣL and ΣD are negative)

Note : Practically this magnitude of error is impermissible for most type of works. Here, as a sample question we are preparing Gale's table.

**Corrections**

As per transit method, correction to latitude (or departure) = Total error in latitude (or departure) x (Latitude (or departure) of that traverse line ) ÷ (arithmetic sum of latitudes (departures)

Line AB

Corrections to southing = 24.2495 x (191.5111/1326.891) = $^{-}$3.4999 m (ΣS<ΣN, the sign of corrections for southings is negative and for northings positive)

Corrections to easting = 29.7592 x (160.6969/1073.394) = $^{+}$4.4552 m (ΣW>ΣE, the sign of corrections for westings is negative and for eastings positive)

Line BC

Correction to northing = 24.2495 x (540.4552/1326.891) = $^{+}$9.8770m

Correction to easting = 29.7592 x (160.6969/1073.394) = $^{+}$10.0118 m

Line CD

Correction to northing = 24.2495 x (110.8655/1326.891) = $^{+}$9.8770m

Correction to westing = 29.7592 x (45.9220/1073.394) = $^{+}$1.2731 m

Line DA

Correction to southing = 24.2495 x (484.0591/1326.891) = $^{+}$8.8463 m

Correction to westing = 29.7592 x (505.6547/1073.394) = $^{+}$14.0189 m

**Corrected consecutive Coordinates**

AB

191.5111 - 3.4999 = 188.0111 m

160.6969+4.4552 = 165.1521 m

BC

540.4552 + 9.8770 = 550.3322 m

361.1206 + 10.0118 = 371.1324 m

CD

110.8566 + 2.0261 = 112.8916 m

45.9220 - 1.2731 =44.6488 m

DA

484.0591 - 8.8463 = 475.2127 m

505.6547 - 14.0189 = 491.6357 m

**Independent Coordinates**

Assuming coordinates of station A as 500,500 (latitude, departure),

Coordinates of B

Latitude = 500.00000 - 188.0111 = 311.9889 m (southing is negative so subtraction)

Departure =500.0000 +165.1521 = 665.1521 m (easting is positive so addition)

Coordinates of C

Latitude =311.9889 + 550.3322 = 862.3211 m

Departure = 665.1521 + 371.1324 = 1036.2845 m

Coordinates of D

Latitude = 862.3211+112.8916 = 975.2127 m

Departure = 1036.2845 - 44.6488 = 991.6357 m

Coordinates of A (check)

Latitude = 975.2127 - 475.2127 = 500.0000 m

Departure = 991.6357 - 491.6357 = 500.000 m



**Gale's table. Traverse balanced using transit method**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Remarks | | Assuming coordinates of A (500.00, 500.00) As maximum value for latitude is 475.2127 and departure is 491.6357 | | | | | | |
| Independent Coordinates (m) | | Easting (+) | 665.1521 | 1036.2845 | 99.6357 | 500 | | |
| | | Northing (+) | 311.9889 | 862.3211 | 975.2127 | 500 | | |
| Corrected consecutive coordinates (m) | Departure E | Westing (-) | | | 44.6488 | 491.6357 | 536.2845 | 0.00 |
| | | Easting (+) | 165.1521 | 371.1324 | | | 536.2845 | |
| | Latitude | Southing (-) | 188.0111 | | | 475.2127 | 663.2238 | 0.00 |
| | | Northing (+) | 550.3322 | 112.8916 | | 663.2238 | | |
| Correction (m) | Departure E | Westing | | -1.2731 | -14.0189 | | | |
| | | Easting | +4.4552 | +10.0118 | | | | |
| | Latitude | Southing | -3.4999 | | | -8.8463 | | |
| | | Northing | | +9.8770 | +2.0261 | | | |
| Consecutive | Departure E Coordinates (m) | Westing (-) | | | 45.922 | 505.6547 | 551.5767 | -29.7592 |
| | | Easting (+) | 160.6969 | 361.1206 | | | 521.8175 | |
| | Latitude | Southing (-) | 191.5111 | | | 484.0591 | 675.5702 | -24.2945 |
| | | Northing (+) | | 540.4552 | 110.8655 | | 651.3207 | |
| | Length (m) | | 250 | 650 | 120 | | | |
| | Quadrant | | SE | NE | NW | SW | | |
| | R.B | | S40°00'00" | N33°45'00"E | N22°30'00" | S46°15'00"W | | |
| | W.C.B | | 140°00'00" | 33°45'00" | 337°30'00" | 226°15'00" | | |
| | Corrected angle | | 93°45'00" | 73°45'00" | 123°45'00" | 68°45'00" | | |
| | Correction | | -1°15'00" | -1°15'00" | -1°15'00" | -1°15'00" | | |
| | Angle | | 95°00'00" | 75°00'00" | 125°00'00" | 70°00'00" | | |
| | Sight to | | B | C | D | A | | |
| | Instrument at | | A | B | C | D | Total | Algebraic sum of latitude or departure |

**Corrections**

As per Bowditch's arithmetical method, correction to latitude = Total error in latitude (or departure) x (length of that traverse line) ¸ (total length of traverse)

Line AB

Corrections to southing = 24.2495 x (250/1720) = $^{-}$3.5246m (SS>SN, the sign of corrections for southings in negative and for northings positive)

Corrections to easting = 29.7592 x (250/1720) =+4.3254m (SW>SE, the sign of corrections for westing is negative and for eastings positive)

Line BC

Correction to northing = 24.2495 x (650/1720) = $^{+}$1.6918m

Corrections to easting = 29.7592 x (650/1720) =$^{+}$11.2462m

Line CD

Correction to northing = 24.2495 x (120/1720) = $^{+}$9.1640m

Correction to westing = 29.7592 x (120/1720) = $^{-}$2.0762m

Line DA

Correction to southing = 24.2495 x (700/1720) = $^{-}$9.8689m

Corrections to westing = 29.7592 x (700/1720) =12.1113m

Corrected consecutive coordinates

AB

191.5111 - 3.5246 = 187.9864 m

160.6969 + 4.3254 = 165.0223 m

BC

540.4552+9.1640 = 549.6192 m

361.1206 + 11.2462 = 372.3668 m

CD

110.8655 + 1.6918 = 112.5573 m

45.9220 - 2.0762 = 43.8457m

DA

484.0591 - 9.8669 = 474.1901 m

505.6547 - 12.1113 =493.5434 m

**Independent Coordinates**

Assuming coordinates of station A as 500,500 (latitude, departure), coordinate of B.

Latitude = 500.0000 - 187.9864=9864 = 312.0136 m

Departure = 500.0000+165.0223 = 665.0223 m

Coordinate of C

Latitude = 312.0136 + 549.6192 = 861.6328 m

Departure = 665.0223 + 372.3668 = 1037.5189 m

Coordinate of D

Latitude = 862.3211+112.5573= 974.1901 m

Departure = 1036.2845 -43.8458 = 993.5434 m

Coordinate of A (check)

Latitude = 974.1901 - 474.1901 = 500.0000 m

Departure = 993.5434 - 493.5434 = 500.000 m

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Remarks | | Assuming coordinates of A (500.00, 500.00) As maximum value for latitude is 475.2127 and departure is 491.6357 | | | | | | |
| Independent Coordinates (m) | | Easting (+) | 665.0223 | 1037.5189 | 993.5434 | 500 | | |
| | | Northing (+) | 312.0136 | 861.6328 | 974.1901 | 500 | | |
| Corrected consecutive coordinates (m) | Departure E | Westing (-) | | | 43.8457 | 493.5434 | 537.3891 | 0.00 |
| | | Easting (+) | 165.0223 | 372.3668 | | | 537.3891 | |
| | Latitude | Southing (-) | 187.9864 | | | 474.1901 | 662.1765 | 0.00 |
| | | Northing (+) | | 549.6192 | 112.5773 | | | |
| Correction (m) | Departure E | Westing | | -1.6918 | -12.1113 | | | |
| | | Easting | +4.3254 | +11.2462 | | | | |
| | Latitude | Southing | -3.5246 | | | -9.8689 | | |
| | | Northing | | +9.1640 | +1.6918 | | | |
| Consecutive | Departure E Coordinates (m) | Westing (-) | | | 45.922 | 505.6547 | 551.5767 | -29.7592 |
| | | Easting (+) | 160.6969 | 361.1206 | | | 521.8175 | |
| | Latitude | Southing (-) | 191.5111 | | | 484.0591 | 675.5702 | -24.2945 |
| | | Northing (+) | | 540.4552 | 110.8655 | | 651.3207 | |
| | Length (m) | | 250 | 650 | 120 | | | |
| | Quadrant | | SE | NE | NW | SW | | |
| | R.B | | S40°00'00"E | N33°45'00"E | N22°30'00"W | S46°15'00"W | | |
| | W.C.B | | 140°00'00" | 33°45'00" | 337°30'00" | 226°15'00" | | |
| | Corrected angle | | 93°45'00" | 73°45'00" | 123°45'00" | 68°45'00" | | |
| | Correction | | -1°15'00" | -1°15'00" | -1°15'00" | -1°15'00" | | |
| | Angle | | 95°00'00" | 75°00'00" | 125°00'00" | 70°00'00" | | |
| | Sight to | | B | C | D | A | | |
| | Instrument at | | A | B | C | D | Total | Algebraic sum of latitude or departure |

## Preparation of gales traverse tables

**Objective :** At the end of this lesson you shall be able to
- **preparation of gales traverse table.**

**Gales traverse table is given below**

**Gale's Traverse Table**

| Traverse legs | Angles | Corrections | Corrected Angles | W.C.B. | Reduced Bearing | Lengths | Stn. | Consecutive Co - ordinates | | | | Corrections | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lat | | Dep. | | Lat | | Dep. | |
| | | | | | | | | N | S. | E. | W. | N. | S. | E. | W. |
| | 95°24' | -6' | 95° 18' | | | | P | 107.97 | | 3.77 | | +0.26 | | -0.01 | |
| PQ | | | | 86° 42' | N86°42'E | 250 | | | | | | | | | |
| | 88°42' | -6' | 88° 36' | | | | Q | 14.39 | | 249.57 | | +0.03 | | -0.71 | |
| QR | | | | 178° 06' | SI°54'E | 123 | | | | | | | | | |
| | 88°12 | -6' | 88° 06' | | | | R | | 122.94 | 4.12 | | | -0.29 | -0.01 | |
| RS | | | | 270° 00' | N90°00'W | 256 | | | | | | | | | |
| | 88°12' | -6' | 88° 00' | | | | S | 0.00 | | | 256.00 | +0.00 | | | +0.73 |
| SP | | | | 02° 00' | NO2°00'E | 108 | | | | | | | | | |
| Sum | 360°24' | -24' | 360° 00' | | | 737 | | 122.36 | 122.94 | 257.46 | 256.00 | | | | |
| | | | | | | | | ΣL = -0.58 | | ΣB = +1.46 | | | | | |

Closing Error =

Perimeter of traverse = 737m

Accuracy of traverse = $\frac{1.57}{737} = \frac{1}{469.43}$

R.B of clossing esser = $\tan^{-1}\left(\frac{\sum D}{\sum C}\right)$ (1.46/0.58)

= S68°20'E

## Calculation of independent Co - ordinates

**Objectives :** At the end of this lesson you shall be able to
- **calculation of independent co - ordinates**
- **advantages of independent co - ordinates.**

The total latitude and total departure of any station with respect to a common origin of co - ordinates, are called as total co - ordinates or independent co - ordinates.

After the traverse properly balanced (ie) the algebraic of the northings is equal is algebraic sum of the southings and the algebraic sum of the easting's is equal to algebraic sum of the westings.

The independent co - ordinate calculate as under.

Two reference axes an chosen, such that the whole traverse falls in the first quadrant and the total latitude and departure of each stations get positive sign

The independent co - ordinates of any station are obtained by adding algebraically the altitudes and departures of the traverse legs between that station and the origin.

It stated mathematically

Total latitude (or departures) of point = algebraic sum of all the latitudes (or departures) up to the point

In case of a closed circuit the co - ordinates of the closing station should agree with these of the starting station.

**Advantages of independent co ordinates**

The accuracy of a survey depends upon its control points are plotted

When plotting of traverse is done with consecutive co ordinates

The accuracy of the location of each point upon the plan depends upon the accuracy with which previous points are plotted

Slight error in plotting of each point due to scaling

The error gets accumulated and the position of the last point may be displaced to a considerable extent from its true position.

This difficulty is over come by plotting the points with independent co ordinates

Thus the error does not accumulate

Knowing independent co ordinates of two points, the distance between them and their reduced bearing

This may be easily calculated by distance formula

$$\text{Distance} = AB = \sqrt{(\Delta E)^2 + (\Delta N)^2}$$

$$\text{Reduced bearing} = \tan^{-1} \frac{\text{departure}}{\text{latitude}}$$

## Computation of arch using co - ordinate

**Objectives:** At the end of this lesson you shall be able to
- **correction of angle, and W.C.B converted to reduced bearing**
- **calculate concecutive co - ordinates**
- **correction of concecutive co - ordinates**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | Consecutive co-ordinates | | | | Correction | | | | Correction consecutive co-ordinates | | | | Independent co-ordinates | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Line and length (m) | Point | Angle | Correction | Corrected angle | WCB | RB | N | S | E | W | N | S | E | W | N | S | E | W | N (Y) | E (X) |
| | P | 95°24' | -6' | 95°42' | | | 107.97 | | 3.77 | | +0.26 | | -0.01 | | 108.23 | | 3.76 | | 150.00 | 100.00 |
| PQ 250 | | | | | 86°42' | N86°42'E | | | | | | | | | | | | | | |
| | Q | 88°42' | -6' | 88°36' | | | 14.39 | | 249.57 | | +0.03 | | -0.71 | | 14.42 | | 248.86 | | 164.42 | 348.85 |
| QR 123 | | | | | 178°06' | S1°54'E | | | | | | | | | | | | | | |
| | R | 88°12' | -6' | 88°06' | | | | 122.94 | 4.12 | | | 0.29 | -0.01 | | | 122.65 | 4.11 | | 41.77 | 352.96 |
| RS 156 | | | | | 270°00' | N90°00'W | | | | | | | | | | | | | | |
| | S | 88°06' | -6' | 88°00' | | | 0.00 | | | 256.00 | +0.00 | | | +0.73 | +0.00 | | | 256.73 | 41.77 | 96.23 |
| SP 108 | | | | | 2°00' | N02°00'E | | | | | | | | | | | | | | |
| SUM | | 360°24' | -24' | 360°00' | | | 122.36 | 122.94 | 257.46 | 256.00 | +0.29 | -0.29 | -0.73 | +0.73 | 122.65 | 122.65 | 256.73 | 256.73 | | |
| | | | | | | | -0.58 | | +1.46 | | +0.58 | | -1.46 | | 0 | | 0 | | | |

**Remark:** All interior angle and bearing of PQ observed corrections are applied by transit rule assumed

Now, Area = $1/2[y_1(x_2-x_n)+y_2(x_3-x_1)+y_3(x_4-x_2)+.....yn(x_1-x_{(n-1)})]$

## Calculation omitted measurements

**Objectives:** At the end of this lesson you shall be able to
- **describe omitted measurements**
- **list out and explain the classification of omitted measurements.**

In a closed traverse, lengths and bearings of all the traverse lines are measured. However, sometimes it may not be possible to take all the measurements due to obstacles or oversights. But such omitted measurements can be computed indirectly, provided number of unknown measurements is not more than two.

As we know, in a closed traverse, algebraic sum of departures and algebraic sum of latitudes are zero, ie. ΣL and ΣD are equal to zero. From this condition it has been derived that,

Length of a traverse line = $\sqrt{L^2 + D^2}$

Reduced bearing of a traverse line = $\tan^{-1}$ (D/L)

The omitted measurements may be classified in the following cases:

1 Length or bearing or both of a line omitted.

2 Length of a line and bearing of an adjacent line omitted.

3 Lengths of two adjacent lines omitted.

4 Bearings of two adjacent lines omitted.

**Length or bearing or both of a line omitted :**

Let ABCDFA is the traverse planned, Due to a building, lengths and included angles at each station are observed. As we know latitudes and departures of all the sides of the traverse are balanced, provided it is a closed traverse. If not, the residual sum left is the latitude and departure of the closing error. Sum up latitudes and departures of all other sides leaving the side DE. Let it be ΣL' and ΣD'.

Then length of DE = $\sqrt{\left(\Sigma L'^2 + \Sigma D'^2\right)}$

And direction of DE, tan = ΣD'/ΣL'

**Exercise**

Following data were obtained for a closed traverse ABCD which was run in anticlockwise direction.

| Line | Length (m) | Bearing | Included Angle |
|---|---|---|---|
| AB | 150 | 30° | <A=110° |
| BC | 120 | | <B=63° |
| CD | 250 | | <C=130° |
| DA | 120 | | <D=53° |

Determine the closing error.

Fig 1

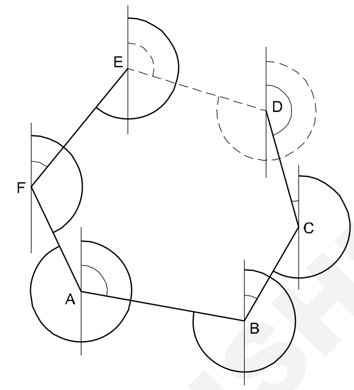



Fig 1. Omitted measurements : Length or bearing or both of a line omitted.

**Solution :**

The sum of the observed interior angles of the traverse is <A +<B+<C +<D = 110° +63°+130°+53° = 356°.

Theoretical sum = (2n-4) x 90°, n=4, so (2x4) x 90° = 360°.

Error is 356° -360° = 4°

Correction = $^+$4°

Applying the corrections equally to all the angles (4°/4) = $^+$1°.

<A = 110° +1° = 111°

<B = 63° +1° = 64°

<C =130° +1° = 131°

<D = 53° +1° = 54°

**360°**

Bearing of AB is 30°

Back bearing of AB is 180°+30° = 210°

<B = 64°

Bearing of BC = 210° +64°= 274°

Back bearing of BC is 274° - 180° = 94°

<C = 131°

Bearing of CD = 94° + 131° = 225°

Back bearing of CD is 225° - 180° = 45°

<D = 54°

Bearing of DA is 45° + 54° = 99°

| Line | Length (m) | Bearing | Included Angle | Corrected Angle | FB | RB | Latitude N (+) | Latitude S (-) | Departure E (+) | Departure W (-) |
|---|---|---|---|---|---|---|---|---|---|---|
| AB | 115 | 30° | <A=110° | <A=111° | 30° | N 30°E | 99.59 | | 57.5 | |
| BC | 50 | | <B=63° | <B=64° | 274° | N 86°W | 3.48 | | | 49.87 |
| CD | 150 | | <C=130° | <C=131° | 225° | S 45°W | 106.06 | | | 106.06 |
| DA | 100 | | <D=53° | <D=54° | 99° | N 81°E | 15.64 | | 98.76 | |
| | | | | | | | 118.71 | 106.06 | 156.26 | 155.93 |
| | | | | | | | +12.65 | | +0.33 | |

Therefore closing error = $\sqrt{(12.65)^2 + (0.33)^2} = 12.65$ m

**Length of one line and bearing of an adjacent line omitted**

In the traverse ABCDEF, the length of ED and bearing of FE are unknown.

If D and F are joined, we will get a closed traverse ABCDEF in which the length and bearing of DF, $L_{df}$ can be computed using the formula

$\sqrt{\left(\sum L'^2 + \sum D'^2\right)}$ and $\tan = \sum D' / \sum L'$

From the bearing of DE and DF, compute the angle FDE. In the triangle FDF, $L_{fe}$, $L_{df}$ and the angle D are known.

< f = 180° - (<d+<e)

$$\frac{EF}{\text{Sin FDE}} = \frac{DE}{\text{Sin DFE}} = \frac{DF}{\text{Sin FED}}$$

$$\frac{L_{ef}}{\text{Sin FDE}} = \frac{L_{de}}{\text{Sin DFE}} = \frac{L_{df}}{\text{Sin FED}}$$

Therefore < e = sin-1 [($L_{df}$ x (sin d /$L_{ef}$)]

Lde = ($L_{ef}$ / sin d ) x sin f from the known values of included angles and bearings, unknown bearings can be computed.

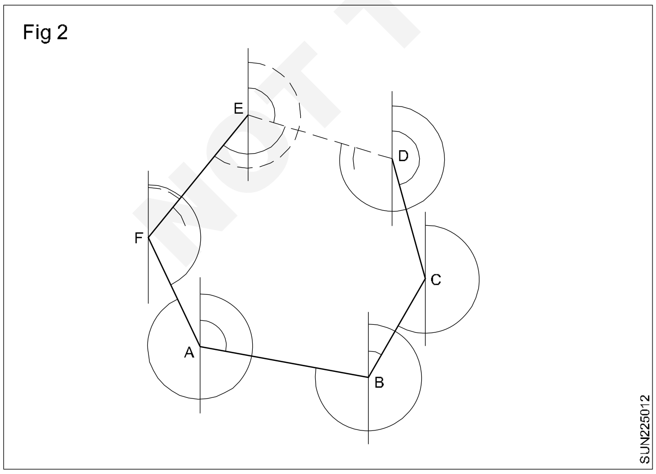


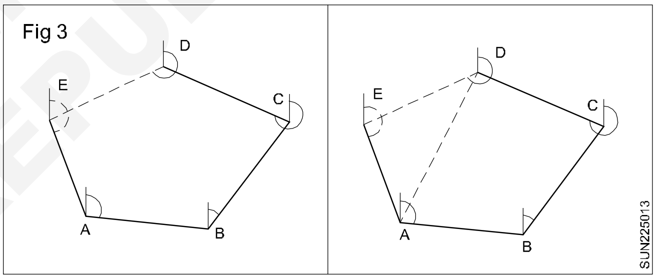

Fig. 2. Length of one line and bearing of an adjacent line omitted.

**Exercise**

Following data shows incomplete observations of a closed traverse ABCDEA. Determine the missing data.

| Line | Length(m) | Bearing |
|---|---|---|
| AB | 400 | 100°00'00" |
| BC | 600 | 30°00'00" |
| CD | 580 | 30°00'00" |
| DE | - | 245°00'00" |
| EA | 592.07 | - |

**Solution (Fig 3, 4)**




| **Line** | **Length(m)** | **Bearing** | **RB** |
|---|---|---|---|
| AB | 400 | 100°00'00" | S80°00'00" E |
| BC | 600 | 30°00'00" | N30°00'00" E |
| CD | 580 | 30°00'00" | N60°00'00" W |
| DE | - | 245°00'00" | S65°00'00" W |
| EA | 592.07 | - | - |

Join the line DA and form a closed traverse ABCDA.

Consecutive coordinates of B.

Latitude = 400 x Cos 80°00'00" = +69.459 m

Departure = 400 x Sin 80°00'00" = +393.923 m

Consecutive coordinates of C

Latitude = 400 x Cos 30°00'00" = +290.615 m

Departure = 600 x Sin 30°00'00" = +300.000 m

Consecutive coordinates of D

Latitude = 580 x Cos 60°00'00" = +290.00 m

Departure = 580 x Sin 60°00'00" = -502.294 m

| Line | Length (m) | RB | Latitude (m) | | Departure (m) | |
|---|---|---|---|---|---|---|
| | | | N (+) | S (-) | E (+) | W (-) s |
| AB | 400 | S80°00'00"E | | 69.459 | 393.923 | |
| BC | 600 | N30°00'00" E | 519.615 | | 300.000 | |
| CD | 580 | N60°00'00" W | 290.000 | | 502.294 | |
| Total | | | 809.615 | 69.459 | 693.923 | 502.294 |
| Σ | | | +740.156 | | +191.629 | |

$\Sigma L = L_{DA} + (+740.156) = 0$

Therefore $L_{DA} = 740.156$ m

$\Sigma D = D_{DA}$ (+191.629)m

Length of DA = $\sqrt{(+740.156^2 + 191.629^2)}$

= 764.56 m

Bearing of DA = $\tan^{-1}$ (191.629/740.156) = 14°30'55" (S-W quadrant) - Quadrant from the sign of $L_{DA}$ and $D_{DA}$ WCB of DA = 194°30'55''. Therefore, Bearing of AD = 14°30'55''.

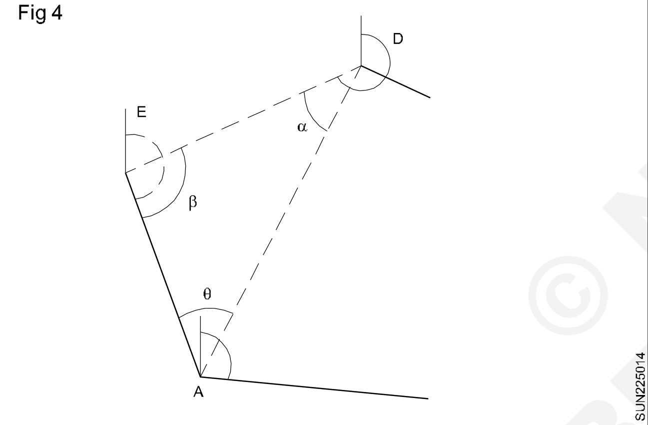


Fig 4

Now in triangle Δ ADE

α = Bearing of DE - Bearing of DA

245°00'00" - 194°30'55" = 50°29'05''

From triangle Δ ADE, we have,

$\frac{DE}{\sin\theta} = \frac{AD}{\sin\beta} = \frac{AE}{\sin\alpha} =$

β= $\sin^{-1}$ (AD/AE) x Sin α = (764.56/592.07) Sin 50°29'05" = 85°00'26"

θ=180°00'00" - (α+β) = 180°00'00" - (50°29'05" + 85°00'26") = 44°30'29"

DE = AD (Sin θ/ Sinβ) = 764.56 x (Sin 44°30'29" / Sin 85°00'26") = 538.00 m

Bearing of ED = Bearing of DE - 180°00'00" = 245°00'00" -180°00'00" = 65°00'00"

Bearing of ED = Bearing of ED + < β = 65°00'00" + 85°00'26" = 150°00'26"

**Exercise**

Following data were collected while running a closed traverse ABCD. Determine the missing data.

**Solution (Fig 5,6,7)**

Join AC

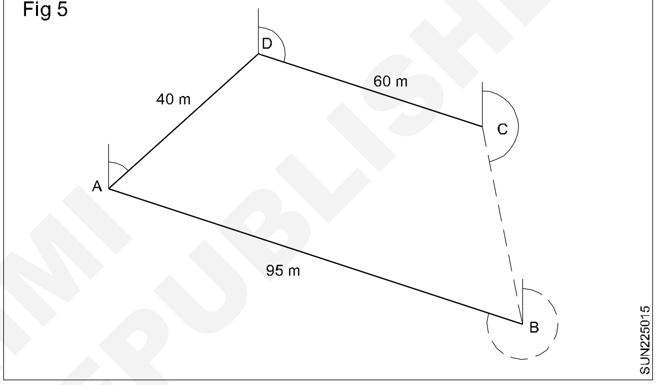


Fig 5

| Line | Length (m) | WCB | RB |
|---|---|---|---|
| AD | 40 | 50° | N50°E |
| DC | 60 | 110° | S70°E |

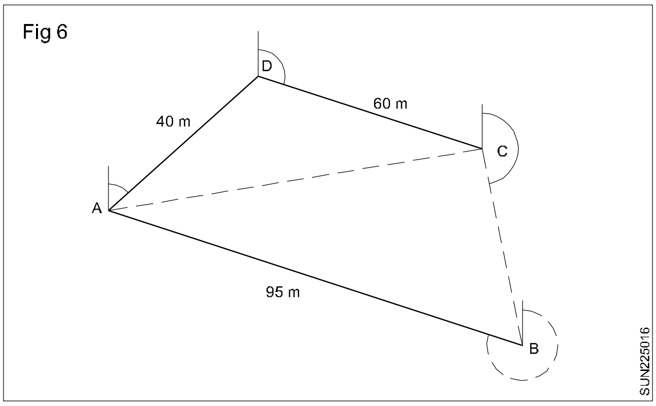


Fig 6

| Line | Latitude | | Departure | |
|---|---|---|---|---|
| | N (+) | S(-) | E (+) | W (-) |
| AD | 25.7115 | - | 30.6417 | - |
| DC | - | 20.5212 | 56.3815 | - |
| Total | 25.711 | 20.5212 | 87.024 | 0.000 |
| Σ | +5.1903 | | +87.024 | |

$\Sigma L = L_{CA} + (+5.190) = 0$

Therefore $L_{CA} = 5.190$ m

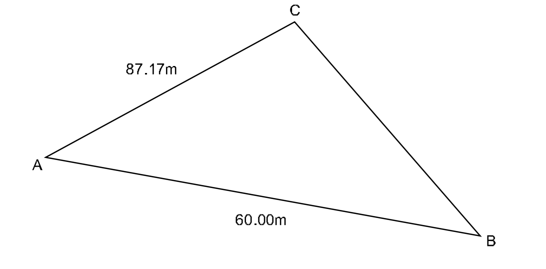
$\Sigma D = D_{CA}$ (+62.024) = 0

Therefore $D_{CA} = 87.024$ m

Length of CA = $\sqrt{(-5.190^2 + -87.024^2)} = 87.17\,m$

Bearing of CA = tan -1 (87.024/5.190) = 86°35'13" (S-W quadrant) - Quadrant from the sign of LCA and DCA WCB of CA = 266°35'13". Therefore, Bearing of AC = 86°35'13"

Fig 7




$$\frac{AC}{\text{Sin ABC}} = \frac{BC}{\text{Sin CAB}} = \frac{AB}{\text{Sin ACB}}$$

(AC/Sin <B) = (BC/Sin<A) = (AB/Sin <C)

(AC/Sin <B) = (AB/Sin <C)

(87.17/Som<B) = (AB/Sin <C)

<A = Bearing of AB - Bearing of AC

= 108°47'00" - 86°35'13" = 22°11'47"

(87.17/Sin <B) = (60.00/Sin 116°35'13")

<B = $Sin^{-1}$ (60.00/87.17) x Sin 115°13'00")

=38°30'53"

<C=180°00'00" - (22°11'47" + 38°30'53")

= 119°17'20"

Bearing of CB = Bearing of CA - <C = 266°35'13" - 119°17'20" = 147°17'53"

Bearing of BC = 147°17'53 + 180°00'00" = 327°17'53"

(BC/Sin <A) = (AB/Sn <C)

BC = AB (Sin <A/Sin <C)

= 60 x (Sin 22°11'47" /Sin 119°17'20")

=26.12 m

**Exercise**

A traverse ABCD was to be run but due to an obstruction between the stations A and B, it was not possible to measure the length and direction of the line aB. Following is the observations made.

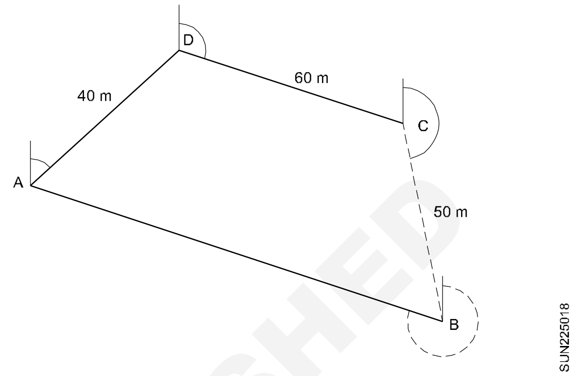
| Line | Length (m) | WCB |
|---|---|---|
| AD | 40 | 50° |
| DC | 60 | 110° |
| CB | 50 | 150° |

Determine the length of directions of the omitted side.

**Solution (Fig 8)**

| Line | Length (m) | WCB | RB |
|---|---|---|---|
| AD | 40 | 50° | N50°E |
| DC | 60 | 110° | S70°E |
| CB | 50 | 150° | S30°E |

Fig 8




Consecutive coordinates of D

Latitude of D = 40 x Cos 50° = +25.7115

Departure of D = 40 x Sin 50° = + 30.6417

Consecutive coordinates of C

Latitude of C = 60 x Cos 70° = -20.5212

Departure of C = 60 x Sin 70° = +56.3815

Consecutive coordinates of B

Latitude of B = 50 x Cos 30° = -43.3012

Departure of B = 50 x Sin 30° = +25.0000

| **Line** | **Latitude (m)** | | **Departure (m)** | |
|---|---|---|---|---|
| | **N (+)** | **S (-)** | **E (+)** | **W (-)** |
| AD | 25.7115 | - | 30.6417 | - |
| DC | - | 20.5212 | 56.3815 | - |
| CB | - | 43.3012 | 25.0000 | - |
| BA | - | - | - | - |
| Total | 25.711 | 63.822 | 112.0232 | 0.000 |
| Σ | -38.111 | | +112.023 | |

$\Sigma L = L_{BA} + (-38.111) = 0$

Therefore $L_{BA}$ = +38.111 m,or $l_{BA}$ x Cos θ = +38.111 m

$\Sigma D = D_{BA}$ (+112.023) = 0

Therefore $D_{BA}$ = 87.024 m, or $l_{BA}$ x Sin θ = -87.024 m

Length of BA = $\sqrt{(-38.111^2 + 112.023^2)} = 118.33$ m

Bearing of BA = tan -1 (112.023/38.111) = 71°12'40" (N-W quadrant) - Quadrant from the sign of $L_{BA}$ and $D_{BA}$ WCB of BA = 288°47'20". Therefore, Bearing of AB = 108°47'20"

**Lengths of two adjacent lines omitted**

Let us consider that the lengths DE and EF could not be measured.

If D and F are joined, we will get a closed traverse ABCDF in which the length and bearing of DF, Ldf can be computed using the formula $\sqrt{(\sum L'^2 + \sum D'^2)}$ and tan $\theta$ = $\Sigma D'/\Sigma L'$.

Consider the triangle DEF, by sine rule

$$\frac{EF}{\text{Sin FDE}} = \frac{DE}{\text{Sin DFE}} = \frac{DF}{\text{Sin FED}}$$

$$\frac{L_{ef}}{\text{Sin FDE}} = \frac{L_{de}}{\text{Sin DFE}} = \frac{L_{df}}{\text{Sin FED}}$$

In the triangle DEF the bearing of all three sides and length of DF are known. From known bearings of sides of the triangle we can compute the included angles of the triangle.

Therefore

$L_{de}$= ($L_{df}$/Sin e ) x sin f

$L_{ef}$ = ( $L_{df}$ /sin e ) x sin d

Fig 9

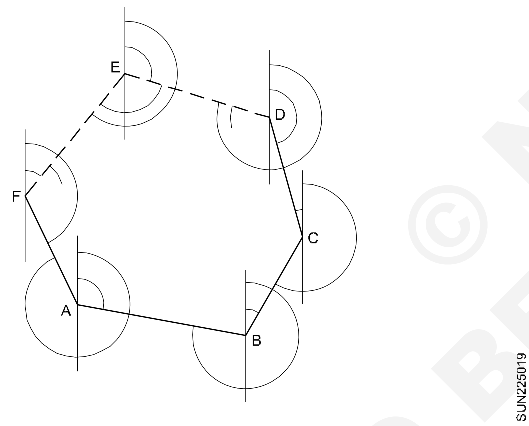



Fig.9. Lengths of two adjacent lines omitted.

**Exercise**

Following data shows incomplete observations of a closed traverse ABCDEA. Determine the missing data.

| Line | Length (m) | Bearing |
|---|---|---|
| AB | 400 | 100°00'00" |
| BC | 600 | 30°00'00" |
| CD | 580 | 30°00'00" |
| DE | - | 245°00'00" |
| EA | - | 150°00'00" |

**Solution (Fig 10,11,12)**

| Line | Length (m) | Bearing | RB |
|---|---|---|---|
| AB | 400 | 100°00'00" | S80°00'00" E |
| BC | 600 | 30°00'00" | N30°00'00"E |
| CD | 580 | 30°00'00" | N60°00'00" W |
| DE | - | 245°00'00" | S65°00'00" W |
| EA | - | 150°00'00" | S30°00'00" E |

Join the line DA and form a closed traverse ABCDA.

Consecutive coordinates of B

Latitude = 400 x Cos 80°00'00" = + 69.459 m

Departure = 400 x Sin 80°00'00" = + 393.923 m

Consecutive coordinates of C

Latitude = 600 x Cos 30°00'00" = +519.615m

Departure = 600 x Sin 30°00'00" = +300.000m

Consecutive coordinates of D

Latitude = 580 x Cos 60°00'00" = +290.00 m

Departure = 580 x Sin 60°00'00" = -502.294 m

| Line | Length (m) | RB | Latitude (m) | | Departure (m) | |
|---|---|---|---|---|---|---|
| | | | N (+) | S (-) | E (+) | W (-) s |
| AB | 400 | S80°00'00"E | | 69.459 | 393.923 | |
| BC | 600 | N30°00'00" E | 519.615 | | 300.000 | |
| CD | 580 | N60°00'00" W | 290.000 | | | 502.294 |
| DE | - | N65°00'00" W | | - | | - |
| EA | - | N30°00'00" E | | - | - | |
| Total | | 809.615 | 69.459 | 693.923 | 502.294 | |
| Σ | | | +740.156 | | +191.629 | |

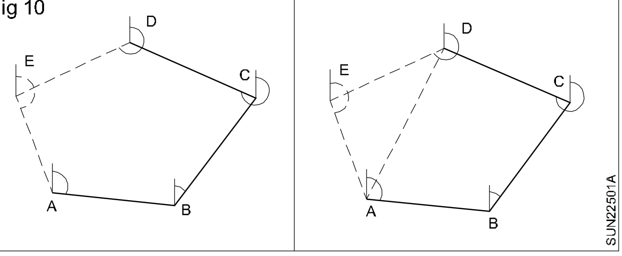



Fig 10

$\Sigma L = L_{DA} + (+740.156) = 0$

Therefore $L_{DA} = 740.156$ m

$\Sigma D = D_{DA}\ (+191.629)$m

Therefore $D_{DA} = 191.629$ m

Length of DA = $\sqrt{(+740.156^2 + 191.629^2)}$

= 764.56 m

Bearing of DA = $\tan^{-1}$ (191.629/740.156) = 14°30'55" (S-W quadrant) - Quadrant from the sign of $L_{DA}$ and $D_{DA}$ WCB of DA = 194°30'55''. Therefore, Bearing of AD = 14°30'55".

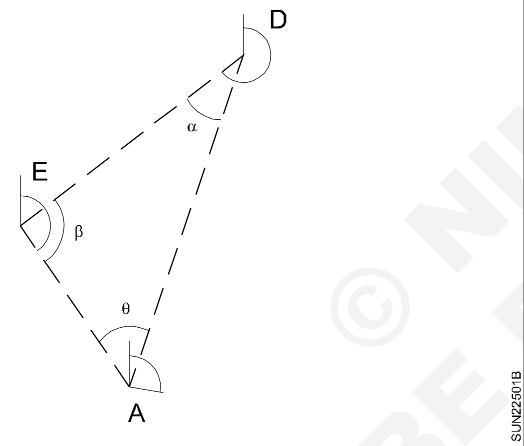



Fig 11

Now in triangle $\Delta$ ADE

$\alpha =$ Bearing of DE - Bearing of DA

245°00'00" - 194°30'55" = 50°29'05''

$\beta =$ Bearing of EA - Bearing of DE

= 150°00'00" - (245°00'00" - 180°00'00") = 85°00'00"

$\theta$ = Bearing of AD + 360°00'00" - (150°00'00" +180°00'00") = 44°30'55"

Check, $\alpha + \beta +$ = 50°29'05" +85°00'00" + 44°30'55" = 180°00'00"

From triangle $\Delta$ ADE, we have,

$\frac{DE}{\sin\theta} = \frac{AD}{\sin\beta} = \frac{AE}{\sin\alpha} =$ ____

DE = AD (Sin $\theta$/ Sin$\beta$) = 764.56 x (Sin 44°30'55" / Sin 85°00'00") = 538.08 m

AE = AD (Sin $\alpha$/ Sin$\beta$) = 764.56 x (Sin 50°29'05" / Sin 85°00'00") = 592.07 m

**Bearings of two adjacent lines omitted**

Let the bearings of DE and EF could not measure. To find the bearings of these lines, D and F are joined, we will get a closed traverse ABCDF in which the length and bearing of DF, Ldf can be computed using the formula $\sqrt{(\sum L'^2 + \sum D'^2)}$ and $\tan\theta = \Sigma D'/\Sigma L'$.

Now the triangle DEF, the length of all the sides and baring of DF is known. We can determine the area of the triangle DEF using the formula.

$\sqrt{[S(S - L_{ef})(S - L_{df})]}$

Area can also be determined using the formula

A = (1/2) x $L_{df}$ x $L_{ef}$ x Sin f

A = (1/2) x $L_{de}$ x $L_{ef}$ x Sin e

A = (1/2) x $L_{df}$ x $L_{de}$ x Sin d

Equating both equations for finding area, we get

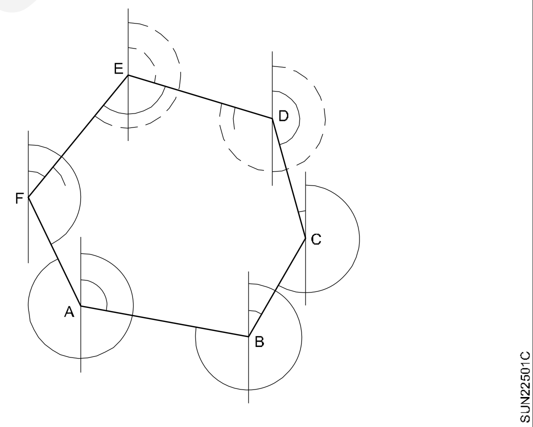
f = $\sin^{-1}$ [(2A) x ($L_{df}$ x $L_{ef}$)] radians

e = $\sin^{-1}$ [(2A) x ($L_{de}$ x $L_{ef}$)] radians

d = Sin-1 [(2A) x ($L_{df}$ x $L_{de}$)] radians

Now, with these included angles and bearings of DE and EF can be computed.

Fig 12



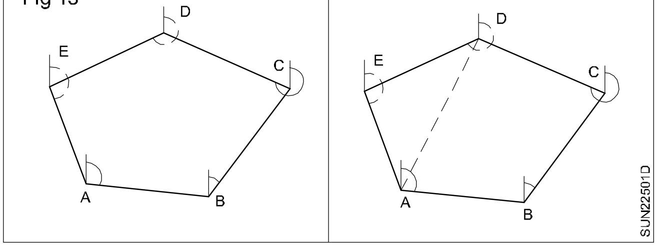

**Exercise**

Following data shows incomplete observations of a closed traverse ABCDEA, Determine the missing data.

| Line | Length (m) | Bearing |
|---|---|---|
| AB | 400 | 100°00'00" |
| BC | 600 | 30°00'00" |
| CD | 580 | 30°00'00" |
| DE | 538.08 | - |
| EA | 592.07 | - |

**Solution (Fig 13,14)**

Fig 13




| Line | Length (m) | Bearing | RB |
|---|---|---|---|
| AB | 400 | 100°00'00" | S80°00'00" E |
| BC | 600 | 30°00'00" | N30°00'00"E |
| CD | 580 | 30°00'00" | N60°00'00" W |
| DE | 538.08 | - | - |
| EA | 592.07 | - | - |

Join the line DA and form a closed traverse ABCDA.

Consecutive coordinates of B

Latitude = 400 x Cos 80°00’00” = + 69.459 m

Departure = 400 x Sin 80°00’00” = + 393.923 m

Consecutive coordinates of C

Latitude = 600 x Cos 30°00’00” = +519.615m

Departure = 600 x Sin 30°00’00” = +300.000m

Consecutive coordinates of D

Latitude = 580 x Cos 60°00’00” = +290.00 m

Departure = 580 x Sin 60°00’00” = -502.294 m

| Line | Length (m) | RB | Latitude (m) | | Departure (m) | |
|---|---|---|---|---|---|---|
| | | | N (+) | S (-) | E (+) | W (-) s |
| AB | 400 | S80°00'00"E | | 69.459 | 393.923 | |
| BC | 600 | N30°00'00" E | 519.615 | | 300.000 | |
| CD | 580 | N60°00'00" W | 290.000 | | | 502.294 |
| Total | | | 809.615 | 69.459 | 693.923 | 502.294 |
| Σ | | | +740.156 | | +191.629 | |



$\Sigma L = L_{DA} + (+740.156) = 0$

Therefore $L_{DA} = -740.156$ m

$\Sigma D = D_{DA} + (+191.629)$

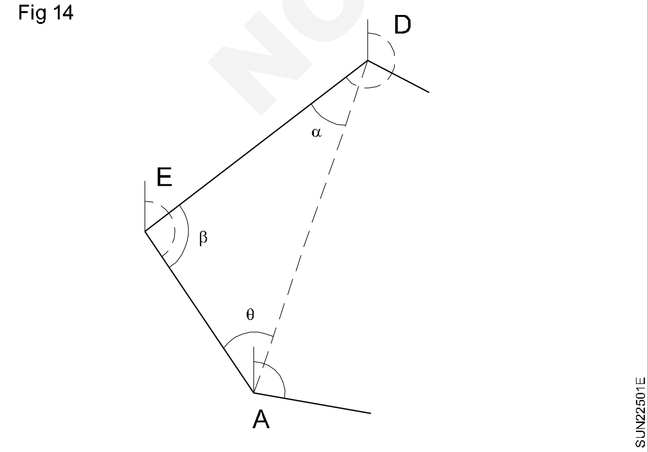
Therefore $D_{DA} = -191.629$ m

Length of DA = $\sqrt{(+740.156^2 + 191.629^2)}$

= 764.56 m

Bearing of DA = $\tan^{-1}$ (191.629/740.156) = 14°30′55″ (S - W quadrant) - Quadrant from the sign of $L_{DA}$ and $D_{DA}$ WCB of DA = 194°30′55″. Therefore, Bearing of AB = 14°30′55″

Fig 14




Area of the triangle, A = $\sqrt{S(S-AD)(S-DE)(S-EA)}$

= $\sqrt{947.355 \times 182.795 \times 409.275 \times 355.285}$

= 158684.52 $m^2$

$\beta = \sin^{-1}$ (2A / (DE x EA))

= $\sin^{-1}$ (2 x 158684.52 / (538.08 x 592.07))

= 85°00′02″

$\theta = \sin^{-1}$ (2A / (AD x EA))

= $\sin^{-1}$ (2 x 158684.52 / (764.56 x 592.07))

44°30′55″

$\alpha = \sin^{-1}$ (2A / (AD x ED))

= $\sin^{-1}$ (2 x 158684.52 / (764.56 x 538.08))

50°29′02″

Bearing of DE = Bearing of DA + <α = 194°30′55″ + 50°29′0.2″ = 244°59′57″

Bearing of ED = 244°59′57″ − 180°00′00″ = 64°59′57″

Bearing of EA = Bearing of ED + <β = 64°59′57″ + 85°00′02″ = 149°59′59″

Bearing of AE = Bearing of EA + 180°00′00″ = 329°59′59″

## Introduction and terms used in levelling

**Objectives:** At the end of this lesson you shall be able to
- **define levelling**
- **describe the uses of levelling**
- **explain the various terms used in levelling.**

**Introduction**

It is the art of determining the relative heights of various points on the surface of the earth. Levelling is the branch of surveying which deals with the measurements in the vertical plane.

**Uses:** Levelling is usually carried out for the following purposes:

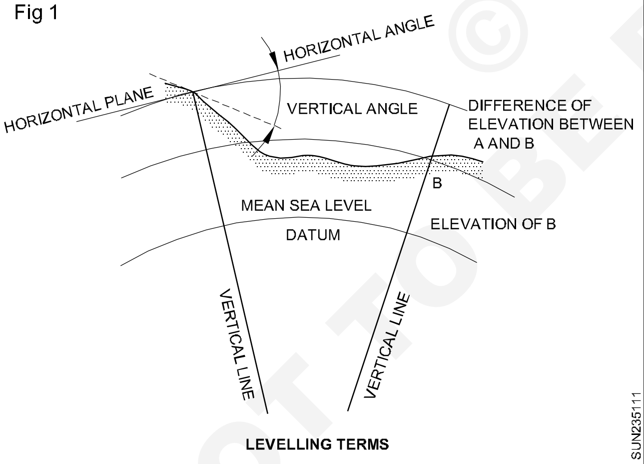
1 To prepare contour map for fixing sites for reservoirs, dams, barrages etc. and to fix the alignments of road, railways, irrigation canals etc.

2 To determine the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth.

3 To prepare a longitudinal section and cross section of a project (roads, railways, irrigation canals, etc.) in order to determine the volume of earth work.

4 To prepare a layout map for water supplying, sanitary or drainage schemes.

Fig 1




LEVELLING TERMS

**Terms used (Fig 1)**

1 **Level surface:** The surface which is normal to the direction of gravity at all points is known as level surface. All the points on a level surface is equidistant from the centre of the earth and so it is a curved surface. It is perpendicular to the plumb line at all points. E.g., surface of a still lake.

2 **Level line**: A line lying on a level surface is a level line. This is normal to plumb line at all points.

3 **Horizontal surface:** A horizontal surface is the one which is tangential to the level surface at any point.

4 **Horizontal line:** A horizontal line is the line lying in a horizontal surface. It is a straight line tangential to the level line.

5 **Vertical line:** A vertical line is a line perpendicular to the level line. It is also otherwise known as plumb line as it passes through the centre of the earth.

6 **Vertical plane:** A vertical plane is the one, which consists of many number of vertical lines.

7 **Vertical angle:** Vertical angle is an angle measured between a line and a horizontal line in a vertical plane.

8 **Datum surface:** Datum surface is an imaginary or any arbitrarily assumed level surface, from which vertical distances of the points above or below the surface are measured. The datum surface adopted by the Great Trigonometrical Survey (G.T.S) department of India is the mean sea level at Mumbai which is taken as zero.

Mean Sea Level (M.S.L.) is the average height of the sea for all stages of tides. It is the average of hourly tides for a long period of 19 years.

9 **Elevation:** The elevation of any point is its vertical height or depth above or below the datum surface. It is also otherwise known as the Reduced Level (R.L).

10 **Difference in elevation:** The difference in elevation is the vertical distance between the level surfaces passing through the two points.

11 **Bench Mark (B.M.):** A bench mark is the reference point of known elevation.

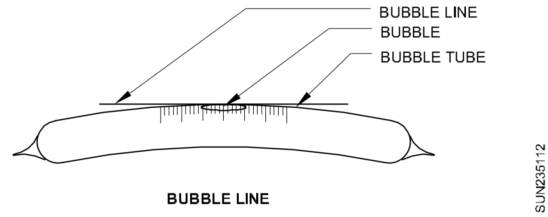
12 **Line of collimation:** A line of collimation is the line joining the intersection of cross-hairs in the diaphragm and the optical centre of the object glass, and its continuation. It is also otherwise known as line of sight.

13 **Axis of the telescope:** An axis of the telescope is the line joining the optical centre of the object glass and the centre of the eye piece. In general, the axis of telescope and the line of collimation coincides each other in case of a perfect levelling instrument.

14 **Bubble line:** A bubble line is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point. It is horizontal when the bubble is centred. (Fig 2)

15 **Vertical axis:** A vertical axis through which the telescope is revolving in the horizontal plane i.e., the axis of rotation. Normally vertical axis is the plumb line from the centre of the instrument when it is levelled.

Fig 2




**16 Back sight (B.S.):** Back sight is the first sight taken on a levelling staff held over a point or known elevation (i.e. B.M. or C.P.) after the instrument is setup and levelled. It gives the amount of height by which the line of collimation is above or below the point, and enables the surveyor to calculate the R.L. of line of collimation. It is also known as 'positive or plus sight' as this reading is added with the R.L. of the point on which it is taken to obtain the R.L. of line of collimation. (Except in the case of Inverted Staff readings.)

**17 Fore sight (F.S.):** Fore sight is the last sight taken on a levelling staff held over a point of unknown elevation (C.P.) before shifting the instrument. It gives the amount of height by which the point is above or below the line of collimation, and enables the surveyor to calculate the R.L. of the point. It is also known as 'negative or minus sight' as this reading is subtracted from the R.L. of line of collimation to obtain the R.L. of the point.

**18 Intermediate sight (I.S.):** Intermediate sight is the sight taken between the back sight and fore sight on a levelling staff held over a point of unknown elevations. It is also known as 'minus or negative sight' as this reading are separated from R.L. of line of collimation.

**19 Change point (C.P.):** A change point is the one which makes the instrument to shift from one point to another. It is a point on which both the fore sight and back sight readings are taken from the previous and new positons of instrument. Stable and well defined objects are selected as change point. A bench mark may also be taken as a change point. It is also otherwise known as turning point.

**20 Height of instrument (H.I.):** Height of instrument is the elevation of reduced level of line of collimation when the instrument is perfectly levelled. It is also otherwise known as 'Height of collimation. (Not the height of telescope from the ground).

**Types of bench marks**

Depending upon the permanency and the precision, bench marks may be classified into four categories as follows:

1 G.T.S. Bench Mark

2 Permanent bench mark

3 Temporary bench mark

4 Arbitrary bench Mmrk

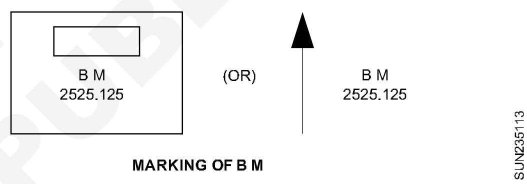
**1 GTS (Great trigonometrical survey) bench mark**

The bench marks established by the survey of India department, at an interval of 100 km all over the country with respect to the mean sea level at Mumbai as datum is known as GTS bench mark. Their positions and reduced levels are shown on GTS maps and catalogues.

**2 Permanent bench mark (Fig 3)**

These are bench marks established in between the GTS bench marks by various government department like PWD and other engineering agencies, on some permanent points, such as kilometre stone, corners of plinths of building, top of parapets of bridge etc.

Fig 3




**3 Arbitrary bench mark**

For small levelling work, any convenient well defined point may be assumed as a bench mark and elevations of other points are determined with reference to this bench mark. Such bench mark is known as arbitrary or assumed bench mark.

**4 Temporary bench mark**

The bench marks, which are established for short duration, such as at the end of a day's work, are called temporary bench marks. The work should be resumed from these bench marks.



## Principle of levelling

**Objectives:** At the end of this lesson you shall be able to
- **describe the principle of levelling**
- **list the instruments required for levelling**
- **explain the parts of a level.**

**Principle of levelling**

Principle of levelling is to obtain a horizontal line of sight from which vertical distances of the points above or below this line are found. They are achieved with the help of a level and a levelling staff respectively.

**Instruments required for levelling**

Two instruments are required for levelling namely

1 a level and

2 a levelling staff.

**1 The level**

Level is an instrument used for furnishing a horizontal line of sight. The essential parts of a levelling instrument are the following

1 Levelling head

2 Limb plate

3 Telescope

4 Bubble tube

5 Tripod stand

**1 Levelling head:** A levelling head consists of a tribrach plate having three arms each carrying a levelling screw in the ball and socket arrangement. These levelling or foot screws are used to bring the telescope bubble to the centre of its run. It has also an outer follow conical socket into which fits the inner solid spindle of the telescope, thus representing its vertical axis. The levelling head has an arrangement to fix the instrument over the tripod.

**2 Limb plate:** A limb plate is the one to which the telescope is fixed by means of standards or supports. The lower portion of the limb plate has a solid spindle which fits into the hollow socket of the levelling head. This spindle freely revolves in the outer socket and locked at the bottom by means of a locking nut.

**3 Telescope:** A telescope is an essential component part, which provides the basic line of sight for making observations in the levelling operation. Telescope consists of two tubes, one slides into the other and fitted with lens and a diaphragm having cross hairs. Depending upon the arrangements made for the movement of this tubes, telescopes are classified into two categories such as:

1 External focussing telescope

2 Internal focussing telescope

**1 External focussing telescope:** In this type of telescope, the body consist of two tubes, one of which is capable of sliding axially within the other by means of rack and pinion arrangements. This action of sliding takes place by operating a focussing screw available in the telescope. As one of this tube moves out of the other and the length gets altered, the telescope is known as external focussing telescope.

**2 Internal focussing telescope:** In this type of telescope, out of two tubes one slides into the other, the outer tube is fitted with both the eyepiece and object glass at its either end. The other interior tube carries a double concave lens, which moves inside to and fro between the diaphragm and the object glass. As the movement of inner tube is within the outer one and the length remains same, the telescope is known as internal focussing telescope.

**3 Bubble tube:** A bubble tube consists of a sealed curved glass tube set in a brass tube with plaster of paris. It is nearly filled with alcohol or either or a mixture of two, and the remaining space is occupied by air bubble. The tube is graduated on both the directions from its centre, which enables to centre the bubble by operating the foot screws available in the levelling head. One division on graduation is equals to 2 mm. The bubble tube is attached to the top of the telescope by means of capstan headed nuts, it is also otherwise known as 'Level tube" and used for levelling up the instrument. In levelling up operation bubble in the bubble tube is brought to the centre (highest point) and a line tangential to the curvature of the tube at that point is known as bubble line. The bubble line is horizontal when the bubble is in the centre.

**4 Tripod stand:** A tripod stand is the one, which supports the instrument when in use. It consists of three legs either solid or framed one. These legs are made of mahogany wood and its lower end is fitted with a pointed steel shoes so that it can be firmly pressed into the ground. The tripod should be rigid and if it has any looseness it affects the position of instrument. The tripod head, as its top carries external threads to which internal threads of the instrument is fitted.

**Types of levels**

There are various types of levels, viz.

1 The dumpy level

2 The wye or Y level

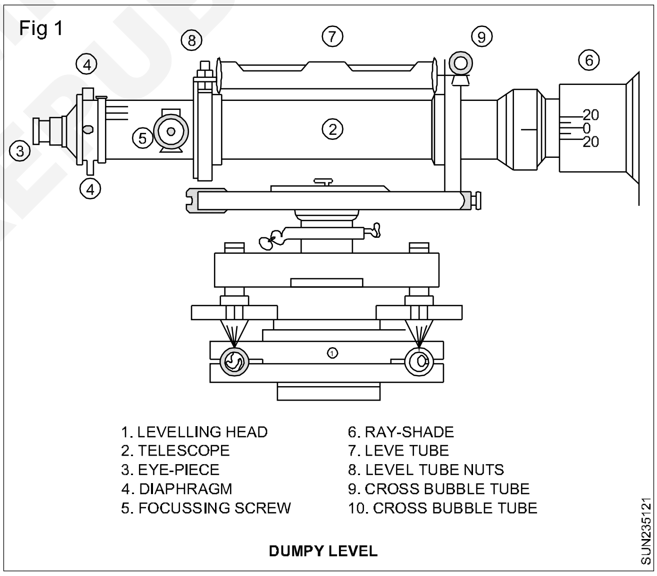
3 The cooke's reversible level

4 The cushing's level

5 Tilting level and

6 The automatic level

Fig 1

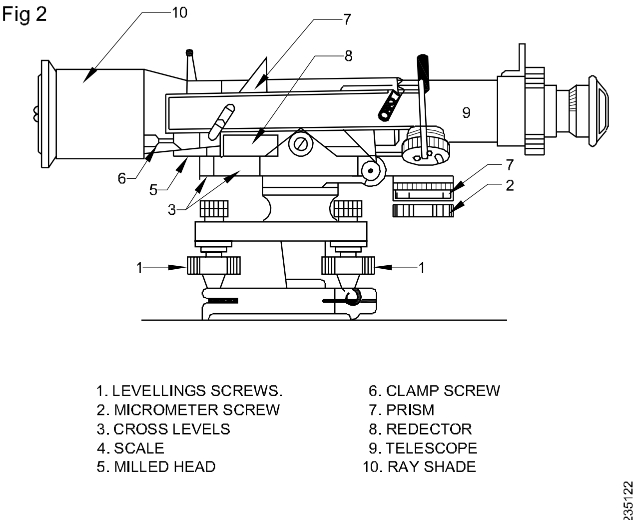



**1 The dumpy level:** The dumpy level is simple, compact, and stable. The telescope is rigidly fixed to its supports and, therefore, can neither be rotated about its longitudinal axis, nor can it be removed from its supports. It has greater stability of adjustments than the Y level.(Fig 1)

**2 The wye or Y level:** The Y level is a very delicate instrument. It consists of many loose and open parts, which are liable to frictional wear. The telescope can be removed from the Y supports, and reversed end for end. It can also be revolved about its longitudinal axis in the Y level.

**3 The cooke's reversible level:** The cooke's level combines good features of both the dumpy and Y levels. By slackening the stop screw the telescope can be

Fig 2




TILTING LEVEL

rotated about its longitudinal axis in its sockets, and can also be withdrawn from its sockets and replaced end for end.

**4 The cushing's level:** In the case of the cushing's level, the telescope can neither be removed from its socket, nor can it be revolved about its longitudinal axis. However, the eye-piece (carrying with it the diaphragm) and the object glass are removable, and can be interchanged to reverse the telescope end for the end, both collars being exactly alike. Similarly, the eye-piece end can be rotated in its fitting.

**5 The modern (Tilting) level:** In the case of this instrument the telescope has a small motion about a horizontal axis. It is, therefore, known as the tilting level. The main perculiarity of this level is that the vertical axis need not be truly vertical, since the line of collimation is not perpendicular to it. The line of collimation, is however, made horizontal for each pointing of the telescope by means of a tilting screws. It is mainly designed for precise levelling work. (Fig 2)

**6 The automatic level:** The automatic level also designated as self aligning level. The fundamental difference between the self aligning level and the classic spirit level is that, in the former the line of sight is no longer levelled manually using a tubular spirit level but is levelled automatically. Within a certain tilt range this is achieved by an inclination compensating device called tilt compensator suspended like a pendulum and inserted in the path of light rays through the telescope.

**Advantages of using auto level**

**1 Operational comfort:** Measurement is not fatiguing. Control of level which is so trying to the eyes, nerves and hands is eliminated. The automatic level does not require any protection from the sun.

**2 High precision:** Mean elevation error on invar staff graduated to 5 mm divisions varies between ± 0.5 to 0.8 mm per km of forward and backward levelling.

**3 High speed:** Time required for levelling work is about 50% of that required with ordinary level. This is an advantage where work is to be carried out in a limited time. Errors due to settlement are thereby eliminated.

**4 Freedom for errors:** The accuracy of a single measurement is increased by an erect telescope image, the levelling rods with erect figures in proper sequence, freedom from fatigue, the possibility of forgetting to get the bubble in the centre as well as simple and quick means of operation.

**5 Freedom from external influences:** The external influences like marshy ground, rain, wind, sun, loss of light due to clouds, magnetic fields, continuous vibrations, transport vibrations, have no influence of the levelling work.

**6 Range of application:** The level can be used on medium and large sized projects and setting bench marks of the 3rd to 1st order.

## Holding of levelling staff

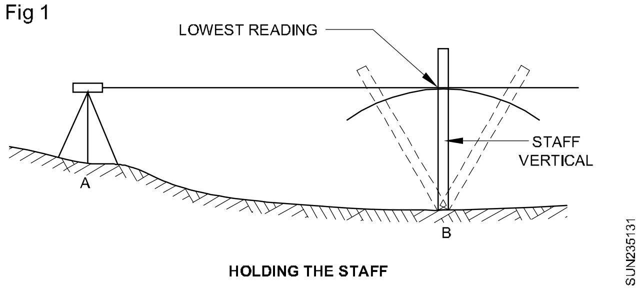
**Objectives:** At the end of this lesson you shall be able to
- **hold and read levelling staff**
- **explain the various adjustments of level**
- **explain the temporary adjustments of level**
- **state the instruction for a staff man and level man**
- **explain about hand signals used during observations.**

**Holding the staff (Fig 1)**

Utmost care should be taken in holding the staff truly vertical while the reading is being taken. To hold the staff in a vertical position, the staff man stands behind the staff, heels together, with the heel of the staff between his toes, and holds it between the palm of his hands at the height of his face. If it is not vertical, the reading will be too great.

In precise levelling, the staff is equipped with a folding circular level or a pendulum plumb bob to make it plumb while in ordinary levelling, the staff is waved slowly forward, i.e., towards the level, and backward, i.e., away from the level, and the lowest reading taken to avoid these errors.

Fig 1




HOLDING THE STAFF

## Reading the staff

The staff readings should be taken in the following order:

i Having set up and levelled the instrument carefully, direct the telescope towards the staff held vertically on the staff station and focus it.

ii Always bring the staff between the two vertical hairs, and always use the portion of the horizontal cross-hair between them in reading staff as the horizontal cross-hair may be slightly inclined. By means of the vertical hairs, the level man can see if the staff is out of plumb (sloping) sideways. If there be only one vertical hair, a reading should be taken at the intersection.

iii Observe if the bubble is central. If not, centre it by using one of the foot screws most nearly in line with the telescope, and note the reading at which the horizontal cross-hair appears to cut the staff. First note the red figure, then the black figure, and finally count the spaces. Record the reading.

When the graduations on the staff are inverted they look erect when seen through the telescope. The staff should be read upwards.

If the target staff is used, the procedure is the same except that the target is set by the staff man as directed by the instrument man, and the reading is then taken and recorded by the staff man.

## Instruction for a staff man

- The staff should be vertical and upright.
- The staff should be held on stable ground.
- When working with telescopic staff care should be taken to the extend all the parts and spring catch should be properly locked.
- When using aluminium staff extra care should be taken while extending near electric posts.

## Instruction for a level man

Levelling should always commence from a permanent BM and end on a permanent BM

The level should be setup on a firm ground and at a place where maximum number of sights can be taken. To avoid errors due to imperfect adjustment of the instrument, the instrument should be setup approximately mid way between the change points.

Move the telescope laterally by gentle tapping to bring the staff exactly between the vertical hairs and focus it.

While looking through the telescope, the staff is seen inverted. Therefore, it should always be read from above downwards and not upwards.

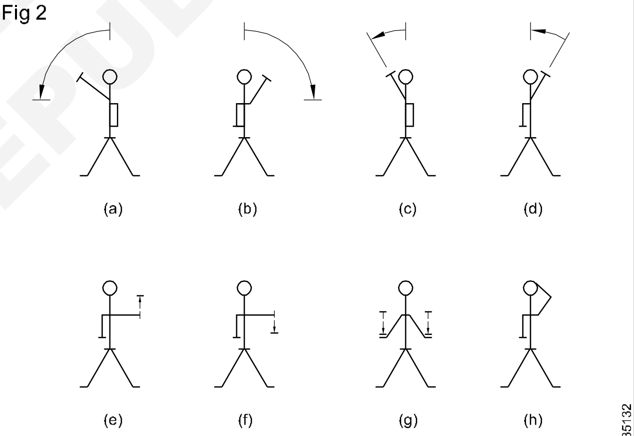
When a group of surveyors are working, one's own staff should be carefully recognized.

**Following hand signals should be observed**

**Hand signals during observations**

When levelling is done at construction site located in busy, noisy areas, it becomes difficult for the instrument man to give instructions to the man holding the staff at the other end through the vocal sounds. In that case, the following hand signals are found to be useful. (Table 1 and Fig 2)

Fig 2



HAND SIGNALS

**Table 1**

| | Signal | Message |
|---|---|---|
| a | Movement of left arm over 90 | Move to my left |
| b | Movement of right arm over 90 | Move to my right |
| c | Movement of left arm over 30 | Move top of staff to my left |
| d | Movement of right arm over 30 | Move top of staff to my right |
| e | Extension of arm horizontally and moving hand downwards | Raise height of peg or staff |
| f | Extension of arm horizontally and moving hand downwards | Lower height of peg or staff |
| g | Extension of both arms and slightly thrusting downwards | Establish the position |
| h | Extension of arms and placement of hand on top of head | Return to me |

# Levelling staff

**Objectives:** At the end of this lesson you shall be able to
- **describe levelling staff**
- **explain the classification of levelling staff**
- **explain the constitution of various types of levelling staff.**

**Levelling staff**

A levelling staff is a straight, rectangular wooden rod graduated into meters and smaller divisions. The bottom of the rod (Levelling staff) represents zero reading. The levelling staff is used to determine the amount of height or depth by which the point is above or below the line of sight. It is usually made up of well seasoned wood.

The graduations on the levelling staves are such that a metre length is divided into 10 main divisions of one division equals to 10 cm or 1 decimetre. Again this one main division is sub divided into 20 more strips of alternate black and white in colour of width 5 mm. Hence the smallest value, which we can observe with the levelling staff is 5 mm. therefore the least count is 0.005m. Main divisions in each metre length is marked with numerals 1 to 9 in black colour. The readings correspond to metre's length is marked with numerals 1, 2, 3, .....etc. in red colour. These numerals are marked in such a way that its top is coinciding with the end of that graduation. For convenience the numerals like 5 and 9 are marked as V and alphabet N respectively, to avoid confusion with the numerals 2 and 6, as the staff is invertedly seen when viewed through the telescope.

**Types of staves:** The levelling staves are mainly classified into two categories based on the method of observation as follows:

1 Self reading staff

2 Target staff

**1 Self reading staff:** Self reading staff is the one, by which the readings are observed directly by an observer (instrument man) who views through the telescope. These staves are further classified based on the construction as follows:

i Solid staff

ii Folding staff

iii Telescopic staff

iv Invar staff

**i Solid staff:** A solid staff is one, which is made of seasoned wood either Pine or Deodar. It is usually 3 m long in one piece length. It has the cross section of 75 mm in width and 25 mm to 40 mm in thick. Due to the absence of range or socket on these staves greater accuracy is achieved. On the other hand it is inconvenient to carry them in the field. Its use is restricted only to precise levelling.

**ii Folding staff:** Folding staff is the one, which is also made of seasoned wood and available in two pieces of length equals to 2 m. The total length of this staff is 4 m. These two pieces are connected by means of a hinge. The folding staff has the cross section of 75 mm in width and 18 mm in thick. The joint provided in the folding staff is such that

a The staff may be folded to a length of 2 m when it is not in use.

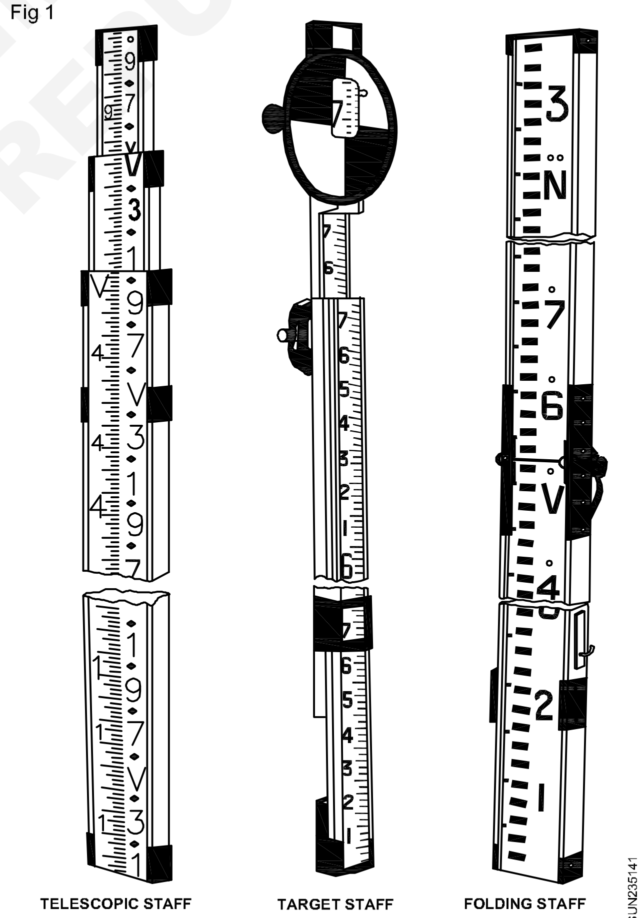
b The pieces may be easily detachable from one another for easy handling.

c When the two pieces are locked together the staff is quite rigid at the joint and perfectly straight.

The foot of the staff is provided with a brass cap to avoid wear and tear due to usage.

**iii Telescopic staff:** A telescopic staff is the one which consists of three pieces, one slide into the other. It has the maximum lengths of 4 m or 5 m when fully extended. The 4 m telescopic staff has a top solid piece of length 1.25 m, which slides into the central bos of 1.25 m length, which in turn slides into the lower box of length 1.5 m. Brass spring catches are provided to hold the extensions in position. (Fig 1)

Fig 1




**iv Invar staff:** The invar staff is also 3 m long. An invar band is fitted to a wooden staff. The band is graduated to millimetres. It is used for precise levelling work.

**2 Target staff:** A target staff is the one by which the readings are observed by the staff man has the target is viewed by the instrument man. This target staff is provided with a movable target. The target is provided with vernier, which is adjusted by the staff man as directed by the instrument man until its centre line coincides with the horizontal cross hair in the diaphram. The readings are then observed and recorded by the staff man. This type of staves are used when the sights are long.

## Temporary adjustments of level

**Objectives:** At the end of this lesson you shall be able to
- **explain the various adjustments of level.**
- **explain the various steps involved in the temporary adjustments of level.**

### Adjustments of the level

There are two types of the adjustments.

1 Permanent, and

2 Temporary

The permanent adjustments are made to establish the fixed relationship between the fundamental lines of an instrument. Once made, the permanent adjustments last for a long time depending on the type of the instrument. The temporary adjustments are made at each set up of the instrument before starting to take the various staff readings.

### Temporary adjustments of the level

These are performed to make the axis of rotation vertical and to eliminate the parallel every time when the instrument is shifted and set up in a new position. It is also known as "setting up" of the instrument and is made in the following steps:

1 Fixing the instrument on stand.

2 Levelling up of the instrument.

3 Focussing.

### Fixing level with tripod stand

The tripod stand is placed at the required position with its legs well apart, and pressed firmly into the ground.

The level is fixed on the top of the tripod stand according to the fixing arrangement provided for that particular level. It should be remembered that the level is not to be set up at any station or point along the alignment.

### Levelling up of the instrument

It is done approximately by legs and correctly by the levelling screws.

### Levelling by legs

Bring all the foot-screws in the centre of their run and place the instrument in a desired position at a convenient height with the tribrach plate as nearly horizontal as possible. Fix any two firmly into the ground by pressing them with hand and turn the telescope to be nearly parallel to the line joining the feet of these two legs.

Then move the third leg to right or left and in or out to bring the long and cross bubbles respectively in their central positions. Much time is saved if nearly all the levelling is done by the tripod legs.

### Levelling by foot-screws

Place the telescope parallel to any pair of the foot-screws and bring the long bubble to the centre of its run by turning these screws equally either both inwards or both outwards (Fig 1) To move the bubble to the right turn the screws inwards and to move it to the left turn the screws outwards (right in and left out)

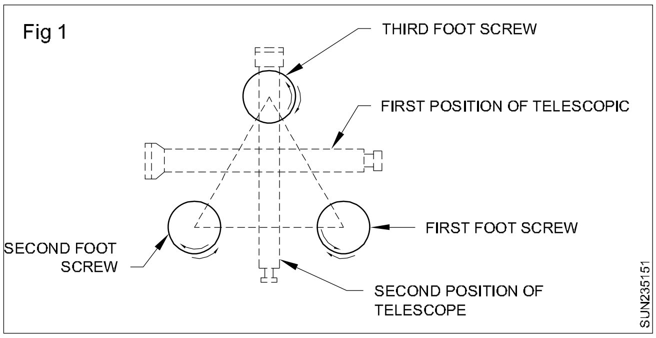
Then turn the third foot screw to bring the cross bubble to its central position. Repeat this until both the bubbles are centred. If the instrument is in permanent adjustment, then the bubbles will traverse for all directions of the telescope.

(i) Note. The instrument should, as far as possible, be set up on a solid ground to avoid its settlement in the course of observation in a setting. However, if such stable ground is not available, the tripod legs should be pressed firmly into the ground.

(ii) While setting the instrument on a pucca floor, the shoes of the tripod should, as far as possible, be placed in the joints to prevent the legs from spreading out through slipping.

(iii) When setting on a sloping ground, two legs should be kept down slope and the third up slope.

Fig 1




### Focussing

This is done in two steps viz. (i) Focussing the eye-piece for distinct vision of the cross-hairs at diaphragm, and (ii) focussing the object-glass for bringing the image of the object into the plane of the diaphragm.

### Focussing the eyepiece

This operation is done to make the cross-hairs appear distinct and clearly visible. The following steps are involved:

1 The telescope is directed skywards or a sheet of white paper is held in front of the objective.

2 The eyepiece is moved in or out till the cross-hairs appear distinct.

**Focussing the objective**

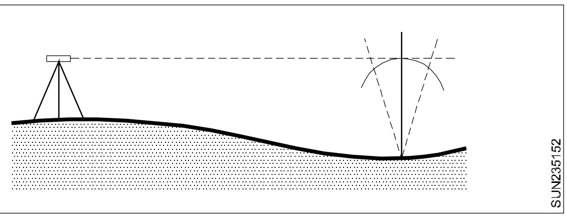
This operation is done to bring the image of the object in the plane of the cross-hairs. The following steps are involved:

1 The telescope is directed towards the staff.

2 The focussing screw is turned until the image appears clear and sharp.

Holding the staff It is imperative that the levelling staff be held vertically while a reading is being taken. If the staff is inclined in any direction, the reading will be erroneous; always more than the actual. The staff reading will be correct only when the staff is truly vertical.

Fig 2




To find the true vertical position of the staff, it is waved slowly towards and away from the level. The lowest reading on the staff will be when the staff is truly vertical.

**Reading the staff**

1 Setup the instrument and level it carefully.

2 Direct the telescope towards the staff and focus it. The telescope is moved till the staff bisects the vertical hair of the diaphragm.

3 Observe if the bubble on the telescope is at the centre before taking the reading. If not, centre it by using one of the footscrews most nearly in line with the telescope.

4 Note the reading at which the horizontal hair appears to cut the staff. The staff should be read upwards.

## Permanent adjustment of level

**Objectives:** At the end of this lesson you shall be able to
- **state the need of permanent adjustment**
- **list the names the fundamental lines of a levelling instrument**
- **describe the types of adjustment.**

**Permanent adjustment**

It is made to establish the fixed relationship between fundamental lines of a levelling instrument, once made, they will last for a long time. Depending upon the construction of the instruments different levels need different permanent adjustments.

The fundamental lines are

- The line of collimation
- The axis of the bubble tube
- The vertical axis
- The axis of the telescope

There are only two permanent adjustments are required in a dumpy level

1 The first adjustment, to make the axis of the bubble tube perpendicular to the vertical axis.

2 The second adjustment, to make the line of collimation parallel to the axis of the bubble tube.

**Tilting level**

In this type of instrument, a single permanent adjustment is required. (i.e) bubble axis should be made parallel to the collimation axis of the telescope.

**Permanent adjustment of a dumpy level**

**Two peg method (Fig 1)**

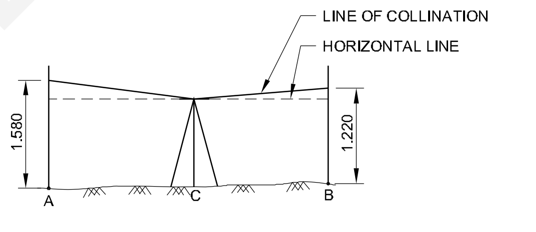
**Example 1**

In a two peg test of a dumpy level, the following readings were taken.

i) Instrument at C, midway between A and B (AB = 150 m)

Staff reading on A = 1.580, Staff reading on B = 1.220

Fig 1




ii) Instrument near A

Staff reading on A = 1.420, Staff reading on B = 1.150

Is the line of collimation inclined upwards or downwards and by how much? with the instrument at A what should be the staff reading on B in order to place the line of collimation truly horizontal.

a) Dumpy level is at mid point 'C' (Fig 1)

Staff reading on A = 1.580

Staff reading on B = 1.220

True difference of level = 1.580-1.220 = 0.360m

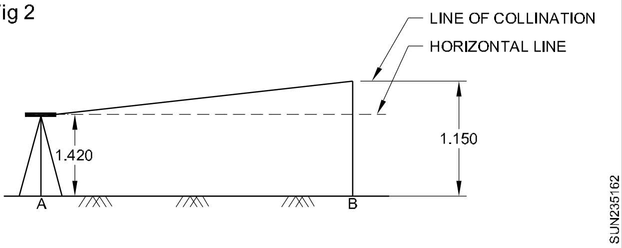
Rise from A to B

b) Level at A (Fig 2)

Staff reading on A

= 1.420m correct reading (uneffected by error of collimation)

Fig 2




Subtract true rise = 0.360m

True staff reading on B = 1.420 - 0.360 =1.060m

Observed staff reading on B = 1.150 m

**Observed staff reading is more than the required true staff reading, the line of collimation is inclined upwards.**

The collimation error = 1.150 - 1.060 = 0.090 m

Staff reading on B which makes the line of collimation truely horizontal

= 1.150-0.090 = 1.060m

**Example 2**

Following observations were taken for testing of a dumpy level.

i) Instrument exactly at the midpoint of line AB

Staff reading at station A = 1.855

Staff reading at station B = 1.600

ii) Instrument is very near to station B

Staff reading at station A = 0.675

Staff reading at station B = 0.925

Find out,

Find i) whether the line of collimation is on adjustment or not.

If it is not in adjustment what is the nature and amount of the error in distance AB?

ii) What will be the correct readings on staff at A and B from station B. When the line of collimation is adjusted.

**Solution**

Instrument exactly at the midpoint (Fig 3a)

i) Staff reading at station A = 1.855

Staff reading at station B = 1.600

True difference in level between A and B.

= 1.855-1.600 = 0.255 m

Station B is higher than station A.

ii) Instrument at station B (3b)

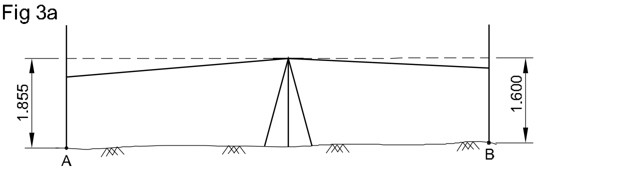
Reading at B, 0.925 is correct

Correct Reading at A = 0.925 + 0.255 = 1.180 m

But observed reading on A = 0.675

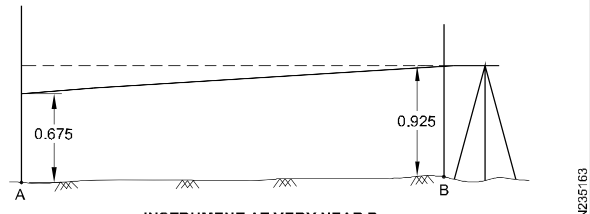
Collimation error = 1.180 - 0.675 = 0.505

Fig 3a




INSTRUMENT AT MIDWAY BETWEEN A& B

Fig 3b




INSTRUMENT AT VERY NEAR B

The observed reading is less than true reading the line of collimation is inclined downwards.

**Example 3**

Following observations were taken for testing of a dumpy level by two peg method.

Instrument at E, mid way between point C and D, 100m apart

Reading at C = 2.000m

Reading at D = 3.000m

Instrument at peg F in line of CD such that CF = 120m and DF = 20m

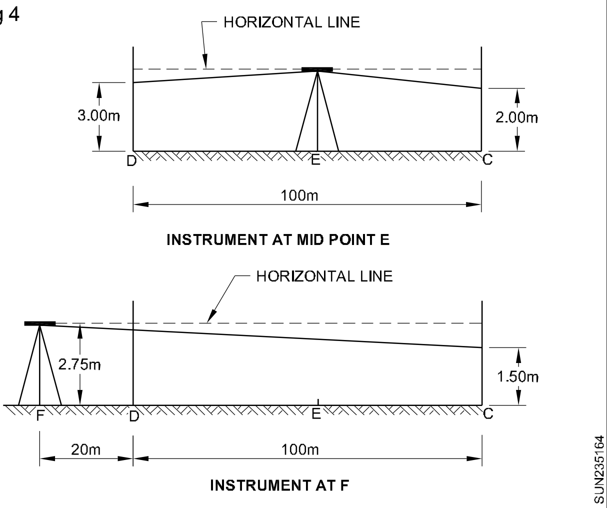
Reading at point C = 1.500m

Reading at point D = 2.750m

Check whether the instrument needs permanent adjustment or not and whether the line of sight is inclined upwards. What should be the correct reading at C is the instrument is to be adjusted.

**Solution** (Fig 4)

Fig 4




Dumpy level at mid point E

Staff reading on D = 3.000m

Staff reading on C = 2.000m

True difference of level = 3.000 - 2.000

= 1.000 (C is at higher)

Dumpy level at point F

Staff reading on D = 2.750m

Staff reading on C = 1.500m

Apparent difference in level = 2.750 - 1.500

= 1.250m (C is at higher)

The staff reading on the point C at the level of D

= Reading on D -True difference in level

= 2.750-1.000 = 1.750m

As the observed reading 1.500m is less than the calculated value 1.75m the line of collimation is inclined downwards.

The net collimation error is 100m = 1.750-1.500 = 0.25m

Correction to the reading on point C,

$$= \frac{120}{100} \text{ x } 0.25 = 0.30 \text{ m}$$

Correction for 100m = 0.25m

Correction for 120m

Correct staff reading on the point C

= Observed reading + correction

= 1.500 + 0.300 = 1.800 m

Correction for 20m = 2

$$= \frac{20}{100} \text{ x } 0.25 = 0.05 \text{ m}$$

Correction staff reading at the point

D = Observed reading + correction

= 2.750 + 0.050 = 2.800m

Check: Correction level difference = 2.800 - 1.800 = 1.000m

(Same as calculated as the instrument at mid way position)

**Exercise 1**

While checking a dumpy level, the following readings were obtained.

Level setup midway between two staff stations A and B 100m apart. Staff readings on A is 1.900m and on B is 1.400m level is setup 10m behind B and in line AB. Staff readings on B = 1.100m and on A = 1.350m. Determine the amount of instrument error and its inclination.

**Exercise 2**

The following observations were taken during the testing of dumpy level.

| Instrument station | Staff readings on A | B | Remarks |
|---|---|---|---|
| C | 1.150 | 1.795 | i) C is exactly midway between A and B |
| D | 1.530 | 1.930 | ii) AB = 100 m apart<br>iii) D lies on BA produced and 20m behind 'A' |

Find the readings on A and B to give a horizontal line of sight when the instrument was setup at D.

# Different types of levelling

**Objectives:** At the end of this lesson you shall be able to
- **name the various types of levelling**
- **explain simple levelling**
- **explain differential levelling**
- **complete the reduced levels of points.**

According to the method adopted, levelling may be classified into two

1 Direct levelling

2 Indirect levelling

**Direct levelling**

The method of levelling in which the relative heights of points are found out by some direct observation is called direct levelling.

**Various methods of direct levelling**

1 Simple levelling

2 Differential levelling

3 Reciprocal levelling

4 Profile levelling

 i Longitudinal sectioning

 ii Cross sectioning

5 Fly levelling

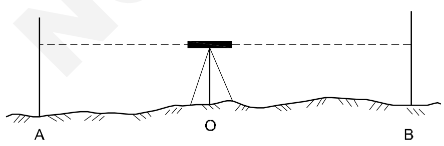
6 Check levelling

**Simple levelling**

When the difference of level between two points is determined by setting the levelling instrument midway between the points, the process is called simple levelling.

Suppose A and B are two points whose difference of level is to be determined. The level is set up at O, exactly midway between A and B. After proper temporary adjustment, the staff readings on A and B are taken. The difference of these readings gives the difference of level between A and B. (Fig 1)

Fig 1




**Differential levelling (Fig 2)**

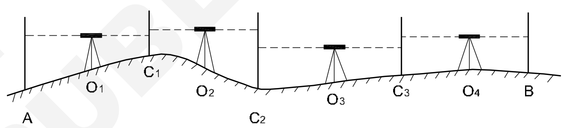
Differential levelling is adopted when (i) the points are a great distance apart, (ii) the difference of elevation between the points is large, (iii) there are obstacles between the points.

This method is also known as compound levelling or continuous levelling. In this method, the level is set up at several suitable positions and staff readings are taken at all of these.

Suppose it is required to know the difference of level between A and B. the level is set up at points O1, O2, O3, etc. After temporary adjustments, staff readings are taken at every set up. The points C1, C2 and C3 are known as change points. Then the difference of level between A and B is found out. If the difference is positive, A is lower than B. If it is negative, A is higher than B.

Knowing the R.L. of A, that of B can be calculated.

Fig 2




**Problems in levelling**

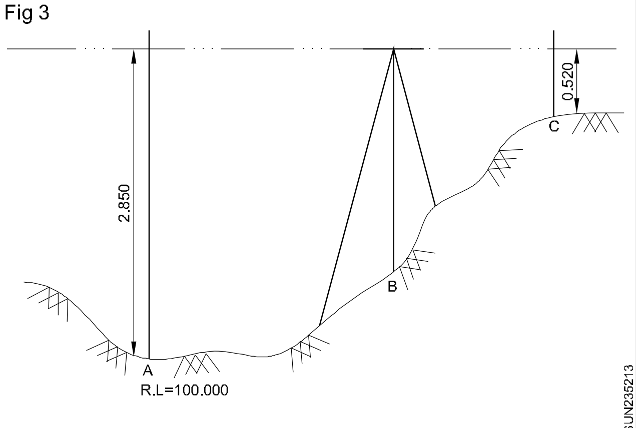
**Example 1**

In a simple levelling the Back sight taken from a point A of R.L. 100.000 is 2.850 m and Foresight taken from point C is 0.520 m find

i The difference of level between the A and C (Fig 3)

ii The R.L. at point C

Fig 3




**Solution**

i The difference of level between A and C

 = 2.850 – 0.520 = 2.330

Height of collimation = R.L. at point A + B.S. taken from point A

= 100.000 + 2.850

= 102.850 m.

ii R.L. at point C

= Height of collimation – Foresight reading at C

= 102.850 – 0.520

= 102.330 m

**Exercise 1**

The back sight reading at A is 3.560 m and the foresight reading at B is 2.860 m. Find the difference in level of A and B.

**Exercise 2**

The back sight reading on a staff held vertically on a bench mark whose R.L. 100.000 was 2.960 m and the foresight on the staff held vertical on a rail was 0.880 m. Find the reduced level of the rail.

**Inverted**

**When the BM or staff station is above the line of sight**

In this case, it occurs when the underside of a string course or sunshade is made a Benchmark, or when the elevation of the underside of a girder, and arch or tie beam is to be determined. It is easy to hold the staff inverted and the reading being negative, is entered in the level book with a minus sign. To avoid confusion "Staff inverted" should be written in the Remarks column against the entry of the reading.

**Problems in inverted level**

**Example 1**

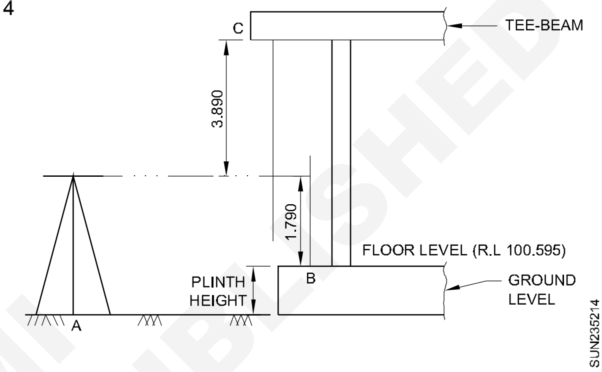
The R.L. of the floor is 100.595 m and staff reading on the floor is 1.790 m. The reading on the staff held upside down against the underside of the tee beam is 3.890 m. Find the height of the beam above the floor level.

**Solution (Fig.4)**

i Sketch

ii Tabulation

Fig 4




| Back sight | Inter sight | Foresight | HCL | Reduced Level | Remarks |
|---|---|---|---|---|---|
| 1.790 | | | 102.385 | 100.595 | Staff reading on the floor (B) |
| | | -3.890 | | 106.275 | Inverted staff reading at bottom of tee beam |

**Calculation**

R.L. of the floor = 100.595 m

Staff reading on the floor (B) = 1.790 m

∴ Height of collimation at A

= R.L. of the floor + Staff reading on the floor

= 100.595 + 1.790

= 102.385 m

R.L. of the underside of the tee beam = 102.385

= 102.385 - (-3.890) = 106.275 m

Height of the tee beam above the floor level

= 106.275 - 100.595 = 5.680 m (Ans.)

**Exercise 1**

Find the height of the tee beam above the floor level from following data. R.L. of the floor level = 100.000, Staff reading on the floor = 1.150 reading on the staff held inverted the bottom touching the underside of the tee beam = 3.450 m.

**Exercise 2**

The back sight reading on a staff held vertical on a benchmark whose R.L. is 501.00 m is 1.580 m and the foresight on a staff held vertically inverted against a beam is 3.580 m. Find the reduced level of the beam.

**Problems in differential levelling**

**Example**

Tabulate and enter the following staff reading were taken in the differential levelling and also find the R.L. of all the points. The first reading was taken on a B.M. of R.L. 100.000 by

**i HCL method (height of collimation method)**

Apply usual check

2.045, 2.680, 2.860, 2.120, 2.975 and 2.860

## Solution

### Height of collimation method

| Back sight | Inter sight | Foresight | HCL | Reduced level | Remarks |
|---|---|---|---|---|---|
| 2.045 | | | 102.045 | 100.000 | Reading taking on B.M. |
| | 2.680 | | | 99.365 | Point 1 |
| | 2.860 | | | 99.185 | Point 2 |
| | 2.120 | | | 99.925 | Point 3 |
| | 2.975 | | | 99.070 | Point 4 |
| | | 2.860 | | 99.185 | Point 5 |
| Σ2.045 | | Σ2.860 | | | |

**Calculation**

Height of collimation = R.L. of B.M. + Back sight

= 100.000 + 2.045

= 102.045 m

R.L. of point 1 = HCL – I.S. reading on point 1

= 102.045 – 2.680

= 99.365

R.L. of point 2 = HCL – I.S. reading on point 2

= 102.045 – 2.860

= 99.185

R.L. of point 3 = HCL – I.S. reading on point 3

= 102.045 – 2.120

= 99.925

R.L. of point 4 = HCL – I.S. reading on point 4

= 102.045 – 2.975

= 99.070

R.L. of point 5 = HCL – F.S. reading on point 5

= 102.045 – 2.860

= 99.185

**Arithmetic check**

The difference between the sum of back sights and the sum of fore sights should be equal to the difference between the last and the first RLS.

Σ B.S. – F.S = Last R.L. – First R.L.

2.045 – 2.860 = 99.185 – 100.000

– 0.815 = – 0.815

### ii Rise and fall method

| B.S. | I.S. | F.S | Rise | Fall | Reduced Level | Remark |
|---|---|---|---|---|---|---|
| 2.045 | | | | | 100.000 | Reading taken on B.M. |
| | 2.680 | | | 0.635 | 99.365 | Point 1 |
| | 2.860 | | | 0.180 | 99.185 | Point 2 |
| | 2.120 | | 0.740 | | 99.925 | Point 3 |
| | 2.975 | | | 0.855 | 99.070 | Point 4 |
| | | 2.860 | 0.115 | | 99.185 | Point 5 |
| Σ2.045 | | Σ2.860 | Σ0.855 | Σ1.670 | | |

**Calculation**

i B.S. on B.M. – I.S. on point 1 = 2.045 - 2.680

= -0.635 (Fall)

ii I.S. on point 1 - I.S. on point 2 = 2.680 - 2.860

= -0.180 (Fall)

iii I.S. on point 2 - I.S. on point 3 = 2.860 - 2.120

= 0.740 (Rise)

iv I.S. on point 3 - I.S. on point 4 = 2.120 - 2.975

= 0.740 (Rise)

v I.S. on point 4 - F.S. on point 5 = 2.975 - 2.860

= 0.115 (Rise)

R.L. of point 1 = R.L. of B.M. - Fall of point 1

= 100.000 - 0.635

= 99.365

R.L. of point 2 = R.L. of point 1 - Fall of point 2

= 99.365 - 0.180

= 99.185

R.L. of point 3 = R.L. of point 2 + Rise of point 3

= 99.185 + 0.740

= 99.925

R.L.of point 4 = R.L. of point 3 - Fall of point 4

= 99.925 - 0.855

= 99.070

R.L. of point 5 = R.L. of point 4 + Rise of point 5

= 99.070 + 0.115

= 99.185

**Arithmetic check**

Σ B.S - Σ F.S. = Σ Rise - Σ Fall = Last R.L. – First R.L.

2.045 – 2.860 = 0.855 – 1.670 = 99.185 – 100.000

- 0.815 = - 0.815 = - 0.815

**Exercise 1**

Tabulate and enter the following readings on the level field book and find the reduced levels of the points.

i Height of collimation method

ii Rise and fall method

2.200, 2.430, 2.400, 2.120, 2.900 and 2.750

Apply usual check

## Level field book

**Objectives:** At the end of this lesson you shall be able to
- **describe the term level field book and its various forms**
- **explain the point to be observed while recording a level book**
- **compute the reduced levels of the staff stations.**

**Form of a level book**

Whenever the levelling operation is carried out and number of observations are taken in the field, they are to be entered in a note book called a 'Level Book.' Each page of this level book has the following columns which helps to enter the readings and reduce the levels. Left side of each page consists of column corresponds to the staff readings and reduction of levels. Right side of each page consists of columns for remarks to note down the details of bench marks for which the readings have been taken

**Two forms of level book**

Page of a level book

**1 Height of collimation method**

| B.S. | I.S. | F.S. | H.I. or H.C. | R.Ls. | Remarks |
|---|---|---|---|---|---|
| | | | | | |

**2 Rise and fall method**

| B.S. | I.S. | F.S. | RISE | Fall | R.Ls. | Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |

Apart from the above, details such as name of work, instrument number, name of the surveyor etc. are to be furnished in each page of a level book.

Name of the work………................… Date……………

Name of the Surveyor…….......  Instrument No…………

**Points to be observed while booking readings in a level book**

1 Every horizontal line in a page of level book represents one station only.

2 Readings are to be entered in the respective columns in the order of observation.

3 First reading in a page of level book should be Back sight and the last reading should be Fore sight.

4 If the last entry happens to be an intermediate sight, enter it in the Fore sight column of that page and the same is repeated in the Back sight column of the next page

5 Fore sight and Back sight reading of a change point should be entered in the same horizontal line

6 R.L. of line of collimation or height of collimation should be written in the same horizontal line corresponds to its back sight.

7 Details of staff station should be written briefly in the remarks column.

7 Details of staff station should be written briefly in the remarks column.

8 All the readings should be entered in ink only.

9 When observations of a work is continued in many number of pages, no reduction of levels in the next page is done unless the previous page is checked.

**Reduction of levels**

Reduction of levels is the process of calculating the R.L. for various points to which observation are taken. There are two methods of calculating the RL. such as:

1 Height of collimation method

2 Rise and fall method

**Height of collimation method**

In this method height of collimation i.e., the R.L. of line of collimation for each set up of the instrument is obtained by adding the back sight reaching to the R.L. of a bench mark on which back sight is taken. The R.L. of line of collimation is taken as a reference and the R.L. for various other points from that set up of the instrument is obtained by subtracting their respective staff readings such as Intermediate sight of Fore sight.

When the instrument is shifted to a new station, the height of collimation for that set up is obtained by adding the staff reading taken on a change point (i.e., the point of which the last observation is taken from the previous instrument station) to its R.L. The R.L. of the other staff stations observed from the new station are obtained by subtracting their respective staff readings from its height of collimation. This process is repeated until the last point is reached.

In general height of collimation method is given by

Height of collimation = R.L. of a BM + Back sight reading

R.L. of other staff stations = Height of a collimation – I.S./ F.S. readings

After the completion of the above calculation it can be checked for its correctness by an Arithmetical check.

**Arithmetical check**

$\Sigma$ BS – $\Sigma$ FS = Last R.L. – First R.L.

**Rise and fall method**

In this method the difference of level between the two consecutive points is obtained by comparing the staff readings taken from the same set up of the instrument. This difference indicates whether the next point is at Rise or Fall than the previous one. If the staff reading is greater, the point is at Fall. If the staff reading is smaller, the point is at Rise. The R.L. of any point is determined

by either adding or subtracting the respective rise or fall values from the R.L. of the previous point. The above procedure is repeated until the last point is reached.

In general Rise and Fall method is given by:

First reading – Second reading = ± Rise / Fall.

(When the second reading is subtracted from the first one, the positive result means the rise and the negative result means fall)

R.L. of any point = R.L. of the previous point ± Rise / Fall of that point (use positive sign for rise and negative sign for fall).

After the completion of the above calculations it can be checked for its correctness by an Arithmetical check.

**Arithmetical check**

This Arithmetical check also provides check only for calculations not the result.

In this the differences between, the sum of B.S. and F.S. the sum of rise and Fall and the last R.L. and first R.L. should be equal.

$\Sigma$ F.S. – $\Sigma$ B.S. = $\Sigma$ Fall = $\Sigma$ Rise = First R.L. = Last R.L. which depends upon the respective values.

This method provides a complete check on the intermediate sight also.

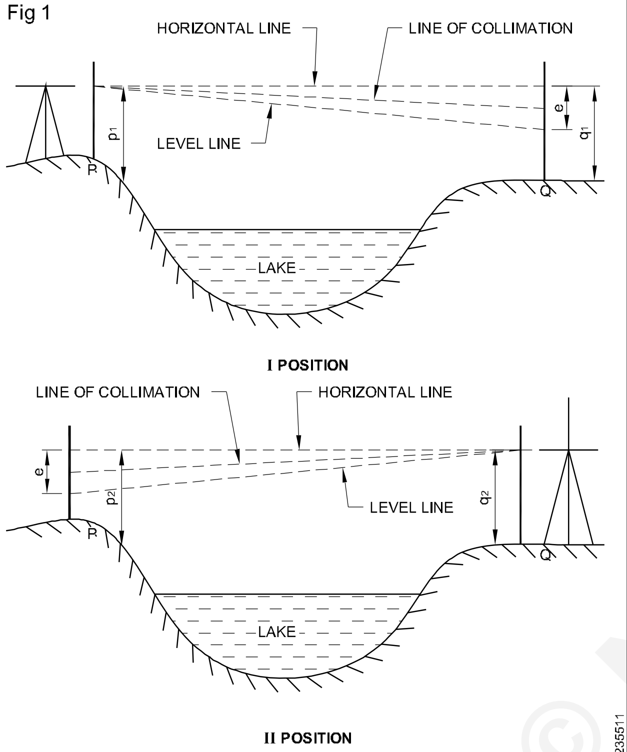
**Comparison of line of collimation method with rise and fall method**

| S.No | Line of collimation method | Rise and fall method |
|---|---|---|
| 1 | It is more rapid and the computation is easier and faster. | Computation is labourious and time consuming, because each and every staff reading is compared. |
| 2 | It is simple method used for reduction in profile levelling. | This method is used where more accuracy is required. |
| 3 | There is no check in reduction of levels for intermediate stations. | There is a complete check for all intermediate |
| 4 | Errors if any commited in reduction of levels for intermediate stations, cannot be deducted | Errors can be noticed and rectified for intermediate stations. |

## Reciprocal levelling

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of reciprocal levelling**
- **explain the procedure of conducting reciprocal levelling.**

Fig 1




RECIPROCAL LEVELLING

### Reciprocal levelling

When it is not possible to setup the level midway between two points, as in the case of levelling across a river or lake, the reciprocal levelling is used.

Let P and Q be two points on opposite banks of a lake.

The difference of level between two points P and Q is found by this method.

### Procedure

Set up the level very near to P (Fig 1)

With bubble tube central, take staff readings on staff held at P and Q

Let the staff readings on P be $p_1$ and Q be $q_1$, reading on P is usually taken through objective. Since the staff is very close, to get the readings clear, a pencil point is moved up and down.

Transfer the instrument to Q and set it up very near to q.

With the bubble central, read the staff held at P and Q.

Let the staff readings at P and Q be $p_2$ and $q_2$ respectively.

### Computation

Let h = true difference of level between P and Q

E = combined error due to curvature refraction and imperfect adjustment of line of collimation.

**First position**

The correct readings on staff Q = $q_1 – e$

The correct reading on staff P = $p_1$

Assuming P to be higher than Q, true difference of level

$h = (q_1 – e) – p_1$

(or) $h = (q_1 – p_1) – e \longrightarrow 1$

**Second position of level**

The correct reading on staff Q = $q_2$

The correct reading on staff P = $(p_2 – e)$

The true difference in level

$H = (q_2 – (p_2 – e)$

(or) $h = (q_2 – p_2) + e \longrightarrow 2$

Adding equation 1 and 2

$h = (q_1 – p_1) – e \longrightarrow 1$

$h = (q_2 – p_2) + e \longrightarrow 2$

$h + H = (q_1 – p_1) – e + (q_2 – p_2) + e$

$2h = (q_1 – p_1) + (q_2 – p_2)$

$$\text{i.e. } h = \frac{(q_1 - p_1) + (q_2 - p_2)}{2}$$

(i.e.) The apparent difference of level between p and q is equal to the mean of the two apparent differences of level.

The combined error can be obtained by equating the equation 1 and 2

$(q_1 – p_1) – e = (q_2 – p_2) + e$

$2e = (q_1 – p_1) – (q_2 – p_2)$

$$e = \frac{(q_1 - p_1) + (q_2 - p_2)}{2}$$

(i.e.) combined error is equal to the half of the apparent difference of the level.

**Reciprocal levelling**

**Example 1**

In levelling between two points A and B on opposite banks of a river, the level was setup near A and the staff readings on A and B were 2.150 and 3.560 respectively. The level was then moved and setup near B, and the respective staff readings on A and B were 1.960 and 3.260. Find the true differences of level of A and B.

**Solution**

a When the level was setup near A, (Fig 2)

Incorrect difference of level = 3.560 – 2.150

= 1.410

b when the level was setup near B,

Incorrect difference of level = 3.260 – 1.960

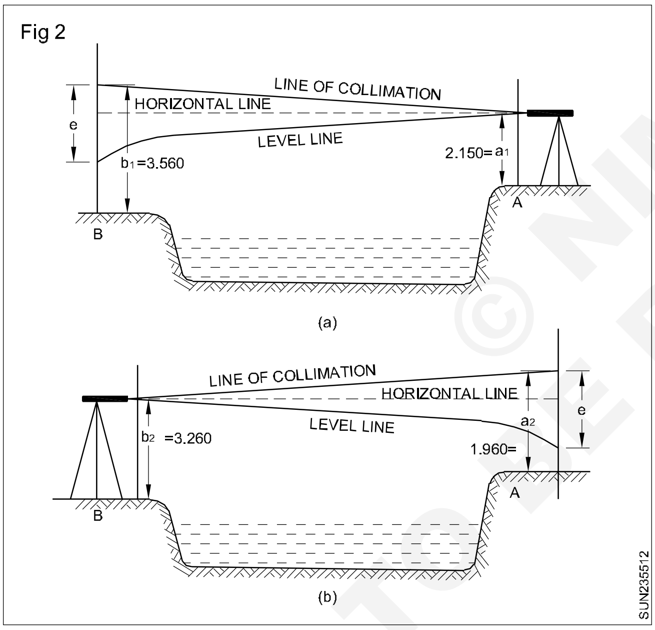
=1.300

True difference of level of A and B

= mean of the two incorrect differences of level

$$= \frac{1.410 + 1.300}{2} = \frac{2.710}{2} = 1.355$$

Fall from A to B




**Example 2**

The following notes refer to the reciprocal levels taken with in level.

| Instrument station | Staff readings on | | Remarks |
|---|---|---|---|
| | A | B | |
| A between A | 1.025 | 1.630 | Distance and B = 800 m |
| B | 0.940 | 1.540 | R.L. of A = 220.540 |

Find

i the true R.L. of B

ii Combined correction for curvature and refraction

iii The error in collimation adjustment of the instrument

i When instrument at A. (Fig 3a)

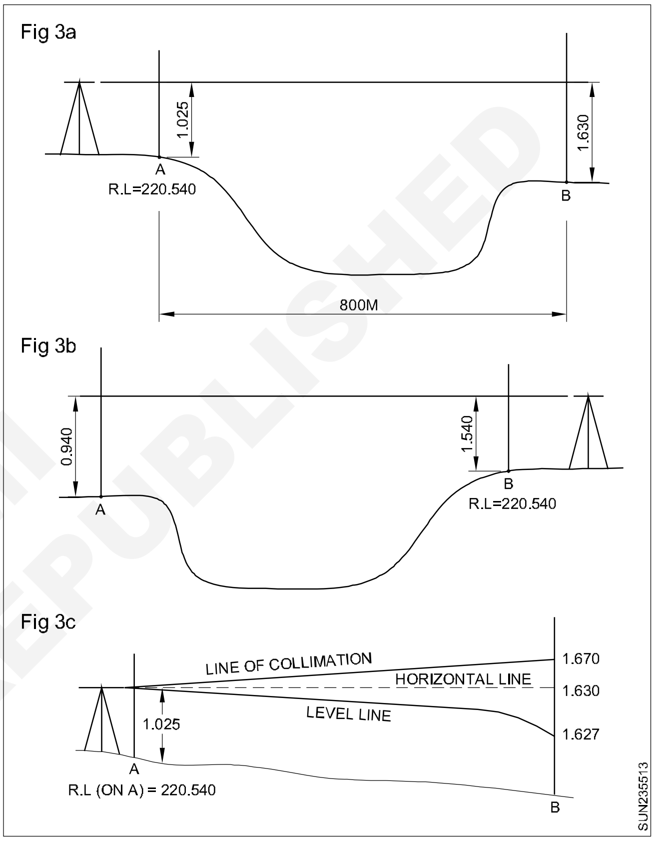
In correct difference of level between A and B

= 1.630 – 1.025 = 0.605

When Instrument at B.

Incorrect difference of level between A and B

= 1.540 – 0.940 = 0.600 m




True difference of level between A and B

= mean of the two in correct difference

$$= \frac{0.605 + 0.600}{2} = 0.6025\text{ m}\left(\text{fall from A to B}\right)$$

R.L. at A = 220.540 m

R.L. at B = 220.54- - 0.6025 m (Subtract fall)

= 219.938 m

ii Combined correction for curvature and refraction, (Fig 3b)

= $0.0673D^2$

= $0.0673 \times (800/1000)^2$

= 0.043 m

iii Instrument at A (Fig 3c)

Reading at A = 1.025

Fall from A to B = 0.602

The required reading touching the level line

= 1.025 + 0.602 = 1.627

(Showing correct readings when the instrument is at A)

**The combined effect of curvature and refraction is to increase the staff reading.**

Therefore, the observed staff readings at B, touching the horizontal line should be

= 1.627 + 0.043 (combined effect of curvature and refraction)

= 1.670

But the actual observed reading at B. The reading touching the line of collimation = 1.630 which is less than 1.670 the line of collimation is inclined downward and the error due to this

= 1.670 – 1.630

= 0.040 m

**Exercise 1**

A dumpy level was setup with its eye piece vertically over a peg C. The height from the top of C to the centre of its eye piece was measured and found to be 1.570 m. The reading on the staff held on the peg D was 1.005. the level was then moved and setup at the peg D. The height of the eye piece above D was 1.250 and the reading on the staff held on the peg C was 1.810. Determine the true reduced level of peg D, if that of peg C was 160.000

**Exercise 2**

The following details refer to reciprocal levels taken with a dumpy level.

**Determine**

a True difference of level between A and B

b The R.L. of A

c The error in collimation adjustment of the level.

| Instrument Station | Staff readings on | | Remarks |
|---|---|---|---|
| | A | B | |
| A | 1.405 | 2.775 | Distance between A and B = 1500 m |
| B | 0.600 | 1.705 | R.L. of B = 100.000 m |

# Problems on reduction of levels

**Objectives:** At the end of this lesson you shall be able to
- **compute the reduced levels by collimation method**
- **compute the reduced levels by rise and fall method.**

**Problem in levelling**

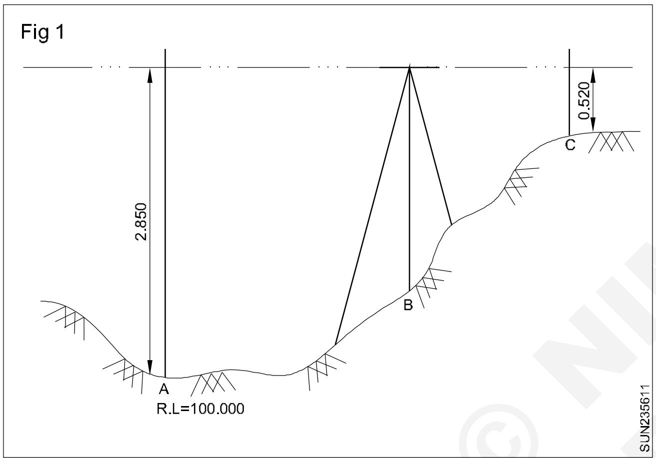
**Example1**

In a simple levelling the Back sight taken from a point A of R.L 100.000 is 2.850m. (Fig.1) and Foresight taken from point C is 0.520m find

i) The difference of level between the A and C (Fig.1)

ii) The R.L at point C.

Fig 1




**Solution**

i) The difference of level between A and C

= 2.850-0.520 = 2.330

Height of collimation = R.L at point A + B.S taken from point A

= 100.000 + 2.850

= 102.850 m.

ii) R.L at point C

= Height of collimation - Foresight reading at C

= 102.850 - 0.520

= 102.330m

**Exercise 1**

The back sight reading at A is 3.560m and the foresight reading at B is 2.860m. Find the difference in level of A and B.

**Exercise 2**

The back sight reading on a staff held vertically on a bench mark whose R.L 100.000 was 2.960m and the foresight on the staff held vertical on a rail was 0.880m. Find the reduced level of the rail.

**Inverted**

**When the BM or staff station is above the line of sight.**

In this case, it occurs when the underside of a string course or sunshade is made a Benchmark, or when the elevation of the underside of a girder, and arch or tie beam is to be determined. It is easy to hold the staff inverted and the reading being negative, is entered in the level book with a minus sign. To avoid confusion "Staff inverted" should be written in the Remarks column against the entry of the reading.

**Problems in inverted level**

**Example 1**

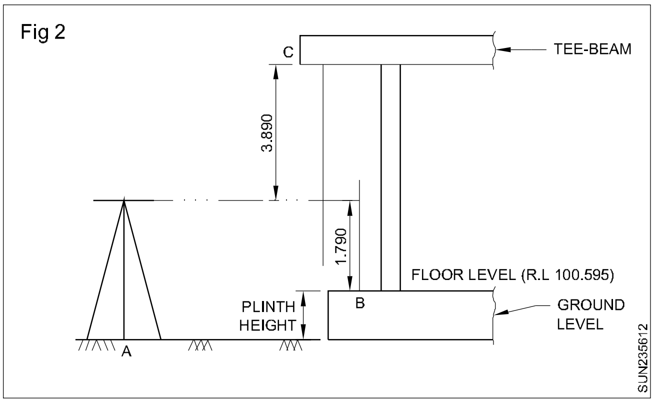
The R.L of the Floor is 100.595 m and staff reading on the floor is 1.790m. The reading on the staff held upside down against the underside of the tee beam is 3.890m Find the height of the beam above the floor level.

**Solution (Fig 1)**

(i) Sketch

ii) Tabulation

Fig 2




| Back sight | Inter sight | Foresight | HCL | Reduced level | Remarks |
|---|---|---|---|---|---|
| 1.790 | | | 102.385 | 100.595 | Staff reading on the floor (B) |
| | | | -3.890 | 106.275 | Inverted staff reading at bottom of tee beam |

iii) Calculation

R.L of the floor = 100.595m

Staff reading on the floor (B) = 1.790m

∴ Height of collimation at A

= R.L of the floor + Staff reading on the floor

= 100.595+1.790

= 102.385m

R.L of the underside of the tee beam = 102.385

= 102.385 - (-3.890) = 106.275m

Height of the tee beam above the floor level

= 106.275-100.595 = 5.680m

**Exercise 1**

Find the height of the tee beam above the floor level from following data. R.L of the floor level = 100.000, Staff reading on the floor = 1.150 reading on the staff held inverted the bottom touching the underside of the tee beam = 3.450m

**Exercise 2**

The back sight reading on a staff held vertical on a benchmark whose R.L is 501.00m is 1.580m and the foresight on a staff held vertically inverted against a beam is 3.580m. Find the reduced level of the beam.

**Problems in simple levelling**

**Example**

Tabulate and enter the following staff reading were taken in the simple levelling and also find the RL of all the points The first reading was taken on a B.M of R.L 100.000 by

i) HCL method (height of collimation method)

ii) Rise and fall method

Apply usual check

2.045, 2.680, 2.860, 2.120, 2.975 and 2.860

**Solution**

**Height of collimation method**

| Back sight | Inter sight | Foresight | HCL | Reduced level | Remarks |
|---|---|---|---|---|---|
| 2.045 | | | 102.045 | 100.000 | Reading taken on B.M |
| | 2.680 | | | 99.365 | Point 1 |
| | 2.860 | | | 99.185 | Point 2 |
| | 2.120 | | | 99.925 | Point 3 |
| | 2.975 | | | 99.070 | Point 4 |
| | | 2.860 | | 99.185 | Point 5 |
| Σ2.045 | | Σ2.860 | | | |

**Calculation**

Height of collimation = R.L of B.M + Back sight

= 100.000 + 2.045

= 102.045m

R.L of point 1 = HCL - I.S reading on point 1

= 102.045 - 2.680

= 99.365

R.L of point 2 = HCL - I.S reading on point 2

= 102.045 - 2.860

= 99.185

R.L of point 3 = HCL - I.S reading on point 3

= 102.045 - 2.120

= 99.925

R.L of point 4 = HCL - I.S reading on point 4

= 102.045 - 2.975

= 99.070

R.L of point 5 = HCL - F.S reading on point 5

= 102.045 - 2.860

= 99.185

**Arithmetic check**

The difference between the sum of back sights and the sum of fore sights should be equal to the difference between the last and the first RLS.

Σ B.S - Σ F.S = Last R.L - First R.L

2.045 - 2.860 = 99.185 - 100.000

-0.815 = -0.815

(ii) Rise and fall method

| B.S | I.S | F.S | Rise | Fall | Reduced level | Remarks |
|---|---|---|---|---|---|---|
| 2.045 | | | | | 100.000 | Reading taken on B.M |
| | 2.680 | | | 0.635 | 99.365 | Point 1 |
| | 2.860 | | | 0.180 | 99.185 | Point 2 |
| | 2.120 | | | | 99.925 | Point 3 |
| | 2.975 | | 0.740 | 0.855 | 99.070 | Point 4 |
| | | 2.860 | 0.115 | | 99.185 | Point 5 |
| Σ2.045 | | Σ2.860 | Σ0.855 | Σ1.670 | | |

**Calculation**

i) B.S on B.M - I.S on point 1 = 2.045 - 2.680

= -0.635 (Fall)

ii) I.S on Point 1- I.S on point 2 = 2.680 - 2.860

= -0.180 (Fall)

iii) I.S on point 2 - I.S on point 3 = 2.860 - 2.120

= 0.740 (Rise)

iv) I.S on point 3 - I.S on point 4 = 2.120 - 2.975

= 0.740 (Rise)

v) I.S on point 4 - F.S on point 5= 2.975 - 2.860

= 0.115 (Rise)

i) R.L. of point 1 = R.L. on BM- Fall on point 1

= 100.000 - 0.635

= 99.365

R.L of point 2 = R.L on point 1-Fall on point 2

= 99.365 - 0.180

= 99.925

R.L of point 4 = R.L on point 3 - fall on point 4

= 99.925- 0.855

= 99.070

R.L on point 5 = R.L on point 4 + Rise on point 5

= 99.070 + 0.115

= 99.185

Arithmetic check

Σ B.S -Σ F.S = Σ Rise - Σ Fall = Last R.L - First R.L

2.045 - 2.860 = 0.855 - 1.670 = 99.185 - 100.000

- 0.815 = 0.815 = -0.815

**Exercise 1**

i) Height of collimation method

ii) Rise and fall method

2.200, 2.430, 2.400, 2.120, 2.900 and 2.750

Apply usual check

## Problems on levelling

**Objectives:** At the end of this lesson you shall be able to
- **determine the reduced levels of the station points by height of collimation method**
- **determine the reduced levels of the station points by rise and fall method.**

### Problems in levelling

**Example 1**

Following consecutive readings were taken on points 1 to 7 along a line.

0785, 1.326, 2.538, 3.435, 1.367, 2.328, 1.234, 1.657

The instrument was shifted after the fourth reading and the first reading was taken on BM with RL = 100.00. rule out a page of level book and work out the RL of all points by collimation method and rise and fall method.

**Solution**

| Station | Readings | | | Height of line of collimation | RL | Remark |
|---|---|---|---|---|---|---|
| | B.S. | I.S. | F.S | | | |
| 1 | 0.785 | | | 100.785 | 100.00 | BM |
| 2 | | 1.326 | | | 99.459 | RL = 100 |
| 3 | | 2.538 | | | 98.247 | |
| 4 | 1.367 | | 3.435 | 98.717 | 97.350 | |
| 5 | | 2.328 | | | 96.389 | |
| 6 | | 1.234 | | | 97.483 | |
| 7 | | | 1.657 | | 97.060 | |
| Total | 2.152 | | 5.092 | | | |

H.I. = R.L. + B.S. = 100.00 + 0.785 = 100.785

R.L. = H.I. – I.S / F.S. = 100.785 – 1.326 = 99.459

**Arithmetical check**

$\Sigma$ B.S. – $\Sigma$ F.S. = 2.152 – 5.092 = -2.940

Last R.L. – First R.L. = 97.060 – 100.00 = -2.940 Ans.

**Solution for the above problem in rise and fall method**

| Station | Readings | | | Rise | Fall | RL | Remark |
|---|---|---|---|---|---|---|---|
| | B.S. | I.S. | F.S | | | | |
| 1 | 0.785 | | | | | 100.00 | BM |
| 2 | | 1.326 | | | 0.541 | 99.459 | RL = 100 |
| 3 | | 2.538 | | | 1.212 | 98.247 | |
| 4 | 1.367 | | 3.435 | | 0.897 | 97.350 | CP |
| 5 | | 2.328 | | | 0.961 | 96.389 | |
| 6 | | 1.234 | | 1.094 | | 97.483 | |
| 7 | | | 1.657 | | 0.423 | 97.060 | |
| Total | 2.152 | | 5.092 | 1.094 | 4.034 | | |

**Arithmetical checks**

$\Sigma$ B.S. – $\Sigma$ F.S. = 2.152 – 5.092 = -2.940

$\Sigma$ Rise – $\Sigma$ Fall = 1.094 – 4.034 = -2.940

Last R.L. – First R.L. = 97.060 – 100.00 = -2.940 Ans.

**Example 2**

**Problem 2**

The readings are entered in the page of level field book as shown below. Reduce the levels by both the Height of collimation method and Rise and Fall method, given the R.L. of a B.M. 1 as 200.000 m. Apply the check.

| Station | B.S. | I.S. | F.S. | R.L. | Remarks |
|---|---|---|---|---|---|
| 1 | 1.430 | | | 200.000 | B.M. 1 |
| 2 | | 2.015 | | | |
| 3 | | 1.005 | | | |
| 4 | 3.370 | | 0.400 | | C.P. |
| 5 | | 2.975 | | | |
| 6 | | 1.415 | | | |
| 7 | | | 0.695 | | B.M. 2 |

**Solution:** By Height of collimation method

| Station | B.S. | I.S. | F.S. | Height of collimation | R.Ls. | Remarks |
|---|---|---|---|---|---|---|
| 1 | 1.430 | | | 201.430 | 200.00 | B.M. 1 |
| 2 | | 2.015 | | | 199.415 | |
| 3 | | 1.005 | | | 200.425 | |
| 4 | 3.370 | | 0.400 | 204.400 | 201.030 | C.P. |
| 5 | | 2.975 | | | 201.425 | |
| 6 | | 1.415 | | | 202.985 | |
| 7 | | | 0.695 | | 203.705 | B.M. 2 |



General rule in height of collimation method is

Height of collimation = R.L. of B.M. + B.S. on that B.M.

R.L. of any point = Height of collimation - I.S. / F.S. of that point.

∴ Height of Collimation for the 1st set up

= 200.00 + 1.430 = 201.430

R.L. of a point 2 = 201.430 - 2.015 = 199.415

3 = 201.430 - 1.005 = 200.425

R.L. of C.P. (4) = 201.430 - 0.400 = 201.030

Height of collimation for the 2nd set up

= 201.030 + 3.370 = 204.400

R.L. of a point 5 = 204.400 - 2.975 = 201.425

6 = 204.400 - 1.415 = 202.985

R.L. of B.M.2 (7) = 204.400 - 0.695 = 203.705

**Arithmetical check**

Σ B.S. = 1.430 + 3.370 = 4.800

Σ F.S. = 0.400 + 0.695 = 1.095

Σ B.S. - F.S. = 4.800 - 1.095 = 3.705

Last R.L. - First R.L. = 203.705 - 200.000 = 3.705

Σ B.S. - Σ F.S. = last R.L. - First R.L.

Hence OK

**By rise and fall method**

| Station | B.S. | I.S. | F.S. | Rise | Fall | R.Ls. | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | 1.430 | | | | | 200.00 | B.M. 1 |
| 2 | | 2.015 | | | 0.585 | 199.415 | |
| 3 | | 1.005 | | 1.010 | | 200.425 | |
| 4 | 3.370 | | 0.400 | 0.605 | | 201.030 | C.P. |
| 5 | | 2.975 | | 0.395 | | 201.425 | |
| 6 | | 1.415 | | 1.560 | | 202.985 | |
| 7 | | | 0.695 | 0.720 | | 203.705 | B.M. 2 |

**General rule**

Difference in level between the successive points

1st reading - 2nd reading = ± Rise / Fall.

R.L. of any point = R.L. of the previous point ± Rise/Fall

Difference in levels for station 2

= 1.430 - 2.015 = - 0.585 (Fall)

For Station 3 = 2.015 - 1.005 = + 1.010 (Rise)

4 = 1.005 - 0.400 = + 0.605 (Rise)

5 = 3.370 - 2.975 = + 0.395 (rise)

6 = 2.975 - 1.415 = + 1.560 (Rise)

7 = 1.415 - 0.695 = + 0.720 (Rise)

R.L. of a station point 2 = 200.00 - 0.585 = 199.415

3 = 199.415 + 1.010 = 200.425

4 = 200.425 + 0.605 = 201.030

5 = 201.030 + 0.395 = 201.425

6 = 201.425 + 1.560 = 202.985

7 = 202.985 + 0.720 = 203.705

**Arithmetical check**

Σ B.S. = 1.430 + 3.370 = 4.800

Σ F.S. = 0.400 + 0.695 = 1.095

Σ B.S. - Σ F.S. = 4.800 - 1.095 = 3.705

Σ Rise = 1.010 + 0.605 + 0.395 + 1.560 + 0.720 = 4.290

Σ Fall = 0.585

Σ Rise - Σ Fall = 4.290 - 0.585 = 3.705

Last R.L. - First R.L. = 203.705 + 200.00 = 3.705

Σ B.S. - Σ F.S. = Σ Rise - Σ Fall = Last R.L. - First R.L.

Hence OK.

## Curvature and refraction in levelling

**Objectives:** At the end of this lesson you shall be able to
- **describe curvature and refraction**
- **describe curvature correction**
- **describe refraction correction.**

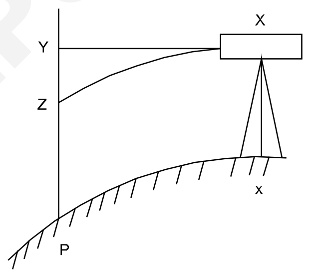


**Curvature and refraction:**

- For long sights and accurate levelling work the effects of curvature of the earth and refraction of the line of sight taken into consideration.
- Due to curvature, the points appear lower than the actual
- While due to refraction they appear high ear than the actual
- The effect of curvature being greater than that of refraction
- The combined effect causes the points to appear lower than the actual
- **Curvature**
- Earth has a curved face but assumed to be a level surface
- The line of sight is furnished by the levelling instrument is horizontal and not the level line
- All points on the line of sight are not equidistant from the surface of the earth
- The points read on the staff are not at the same level as horizontal hair of the diaphragm
- The level of line falls away from the horizontal line of sight and the vertical distance between the horizontal line and the level line denotes the effect of curvature of the end.
- **Fig - (1)**
- x - is the instrument station and P- the point where staff is held xy - the horizontal sight. PY - staff reading
- Point Y- is considered to be at the some level as x.
- But the points 2x are the same level
- The true reading is therefore PZ.
- The difference YZ between the observed and true staff reading denotes the error due to curvature of the earth which may be determined as follows.

**The curvature correction**

Fig 1




From the Fig (2)

D = Distance from the instrument to the staff - station in kilometers

YZ = The error due to curvature

O = Centre of earth

R = Radius of earth

By geometry

(YZ + ZE) = $XY^2$ (or)

YZ (YZ + ZE) = $xy^2$

Since the YZ in usually very small

ZY x ZE = $XY^2$

$$\frac{XY^2}{ZE} = \frac{D^2}{2R}$$

Taking diameter of earth is 12742km.

YZ = $D^2$ / 12,742 km

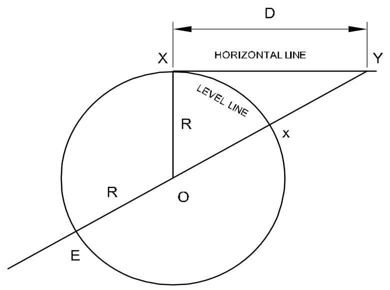
$\therefore$ Curvature of earth correction $\}$

$$\frac{D^2 \times 1000}{12,472} = 0.0785D^2$$

The error is the +Ve

$\therefore$ The correction is - Ve = - $0.0785D^2$ meter

Fig 2

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**Refraction correction**

Established from law of physics The rays of light passing through the different layers of densities donot remain straight bent refracted or bent down towards the denser medium.

From the Fig 3

In normal atmospheric condition arc AD may he taken as circular and of radius seven times of that earth. The effect of refraction is therefore 1/7th of that of curvature in opposite nature.

correction for refracture is added to staff reading

BD = 1/7 BC

= 1/7 X $0.0785D^2$ = $0.0112\ D^2$ meters

**Problems in curvature and refraction**

1 Find the correction for curvature for a distance of (a) 10km & (b) 800 m.

(i) Correction for curvature = $0.0785\ D^2$ meters

Where 'D' in km $\therefore$ correction for curvature for 10km $\}$ $0.0785 \times 10^2$

= 0.0785 x 100

= 7.8500 meters (Ans)

**(ii) Correction for curvature for 800 km**

$$= 0.0785\left(\frac{800}{1000}\right)^2$$

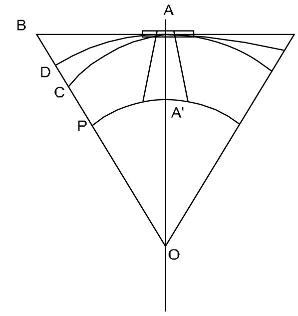
$$= \frac{0.0785 \times 800 \times 800}{1000 \times 1000} = 0.05024 \text{ meter}$$

= 0. 05024 meters (Ans)

2) Find the correction for refraction for a distance of (a) 5 km and 800 meters

Correction for refraction = 0. 0112 $D^2$ meters (Distance in km)

Fig 3

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(a) Correction for refraction for 5km.

$0.0112 \times 5^2$

$\therefore$ = 0.28m (Ans)

(b) Correction for refraction for 800 meters

$$= 0.0112 \times \left(\frac{800}{1000}\right)^2$$

= 0.007168 meters (Ans)

3) Calculate the combined correction for curvature and refraction for a distance of

(a) 5km and (b) 700m.

Combined correction for refraction & curvature Where 'D' is in km. $\}$ $0.0673\ D^2$ meters

(a) Combined correction for refraction & curvature for 5km = $0.0673 \times 5^2$

= 1.6825 meters (Ans)

(b) Combined correction for refraction & curvature for 700m

$$= 0.0673 \times \left(\frac{700}{1000}\right)^2$$

= 0.033 meters (Ans)

4) A level is set up at 'X' on a line AB 70m from A and 800m. from B. The back sight on A is 2.785m and the fore - sight on B is 2.975m.

Find the true difference of level between A & B' reading 'At 'A' is assumed to be correct

Combained correction for curvature & refraction 800m.

$$= 0.0673 \times \left(\frac{800}{1000}\right)^2$$

800m = 0.043m

The currect reading at 'B' = 2.975 - 0.043 = 2.932m

Difference of level between A & B = 2.932 - 2.785

true fall from A to B (Ans) = 0.147 m

## Auto / digital level

**Objectives:** At the end of this lesson you shall be able to
- **state the parts of auto level**
- **explain setting up an automatic level**
- **explain sighting and reading the staff**
- **state the laser level.**

Automatic levels make use of a compensator that ensures that the line of sight remains horizontal once the operator has roughly levelled the instrument (to within maybe 0.05 degree). The surveyor sets the instrument up quickly and doesn't have to leave it carefully each time he sights on a rod on another point. It also reduces the effect of minor setting of the tripod to the actual amount of motion instead of leveraging the tilt over the sight distance. Three level screws are used to level the instrument.

1 Gun sight

2 Circular level (pond bubble)

3 Levelling screw

4 Base plate

5 Objective lens

6 Focusing knob

7 Horizontal fine motion screw

8 Horizontal circle window

9 Horizontal circle setting ring

10 Reticle adjusting screw cover

11 Eyepiece

**Setting up an automatic level**

Set up the tripod at just above chest height. Make sure it is stable, and mount the level on the top. Adjust the levelling screws until the pond bubble is centralised. As long as the pond bubble is central, the automatic compensators are able to finely level the instrument. To ensure this is the case, whilst looking through the scope, gently tap the level. The view will waver for a few moments before steadying. If this does not happen, the instrument is not level enough for the compensators to cope, and needs adjustment.

**Sighting**

Sight towards the staff using the gun sight. Look through the eyepiece and focus the reticle by gradually turning the reticle focusing ring anti-clockwise. Turn the focusing knob to focus on the staff. Turn the fine motion screw to centre the staff in the field of view. Turn the focusing knob to eliminate parallax between the staff and reticle.

**The levelling staff**

**Reading the staff**

The staff starts at zero, on the ground, Every 10 cm is a number, showing ( in meters to one decimal) the height of the bottom of what appears to be a stylised E (even numbers) or 3 (odd numbers), 5 cm high. The stems of the E or 3 and the gaps between them are each 10mm high. These 10mm increments continue up to the next 10 cm mark.

To read the staff, take the number shown below the reticle. Count the number of whole 10mm increments between the whole number and the reticle. Then estimate the number of mm between the lest whole 10mm block and the centre of the reticle.

The person holding the staff should endeavour to hold it as straight as possible. The leveller can easily see if it is tilted to the left or right, and should correct the staff-holder. However, it cannot easily be seen that the staff is tilted towards or away from the leveller. In order to combat this possible source of error, the staff should be slowly rocked towards and away from the leveller. When viewing the staff, the reading will thus vary between a high and low point. The correct reading is the lowest value.

Digital levels electronically read a bar-coded scale on the staff. These instruments usually include data recording capability. The automation removes the requirement for the operator to read a scale and write down the value, and so reduces blunders. It may also compute and apply refraction and curvature corrections.

**Laser level**

**Main article: Laser level**

Laser levels [5] project a beam which is visible and/or detectable by a sensor on the levelling rod. This style is widely used in construction work but not for more precise control work. An advantage is that one person can perform the levelling independently, whereas other types require one person at the instrument and one holding the rod.

The sensor can be mounted on earth-moving machinery to allow automated grading.

# Longitudinal sectioning and cross sectioning

**Objectives:** At the end of this lesson you shall be able to
- **explain profile levelling and cross sectioning**
- **explain plotting profile and cross sectioning and working profile.**

**Longitudinal sectioning (or) Profile levelling**

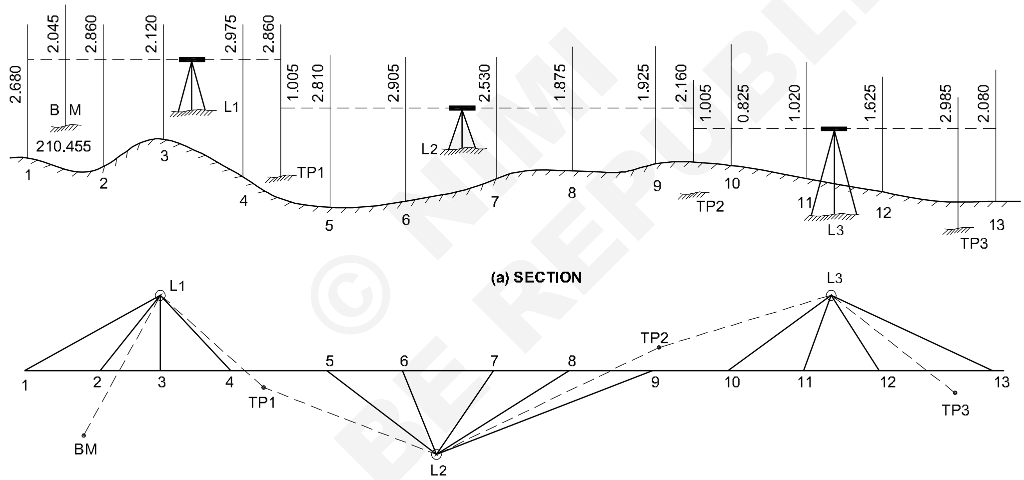
The object of this levelling operation is to obtain a record of the undulations of the ground surface along the centre line of a proposed engineering project such as a road, railway projects, sewerage and drainage projects, water line network projects etc.

The outline of the surface thus obtained is called the longitudinal section or profile. Therefore, it is also known as profile levelling. From such a section an engineer is in a position to study the relationship between the existing ground surface and the proposed formation of the new work in the direction of its length.

The operation involves observing the elevations of a number of points along the centre line and also their distances along it. The line of section may be a single straight line running in the centre or may consists of a series of straight lines according to the change of direction and connected by curve.

The levels are taken at uniform intervals of distance along the centre line depending upon the requirements of work and nature of ground. (A typical profile levelling is shown in Fig.1)

Fig 1




(a) SECTION

(b) PLAN

TYPICAL PROFILE LEVELLING

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Besides these points the staff readings are taken at the fairly significant points where outlines of the ground changes appreciably, so that the profile may be obtained as natural as possible.

The change point may or may not be on the line of section.

The instrument is then shifted and set up in a new commanding position and the readings are taken and entered in the field book.

The same procedure is adopted until the end of last point on the section.

If the permanent bench mark is available near the end joint of the section line, the work may be closed on it by running fly levels from the last station.

While entering the readings in the field book with salient topographic features like river, road, railway, canals, foot path, drains etc. recorded in remarks column.

**Running the longitudinal section**

The line of section is set up on the ground and marked with pegs driven at equal intervals (varies 10 m – 30 m) before starting the levelling operation.

The levelling operation always commence at a bench mark and end on a bench mark.

If the permanent bench mark is not available near the line of section, a flying level is to run from any permanent bench mark to establish a bench mark near the line of section.

The instrument is set up in such a manner as to command as many points on the section as possible.

Staff readings are taken on pegs fixed already at desired regular intervals and also at significant points of change of slope.

The readings are entered in the appropriate columns of the level book against the respective chainages along the line which are recorded in the distance column.

It is necessary to shift the instrument, when the line of sight is within 100 m distance and a change point is selected on a firm ground or a well-defined object.

**Checking the levels**

At the end of day's work, the accuracy of work should be checked by taking fly levels either from permanent bench mark to another permanent bench mark if available (or) returning back to the permanent bench mark at which the work started.

The closing error = (Σ B.S. – Σ F.S.) – (Last R.L. – First R.L.) is calculated.

If the closing error exceeds the permissible limit, the work must be repeated.

**Plotting the 'L' section**

In plotting the longitudinal section, a horizontal line drawn as datum line and chainages of the staff points are marked along this line to a convenient scale and in black colour.

At the plotted points, perpendiculars are erected and on each lines, the respective levels are set off usually in black, and the perpendiculars are in thin blue lines.

The plotted points are then joined by straight lines to obtain the outlines of the ground surface are in black ink.

(Usually horizontal scale be 1 cm = 10 m or 1 cm = 20 m, depends on the vertical scale chosen)

The vertical scale for showing the reduced levels is enlarged to ten times the horizontal scale (i.e.) = 1 cm = 1 m or 2 m.

The plotting of maximum level above datum is usually limited to 15 cm.

**Working profile**

It is used for the purpose of executing the construction works for an engineer at site.

It shows the features of original ground surface, formation levels of new work, the proposed gradient. The depths of cutting and heights of filling and any other information which may be used for the construction work. The new work and the formation levels are represented by thick red line. The original ground (i.e.) natural surface levels are written in black.

The gradients of new work are shown prominently and the limits of each clearly shown by arrows.

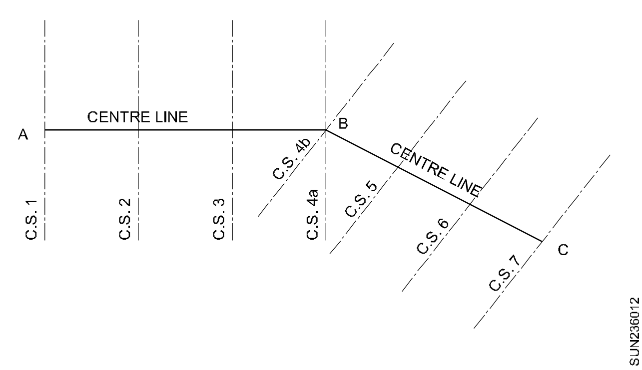
The depths of cutting are written in red.

The heights of filling are written in blue.

**Cross-sectioning (Fig 2)**

Cross-sections are run at right angles to the longitudinal sectioning and on either side of it for the purpose of lateral outline of the ground surface. They provide the data for estimating quantities of earth work and other purposes.

Fig 2




The cross-sections are numbered consecutively from the beginning of the centre line and are set out right angles to the centre line of the section with use of cross staff.

The distances are measured left and right from the centre line. Cross-sections are taken at each of these points. The length of cross-section depends upon the nature of work.

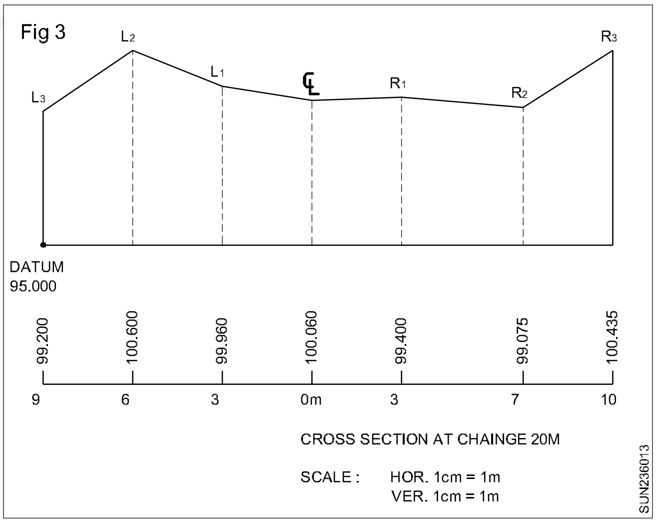
The longitudinal and cross sections are worked together and the observations are recorded in the field work showing left and right of the centre line as given in the model tabulation below.

**Plotting the cross section**

Cross sections are plotted in the same manner as the longitudinal section except that in this case both the scales are kept equal (i.e.) horizontal 1 cm = 1 metre and vertical 1 cm = 1 metre. (Fig 3)

The points to left of the centre point are plotted to the left and those to the right are plotted to the right. The points obtained are joined by a straight line.

Fig 3



| Station | Distance (m) | | | B.S. | I.S. | F.S. | H.I. | R.L. | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | L | C | R | | | | | | |
| BM | | | | 1.325 | | | 101.325 | 100.000 | Cross-section at 0 m chainage |
| O | | 0 | | | 1.865 | | | 99.460 | |
| L1 | 3 | | | | 1.905 | | | 99.420 | |
| L2 | 6 | | | | 2.120 | | | 99.205 | |
| L3 | 9 | | | | 2.825 | | | 98.500 | |
| R1 | | | 3 | | 1.705 | | | 99.620 | |
| R2 | | | 7.5 | | 1.520 | | | 99.805 | |
| R3 | | | 10 | | 1.955 | | | 99.370 | |
| I | | 20 | | | 1.265 | | | 100.060 | |
| L1 | 3 | | | | 1.365 | | | 99.960 | Cross-section at 20 m chainage |
| L2 | 6 | | | | 0.725 | | | 100.600 | |
| L3 | 9 | | | | 2.125 | | | 99.200 | |
| R1 | | | 3 | | 1.925 | | | 99.400 | |
| R2 | | | 7 | | 2.250 | | | 99.075 | |
| R3 | | | 10 | | 0.890 | | | 100.435 | |
| T.P. | | | | | | 2.120 | | 99.205 | |
| Check | | | | 1.325 | | 2.120 | | 100.00 | |
| | | | | | | 1.325 | | 99.205 | |
| | | | | | Fall | 0.795 | Fall | 0.795 | |

## Sensitiveness of a level tube

**Objectives:** At the end of this lesson you shall be able to
- **describe sensitiveness of a level tube**
- **describe measurement of sensitiveness**
- **calculate the sensitiveness of a level tube.**

Sensitiveness / sensitivity of a level tube having capability of exhibiting small deviation of horizontal. The possibility is mainly depends up on the radins of curvature of level tube. The level tube curvature vary from 10 to 300m.

The larger radius having more sensitivity. It also further increased by increase in length of bubble, decreases viscosity and surface tension of liquid in level tube

Sensitiveness designated sometimes in terms of radius of curvature of level tube but better to state in angle; even though the axis must be tilted to cause the bubble to travel one division of scale.

The angular value one “2mm division” may be vary from 8 to 45 seconds depending up on the instrument.

Such instruments required for sensitivity for accuracy of work

**Measurement of sensitiveness :**

To find (a) radius of curvature of level tube or angular value of one division of level tube.

- On a fairly level ground select a baseline of 50 to 100m. (measure with steel tape)
- Set the levelling instrument at one end of line & staff level at ‘P’ other end of base line
- Get the bubble / Bring the bubble. Near of its run by using instrument foot screws. (Extreme left end) & read the both ends of the bubble
- Observe the staff reading say ‘AP’
- As before now bring the bubble tube, bubble to extreme right end.

**Now note down the two end readings of bubble**

**Let:**

D = Length of base

S = Average length of staff intercepted between the upper and lower lines of sights

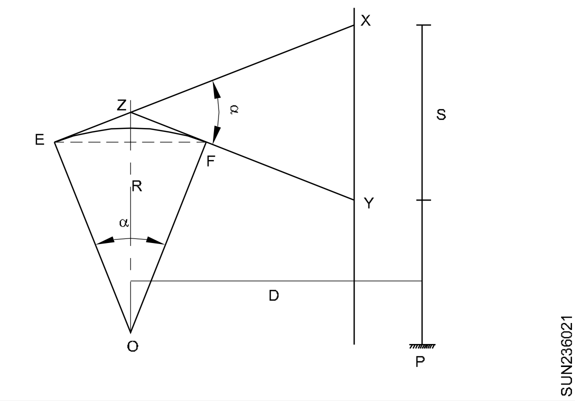
(i.e) The difference of (px - py)

α = The angle between the line of sight

η = η o. of division through which moved by bubble

d = length of one division on tube in meters

Fig 1




R = Radins of bubble tube curvature

The length through which the centre of bubble moves E & F.

From segment 'OEF' we get.

R $\alpha$ = arc EF. (ie) EF = FE.

$$\alpha = \frac{EF}{R} \qquad - \quad 1$$

From similart triangles OEF and xyz

$$\frac{EF}{XY} = \frac{R}{D}.$$

$$\therefore \frac{EF}{R} = \frac{XY}{D} = \frac{S}{D} \quad - \quad 2$$

Combining 1 & 2 $\alpha = \frac{EF}{R} = \frac{S}{D}$

$$\therefore R = \frac{n.d.D}{s.}$$

Angular value of one division in radians $= \frac{\alpha}{n} = \frac{d}{R} = \frac{S}{Dn}$

But 1 Radian = 206, 265 sec

$\therefore$ The angular value of one division $= \frac{S}{D\,n} \times 206{,}265$ sec

$$= \frac{d}{R} \times 206265$$

$$= \frac{d}{R.\sin 1''} = \frac{S}{DN\sin 1''} = \frac{1}{206\ 265}$$

1 Radian = 206 265 Sec and sin 1" $= \frac{1}{206265}$ (Ans)

**Problems on senstiveness of level table(or) bubble tube**

A bubble tube of has a sensitiveness of 28 sec. For 2mm divisions. Find the error in staff reading at a distance of 150 meters caused by the bubble out lay one division

1 Division = Displacement of centre bubble tube the angle through which the Line of collimation is moved due to displacement of bubble.

$$\alpha = 1 = 28 = \frac{28}{206\ 265} \text{ radians}$$

Now error in staff reading = distance x $\alpha$ (in radians)

$$= \frac{150 \times 28}{206265} = \frac{4200}{206265} = 0.0631\text{m (Ans)}.$$

On a level angular value of one division of the bubble tuble is 30 seconds find

(a) The radius of curvature of bubble tube

(b) Reading on a staff held at 120m. away for a disturbance of bubble 3.5 division from centre towards the eye piece, the reading with bubble tube in the centre being 2.575m.

Task: Bubble tube 2mm. apart (division) standard (Inspecial.case it is stated)

(a) Radius of curvature) (one division = 2mm)

Since $\alpha = \frac{nl}{R} \therefore R = \frac{nl}{\alpha}$

Here $\eta = 1 \therefore \alpha = \frac{30}{206265}$ radians

l = 2mm = 0.002 m

$$\therefore R = \frac{1 \times 0.002}{30/206265} \quad \therefore \quad \frac{1 \times 0.002 \times 206265\ 68{,}75{,}5}{30}$$

= 22.916m.

(b) For 3.5 Division

$$\alpha = \frac{3.5 \times 30}{206265} \text{ radian.} \quad = 0.000509$$

If the difference between correct & new reading 's' meters

$$\therefore \alpha = \frac{S}{D} = \frac{S}{120}$$

$$\therefore \frac{S}{120} = \frac{3.5 \times 30}{206265}$$

$$\therefore S = \frac{3.5 \times 30 \times 120}{206265} = \frac{12600}{206265} = 0.06108\text{m}$$

$\therefore$ 2.575 - 0.061

= 2.514m Ans.

= 0.06108m (since the bubble is to wards eye piece) (-)

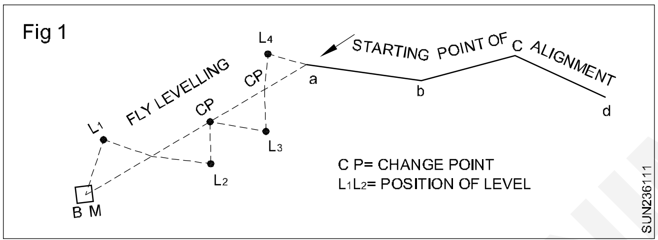
# Fly levelling & check levelling

**Objectives:** At the end of this lesson you shall be able to
- **explain fly levelling**
- **explain check levelling**
- **explain indirect levelling.**

### Fly levelling (Fig 1)

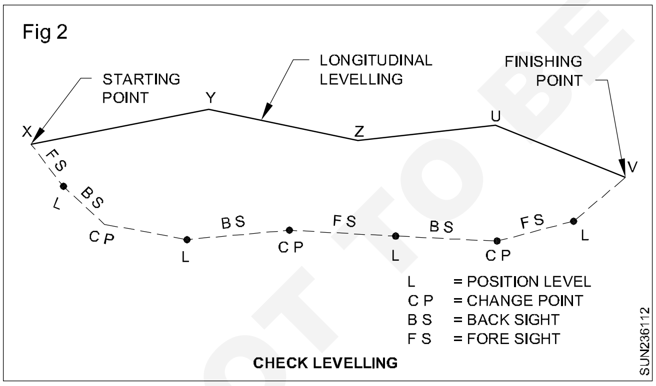
When different levelling is done in order to connect a bench mark to the starting point of the alignment of any project, it is called fly levelling. Fly levelling is also done to connect the BM to any intermediate point of the alignment for checking the accuracy of the work.

In such levelling, only the back sight and fore-sight readings are taken at every set up of the level and no distances are measured along the direction of levelling. The level should be set up just midway between the BS and the FS.




### Check levelling (Fig 2)

The fly levelling done at the end of day's work to connect the finishing point with the starting point on that particular day is known as check levelling. It is undertaken in order to check the accuracy of the day's work.




### Indirect levelling

The method of levelling in which the relative elevations of the points are found out by some indirect observation is known as indirect levelling. It may be carried out in this following three forms:

a Barometric levelling

b Hypsometry

c Trigonometrical levelling

### Barometric levelling

The indirect levelling which is conducted to fix the relative elevations of points by the measurement of pressure at these points using barometer is known as barometric levelling.

Barometric levelling is based on the principle that the atmospheric pressure varies inversely with the height. This method gives approximate result and so it is adopted in the reconnaissance or in the preliminary survey.

### Hypsometry

The method of indirect levelling adopted to find the relatives elevations of points by the measurement boiling points at these points using hypsometer is known as hypsometry. It works based on the principle that boiling points of water decreased at higher altitudes.

### Trigonometric levelling

The method of indirect levelling in which the relative elevations of different points are obtained by measuring the vertical angles and horizontal distance is known as trigonometric levelling.



# Problem on reduction of levels

**Objective:** At the end of this lesson you shall be able to
- **compute the reduced levels of points and gradients of lines on sloping ground.**

### Problem in differential levelling

**Example**

Following consecutive readings were taken on points 1 to 7 along a line

0.785, 1.326, 2.538, 3.435, 1.367, 2.328, 1.234, 1.657

The instrument was shifted after the fourth reading and the first reading was taken on BM with RL = 100.00. rule out a page of level book and work out the RL of all points by collimation method and rise and fall method.

# Principles of road alignment and classification of roads

**Objectives:** At the end of this lesson you shall be able to
- **state principles of road alignment**
- **describe the classification roads.**

**Introduction**

Road alignment is the position occupied by the centre line of the road in plan. The centre line of the road is marked before the commencement of its actual, construction. The cost of construction, maintenance, safety and ease in travel depends up on its alignment. Therefore a road alignment should be selected carefully.

The basic principles of road alignments are as follows.

**Principles of road alignment**

Road alignment is the position occupied by the centre line of a road in plan. The centre line of the road is marked before its actual construction. The cost of construction, maintenance, safety and ease in travel depends upon its alignment. Therefore a road alignment should be selected carefully.

**The basic objects of road alignment are as given below:**

The align of the road should be as short as possible to provide economy in the cost of construction.

The alignment should be as straight as possible which ensure higher speed to the traffic and lower cost of construction.

The alignment should be easy for construction, maintenance and traffic operations.

The alignment should cross the railway lines and other roads and bridges at right angles.

It should cross the rivers, canals or streams etc. at place where its width is minimum.

The alignment serves maximum population by connecting intermediate important towns and group of villages.

The alignment should pass through regions of natural beauty and scenery.

The alignment should be such that it crosses the minimum number of bridges, crossings, culverts and embankment places.

It should provide smooth curves and easy gradients.

It should be such that minimum earthwork in embankment or cutting is done.

The alignment should provide good sight distance.

It should be free from obstructions like ponds, lakes. Wells, monumental buildings and historical buildings etc.

The alignment should run through such places where materials of road construction and labour are easily available.

As far as possible it should run on good soil having good bearing capacity to bear the loads of traffic safety without any damage to the road.

The alignment should not run through much costly and cultivated land. It should also avoid forests.

The alignment should not have uneasy zig-zags in the way which reduces the speed of the traffic and increases accident possibility.

The alignment should not have lengthy straight routes to avoid monotony. Hence after certain length of straight routes (say 5 km) of a road, a slight bend should be provided to break the monotony and to keep the drivers alert.

**Classification of roads:**

**The roads are classified as under:**

- According to location.
- According to importance.
- According to traffic.
- According to tonnage.

**Classification of roads according to location:**

The classification of roads was done as per recommendations made in the Nagpur plan finalized by the Indian road congress in 1943. So this classification is called as I.R.C. classification of roads. According to this, the roads are broadly classified into the following four main types:

- National highway (NH).
- Provincial or state Highways (SH)
- District roads:
  - Major district roads (MDR).
  - Other district roads (ODR).
  - Village roads (VR).

**National highways**

All the main highway running through length and breadth of the country, connecting major ports, capitals of states, foreign highways etc. are known as national highways. These roads constitute the main arteries of the transport in the country and are also of military importance. These roads should be selected in such a manner that they afford uninterrupted road communication through the country. These national highways should have carriageway of at least two lane width i.e., of 8 m width. These should have modern type of surfacing. The responsibility of construction and maintenance of these highways lies with the central government.

**State highways**

It is the highway which connects important cities and towns in a state or important cities and district head quarters with national highways. These roads serve as the main arteries of traffic to and from district roads within the state. The state highway should also have two lane width with 2.0 m wide shoulders on each side. The responsibility of construction and its maintenance rests with the state government. However, the central government gives grant for the development of these roads.

**District roads**

The district roads traverse each district serving areas of production and markets, industries, residential areas, railway stations and airports etc. and connecting these places with each other. These roads take road traffic into the heart of rural areas without any interruption. The responsibility of construction and maintenance of these roads lies with the district authorities. However, the state government gives grant for the development of these roads. In the Nagpur plan it was decided that every village in highly populated area should be within about 3 km of such areas and about 8km or so in the other areas.

**The district roads are further divided into two types:**

- Major district roads.
- Other district roads.

**Major district roads**

These are the roads which connect important towns or areas of production, and markets with either a national highway, state highway or railway station. The specifications of the major district roads are same as of state or provincial highways. They should have at least single lane metalled carriageway.

**Other district roads**

These roads run within a particular town connecting a town and village or a town with major district road or state highway. These roads are of the specifications lower than major district roads. Many of these roads remain closed due to the traffic during monsoon. These should have single lane width of at least stabilized soil, gravel or water bound-macadam surface. District authorities look after these roads.

**Village roads**

Roads connecting the villages or group of villages with each other or with the nearest district road is called a village road. These also sometimes connect towns or railway stations etc. These are generally unmetalled with stabilised soil or gravel. These roads allow the transport to carry the rural products to the market. The local district board authorities are responsible for the construction and maintenance of these roads.

**Classification of roads according to importance:**

According to this classification, roads are classified as under:

- Class I roads
- Class II roads
- Class III roads

**Classification of roads according to traffic**

According to intensity of traffic, the roads are classified as under:

**Very heavy traffic roads:** Which carry above 600 vehicles a day.

**Heavy traffic roads:** Which carry 251 to 600 vehicles a day.

**Medium traffic roads:** Which carry 70 to 250 vehicles a day.

**Light traffic roads:** Which carry below 70 vehicles a day.

**Classification of roads according to tonnage**

According to this category, the roads are classified as under:

**Very high traffic roads:** Which carry over 1524 metric tonne per day.

**Heavy traffic roads:** Which carry 1017 to 1524 M.T. per day.

**Medium traffic roads:** Which carry 508 to 1016 M.T. per day.

**Light traffic roads:** Which carry below 508 M.T. per day.

These standards have been fixed by the British road engineers.

## Reconnaissance survey in Road project

**Objectives:** At the end of this lesson you shall be able to
- **describe the necessity of road projects**
- **explain various types of surveys involved in road projects.**



**Introduction**

Before constructing a new road due to public demand or some strategic reason, a primary investigation is carried out to examine whether this road is necessary.

The following points are to be kept in mind at the time of such investigation.

Total population benefitted by the project.

Number of villages, towns, industrial places etc to be connected.

Prospect of tourism, if any

Strategic importance for the defense of the country.

Any other information related to the project should be noted.

**Types of surveys for the location of a road**

Before finalising the alignment of a road, the engineering surveys must be carried out in four following stages.

1 Map study

2 Reconnaissance survey

3 Preliminary survey

4 Final survey

**1 Map study**

In this map study if the topographic map of the area is available, the selected routes of the road may be marked on it. The alignment can be located on the map from the following available details.

- Avoidable points, such as ponds, valleys, lakes etc.
- Possibly of crossing through a mountain pass.
- Location of a bridge site for crossing the river, avoiding bends etc.

**2 Reconnaissance survey**

The main object of this survey is to examine the general characteristics of the area for determining the most feasible route or routes for further detailed investigations. The reconnaissance survey may be conducted in the following sequence.

(i) Study of topographical survey sheets, agricultural soil, geological and meteorological maps and aerial photographs if available.

(ii) Aerial reconnaissance

(iii) Ground reconnaissance

**(i) Study of topographical survey sheet**

Reconnaissance begins with the study of all available maps. In India topographical sheets are available to the scale of 1:50,000. After the study of the topographical features on the maps, a number of alignment feasible in a general way are selected while selecting the alignment following points should be kept in view.

- The alignment should be shortest and most economical with the requirements of gradient and curvature.
- Shape of the alignment
- As far as possible avoid marshy ground, step terrain, unstable hill features.
- Need of connecting important villages and towns, industrial places, or religious importance etc.
- Number of bridges and their lengths.

If the photographs of the area are not available, aerial photography may be arranged for further study for the sake of overall economy. These photographs may be taken on a scale of 1:20,000 to 1:50,000.

**(ii) Aerial reconnaissance**

Final alignment is selected on the basis of the aerial reconnaissance. It will also help to identify factors which may be helpful with rejection or modification of any of the alignment. This will provide a bird's eye view of the alignments under consideration along with the surrounding area.

**(iii) Ground reconnaissance**

It consists of general examination of the ground by walking or riding along the selected alignment of a road. It may be done by using the following instruments.

- Compass
- Abney level
- Pedometer
- Cline meter
- Ghats tracer

During this survey following points should be kept in mind.

- Details of route
- Length of the road
- Number of bridges and their lengths

- Geometrics/Gradients, curves and hair pin bends etc.
- Right of way available.

**Terrain and soil conditions** - Geology of area, nature of soil, drainage conditions and nature of hill slopes.

**Road length passing through**

- Mountainous terrain
- Steep terrain
- Area subjected to inundation and flooding
- Area of poor soil and drainage conditions.
- General elevations of the road

**Climatic conditions**

- Temperature-maximum and minimum readings
- Rainfall
- Wind velocities and direction
- Water table conditions.

**Value of land -** agricultural land, irrigation land, built up land, forest land etc.

- Approximate cost of construction
- Period required for construction
- Important villages, towns and marketing centres connected
- Crossings with railway lines and other existing highways.
- Position of ancient monuments, burial grounds, religious structures, hospitals and schools etc.

**3 Preliminary survey**

This survey is relatively large scale instrument survey conducted for the purpose of collecting all physical information which affects the proposed location of a new highway. In case of new road it consists of running an accurate traverse line along the new route selected, on the basis of reconnaissance survey. During this phase of survey, topographic features and other features like houses, places of worships etc. are to be considered.

Longitudinal sections and cross sections are taken and bench marks established. This data will form the basis for the determination of final centre line of the road.

During preliminary survey usually levelling work should be kept to the minimum. Generally fly levels at 50 m intervals and at all intermediate breaks in ground should be taken along the traverse line.

**The cross section at about 100m to 250m interval in plain terrain and at about 50m intervals in rolling terrain should be taken.**

**4 Final location survey**

This survey is carried out to lay out the final centre line of the road in the field based on the alignment selected in the design office and to collect necessary data for the preparation of working drawings. In this survey only two steps are involved.

- Staking out the final centre line of the road by means of a continuous transit survey.
- Detailed levelling.

**Road alignment**

The position or the layout of the centre line of the highway on the ground is called the alignment. In a new road should be aligned carefully otherwise it is faulty. It causes more construction, maintenance cost and also increase the accident rates.

The alignment may be,

- Short
- It should be easy
- It should be safe
- It should be economical
- Height of embankment

The height of the embankment depends upon the desired grade line of the highway and topography of the area. Sometimes it is also governed by the stability of foundation specially when the soil is weak usually it is taken 0.6m

**Road gradient**

The rate of rise or fall along the length of the road with respect to the horizontal length is called gradient.

The maximum, ruling and exceptional gradients as recommended by Indian Road Congress are given below.

| Sl.No. | Type of Terrain | Maximum gradient |
|---|---|---|
| 1 | Plain or rolling | 1 in 20 |
| 2 | Mountainous and steep terrain with elevation upto 3000m | 1 in 16.7 |
| 3 | Elevation more than 3000m | 1 in 14.3 |

**Road way**

Road way comprises of the width of carriageway including traffic separator and shoulders on either side.

Road way width as per recommendations of I.R.C

| | |
|---|---|
| National and State highway | 12.0m |
| Major district roads | 10.0m |
| Other district roads | 8.0m |
| Village roads | 7.5m |

## Computation of earth work in embankment and cutting

**Objectives:** At the end of this lesson you shall be able to
- **explain the various methods for the quantity of earth work**
- **compute quantity of earth work by average depth method**
- **compute the quantity of earth work by trapezoidal formula and prismoidal formula.**

**Introduction**

The volume of earth work in excavations and embankments of roads, railways, canals, etc., it is usually determined by finding the areas of a number of sections at known distance. The cross sections are generally of well defined geometrical shapes, hence, their areas may be obtained by ordinary methods of menstruations i.e.

Area of a triangle = $= \frac{1}{2} \times$ base x height

Area of a rectangle = base x height

Area of trapezium = $= \frac{h}{2}$ X sum of parallel sides

perpendicular distance between them canal projects, a longitudinal section along the proposed alignment is prepared by normal methods of levelling. Cross sections of the ground at desired intervals, depending upon the topography of the terrain, are also plotted. The formation levels is decided as per design requirements. Knowing the formation levels and ground levels at different sections, the height of embankments and depth of cutting, are calculated.

For proper utilization of the excavated materials, the alignment of the proposed project is so selected that the excavated material is used for the embankments.

**Accuracy of Measurements of earth work**

As per ISI : 1200 (Part I) 1974, the earth work shall be calculated in cubic metres. For the calculation of the cubic content, the following accuracies in the measurements of the quantities, are recommended.

(i) Each dimension of the earth work shall be measured correct to one centimetre. In case any dimension is more than 25 m, its value may be obtained correct to 0.1 metre.

(ii) Areas of cross sections shall be calculated to the nearest to $0.01 m^2$.

(iii) The volume of the earth work shall be calculated to the nearest $0.001 m^3$.

**Methods of Calculation of earth work**

The quantities of the earth work of roads, railways, and canals may be calculated by the following methods :

1 Average depth method

2 Average cross sectional area method

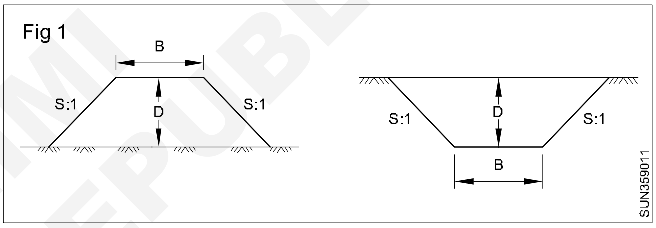
3 Prismoidal formula

4 Graphical method

**1 Average depth method**

In this method, the average height of embankments or average depth of cuttings at the mid - section of two known sections, are calculated. Knowing the formation width, average depth and side slopes, the area of the corss -section at mid - section may be calculated as explained below (Fig 1).

Fig 1




Let B = formation width

D = depth/height of the cutting/ embankment.

S : 1 = side slopes i.e horizontals : 1 vertical

The cross sectional area

$$A = BD + 2\left\{\frac{1}{2}.SD.D\right\}$$

$$= BD + SD^2 \qquad .................. (1)$$

Now, knowing the area A of the mid-section and length L between two sections, the volume of the earth work.

$$V = A.L \qquad .................. (2)$$

**Derivation of the formula (Fig 2)**

Let $d_1$ and $d_2$ = height of the embankment at two sections

ι= distance between the sections

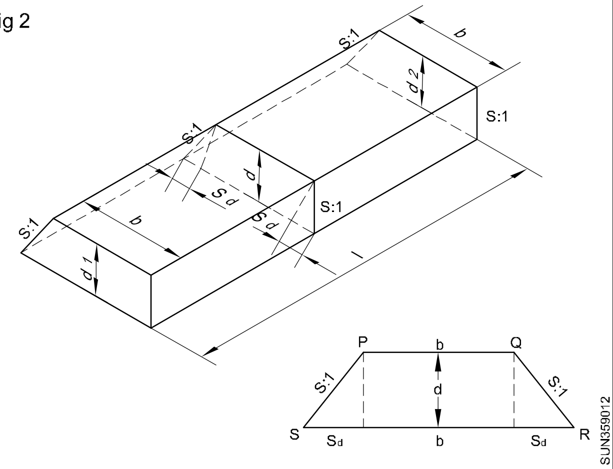
b= formation width

S: 1 = sides slopes i.e horizontals : 1 vertical

The average height of the embankment. (Fig 2)

$$= \frac{d_1 + d_2}{2} = d$$

Fig 2




The quantity of the earth work = Area of trapezium x length.

From eqn. (1), the area of the trapezium PQRS = bd + $sd^2$

$\therefore$ The quantity of the earth work V= $(bd+sd^2)\iota$........(3)

Similarly, it can be shown that quantity of the cutting

V= $(bd+sd^2)\iota$

where: b is formation width, d is the depth of cutting and S:1 is the slope of the cutting

**2 Average cross sectional area method**

In this method, the average area of mid - cross section is obtained from the areas of cross - section of two sections and is multiplied by the distance between the sections.

Let $d_1$ and $d_2$ be the lengths of the embankment at two sections.

l is the distance between two sections

b is the formation width

S : 1 is the side slope i.e S horizontal : 1 vertical

The cross sectional area of section 1.

$A_1 = bd_1 + sd^2_1$

The cross sectional area of section 2

$A_2 = bd2 + sd_2^2$

$\therefore$ The mean sectional area $= \frac{A_1 + A_2}{2} + A$

Quantity of the earth work = mean area x length

V = A x l

**3 Prismoidal formula**

Let $d_1$, $d_2$= heights of the embankment at sections 1 and 2.

l = distance between the given sections.

b = formation width

S : 1 = side slopes i.e S horizontals : 1 vertical

d = average height at the mid - section

$A_1$, $A_2$ = cross sectional areas of sections 1 and 2.

A = cross- sectional area at the mid - section.

Apparently,

$$= \frac{L}{6}\left[\left(Bd_1 + Sd_1^{\,2}\right) + 4\left\{B \times \frac{d_1 + d_2}{2} + S\left(\frac{d_1 + d_2}{2}\right)^2\right\} + \left(Bd_2 + Sd_2^2\right)\right]$$

$$= \frac{L}{6}\left[Bd_1 + Sd_1^2 + \frac{4B\left(d_1 + d_2\right)}{2} + \frac{4S\left(d_1 + d_2\right)}{4} + Bd_2 + Sd_2^2\right]$$

$$= \frac{L}{6}\left[Bd_1 + Sd_1^2 + 2Bd_1 + 2Bd_2 + Sd_1^2 + 2Sd_1d_2 + Sd_2^2 + Bd_2Sd_2^2\right]$$

$$= \frac{L}{6}\left[3Bd_1 + 3Bd_2 + 2Sd_1^2 + 2Sd_2^2 + 2Sd_2^2 + 2Sd_1d_2\right]$$

$$= \frac{3BL}{6}\left[\left(d_1 + d_2\right) + \frac{2LS}{6} + \left(d_1^2 + d_2^2 + d_1d_2\right)\right]$$

$$= \frac{BL}{2}\left[\left(d_1 + d_2\right) + \frac{LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)\right]$$

$$\text{or} V = \left[\frac{B\left(d_1 + d_2\right)}{2} + S\frac{\left(d^1_2 + d^2_2 + d_1d_2\right)}{3}\right] \times L$$

**Prismoidal formula**

d = mean height = $= \frac{d_1 + d_2}{2}$

By applying the Simpson's rule we get

$$V = \frac{L}{6}\left[A_1 + 4A + A_2\right]$$

The eqn. (5) may be reduced to a more practical form as under :

$$V = \frac{L}{6}\left[A_1 + 4A + A_2\right]$$

**General formulae for the earth work calculations**

In case, the earth work consists of a series of cross - sections taken at equal intervals, the trapezoidal and Prismoidal formulae for the earthwork reduce to :

**Volume by trapezoidal formula :**

$$V = \frac{L}{2}\left[A_1 + 2A_2 + 2A_3 + 2A_4 + ........ + 2A_{n-1} + A_n\right]$$

$$L\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + A_4 + ....... + A_{n-1}\right]$$

**Volume by Prismoidal formula :**

$$V = \frac{L}{3}\left[A_1 + 4A_2 + 2A_3 + 4A_4 + 2A_5 + ....... + A_n\right]$$

$$V = \frac{L}{3}\left[A_1 + A_n + 4\left(A_2 + A_4 + A_6 + ........... +\right) + 2\left(A_3 + A_5 + A_7 + ............)\right)\right]$$

$$= \frac{L}{3}\left[\text{Firstsection} + \text{Lastsection} + \text{Four}\sum\text{Even} + \text{Twice}\sum\text{odd}\right]$$

where $A_1$, $A_2$, $A_3$, ...... $A_n$ represent the areas of cross sections and L is the distance between the sections.

Note : The following points may be noted :

(i) For the application of the Prismoidal formula, the number of cross sections should be odd. If the number of cross sections is even, the volume of the portion bounded by the sections at either end, may be calculated by trapezoidal formula and the volume of the portion containing only odd sections may be calculated by the Prismoidal formula.

(ii) The volume calculated by the Prismoidal formula is more accurate than that calculated by average depth method and average cross sectional area method.

**Road and railway embankments**

While calculating the volume of the earthwork involved in road or railway projects, the following cases may arise:

1 The transverse slope of the ground being zero.

2 The transverse slope of the ground being r :1 i.e r horizontals : 1 vertical.

3 The transverse slope of the ground being $r_1$ : 1 and $r_2$ : 1 1 on either side of the alignment.

4 The transverse slope of the ground being irregular.

# Commands & co - ordinate system

**Objectives :** At the end of this exercise, you shall be able to,
- **use draw command line**
- **practice co - ordinate system**
- **use modify command erase.**

**Draw commands Line**

From tool bar:- Line

Draw menu:- Line

Command : Line, L

Example:

**Command: L - Line**

Specify first point: Select one point on the screen

Specify next point or [Undo]: Select second point on the screen

Specify next point or [Undo]:

**Continue**

Continue a line from the end point of the most recently drawn line

If the most recently drawn line is an arc, its end point defines the starting point of the line, and the line is drawn tangent to the arc.

**Close**

Ends the last line segment at the beginning of the first line segment, which forms a closed loop of line segments. You can close after you have drawn a serious of two or more segments.

**Undo**

Erase the most recent segment of a line sequence. Entering “U” more than once back tracks through line segments in the order you created them.

**Co- ordinate system in Autocad**

All drawings are superimposed on an invisible grid, or co - ordinate system, with a horizontal X - axis and a verticals Y - axis.

You can establish grid and snap setting that match the units of the co - ordinate system or some multiple or fraction of it.

1. ABSOLUTE CO - ORDINATE SYSTEM (X, Y):- To enter an absolute coordinate, specify a point by entering its X and Y values in the format X,Y. (Fig 1)

Use absolute coordinate when you know the precise X and Y values in the point from the origin. The following sequence of coordinates draw a triangle, as shown below.

**Command _** Line specify first point: 2,2

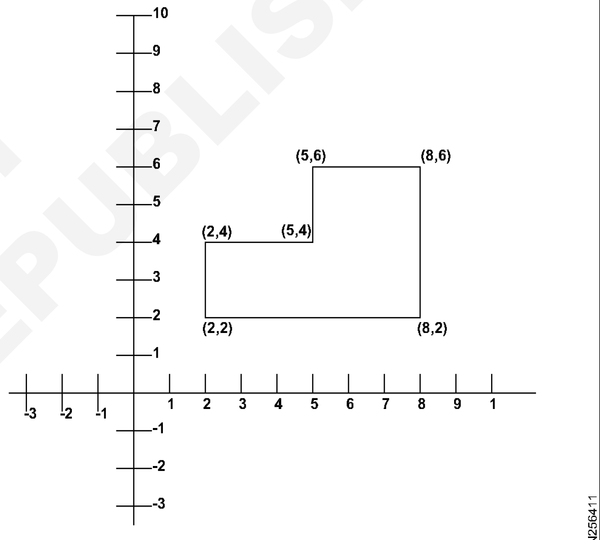
Specify next point or [undo]: 8,2

Specify next point or [undo]: 8,6

Specify next point or [undo]: 5,6

Specify next point or [undo]: 5,4

Fig 1




ABSOLUTE CO-ORDINATE SYSTEM

Specify next point or [undo]: 2,4

**Relative rectangular co-ordinate system @ X distance, Y distance (Fig 2)**

Use relative coordinates when you know the position of a point with respect to the previous point, the relative rectangular coordinate is represented in the following format.

**X displacement, Y- displacement.**

Command:_ line specify first point:2,2

Specify next point or [undo]: @ 4,0

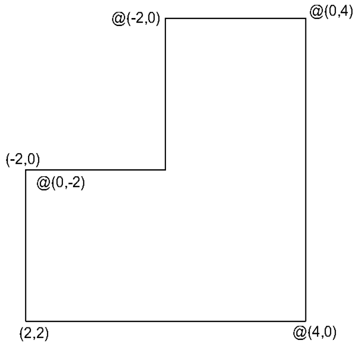
Specify next point or [undo]: @ 0,4

Specify next point or [Close/ undo]: @ -2,0

Specify next point or [Close/ undo]: @ 0,-2

Specify next point or [Close/ undo]: @ -2,0

Fig 2




RELATIVE RECTANGULAR CO-ORDINATE SYSTEM

SUN256412

Specify next point or [Close/ undo]: @ c

**Relative polar co-ordinate system @ distance angle**

Polar co - ordinate system uses a distance and an angle with reference to the previous point to locate a point. Angle is measured in anti - clock direction, taking 0° towards right.

The relative polar coordiante is representing in the following format: (Fig 3)

**@Distance<angle.**

Command: _ line specify first point:2,3

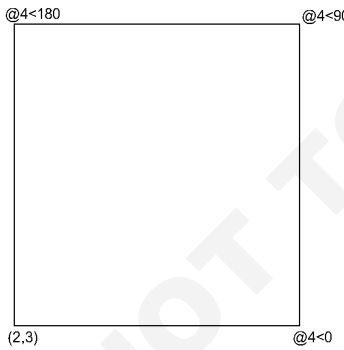
Specify next point or [undo]: @ 4<0

Specify next point or [undo]: @ 4<90

Specify next point or [close / undo]: @ 4<180

Specify next point or [close / undo]:c

Fig 3




RELATIVE POLAR CO-ORDINATE SYSTEM

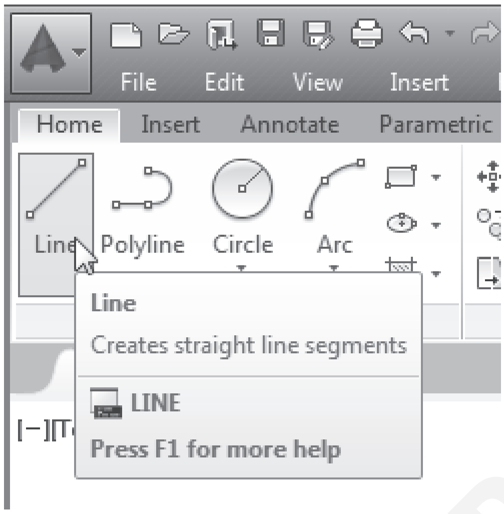
SUN256413

| SEM II | COORDINATE SYSTEM | EX.NO.2.6.06 |
|---|---|---|

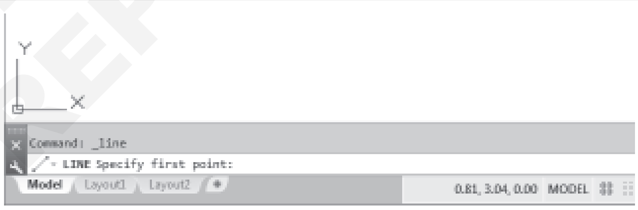
**Drawing lines with the LINE command**

1 Move the graphics cursor to the first icon in the Draw panel. This icon is the **Line** icon. Note that a brief description of the Line command appears next to the cursor.

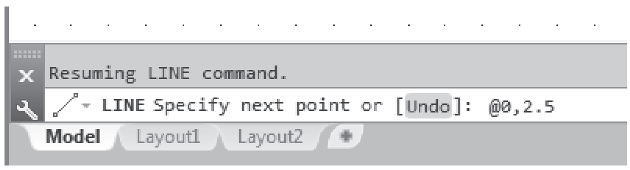
2 Select the icon by clicking once with the **Left - mouse - button,** which will activate the line command.



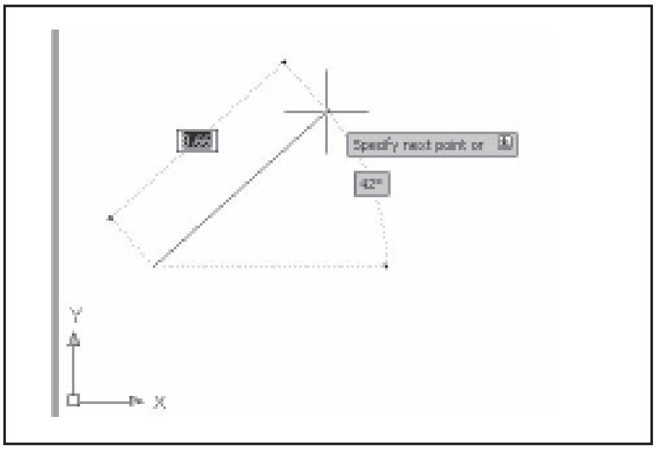

3 In the command prompt area, near the bottom of the AutoCAD drawing screen, the message " - line specify point:" is displayed. AutoCAD expects us to identify the starting location of a straight line. Move the graphics cursor inside the graphics window and watch the display of the coordinates of the graphics cursor at the bottom of the AutoCAD drawing screen. The three numbers represent the location of the cursor in the X,Y, and Z directions. We can treat the graphics window as if it was a piece of paper and we are using the graphics cursor as if it were a pencil with which to draw.



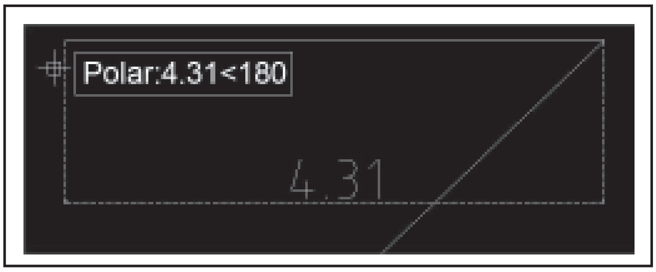

We will create a freehand sketch of a five - point star using the Line command. Do not be overly concerned with the actual size or the accuracy of your freehand sketch.



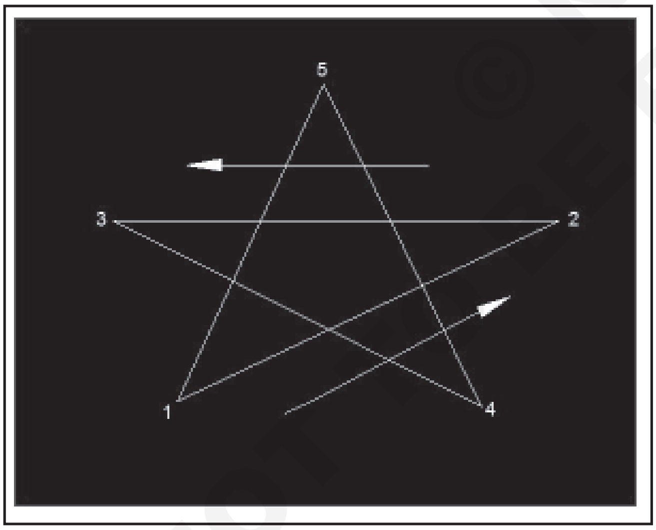

4 We will start at a location about one - third from the bottom of the graphics window. Left - click once to position the starting point of our first line. This will be point 1 of our sketch. Next move the cursor upward and toward the right side of point 1. Notice the rubber - band line that follows the graphics cursor in the graphics window. Left - click again (point 2) and we have created the first line of our sketch.




5 Move the cursor to the left of point 2 and create a horizontal line about the same length as the first line on the screen.



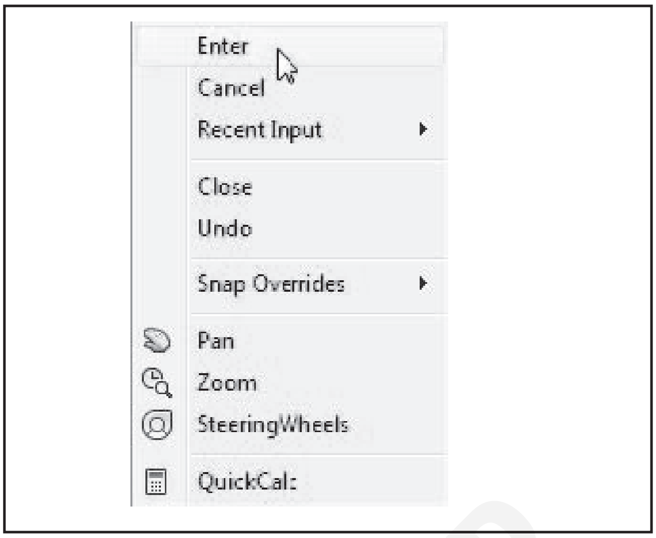

6 Repeat the above steps and complete the freehand sketch by adding three more lines (from point 3 to point 4, point 4 to point 5, and then connect to point 5 back to point 1).




7 Notice that the Line command remains activated even after we connected the last segment of the line to the starting point (point 1) of our sketch. Inside the graphics window, **Click once** with the **right - mouse - button** and a popup menu appears on the screen.

8 Select Enter with the left - mouse - button to end the Line command. (This is equivalent to hitting the [ENTER] key on the keyboard.)

9 Move the cursor near point 2 and point 3, and estimate the length of the horizontal line by watching the displayed coordinates for each point.




**ERASE**

There are 3 methods to **erase** (delete) objects from the drawing. You decide which one you prepare to use. They all work equally well.

**METHOD 1.**

**Select the Erase command first and then select their objects.**

1 Start the Erase command by using one of the following.

**TYPING = E <enter>**

**PULLDOWN = MODIFY / ERASE** 

**TOOLBAR = MODIFY**

2 Select objects: **Pick one or more objects**

Select objects: **Press <enter> and the objects will disappear**

**METHOD 2.**

**Select the objects first and then the Erase command from the shortcut menu.**

1 Select the object (s) to be erased.

2 Press the right mouse button.

3 Select **"Erase"** from the short - cut menu.

**METHOD 3.**

**Select the objects first and then the Delete key**

1 Select the object (s) to be erased.

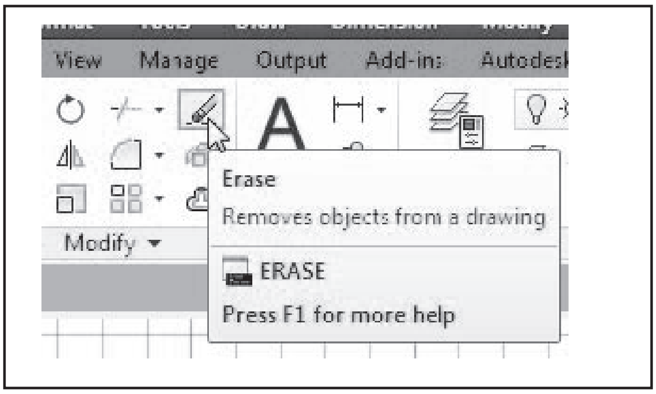
2 Press the Delete key.

**Very important : If you want the erased objects to return, press U <enter> or Ctrl + Z or the Undo arrow icon. This will "Undo" the effects of the last command.**

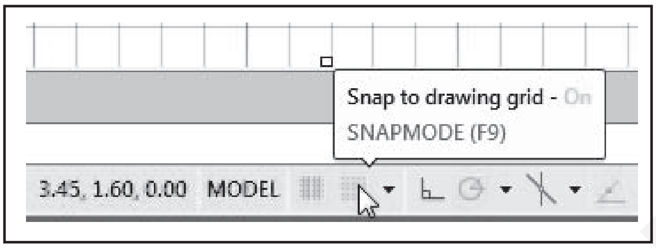
**Using the ERASE command**

One of the advantages of using a CAD system is the ability to remove entities without leaving any marks. We will erase two of the lines using the Erase command.

1. Pick Erase in the modify toolbar. (The icon is a picture of an eraser at the end of a pencil.) The message “Select objects” is displayed in the command prompt area and AutoCAD awaits us to select the objects to erase.



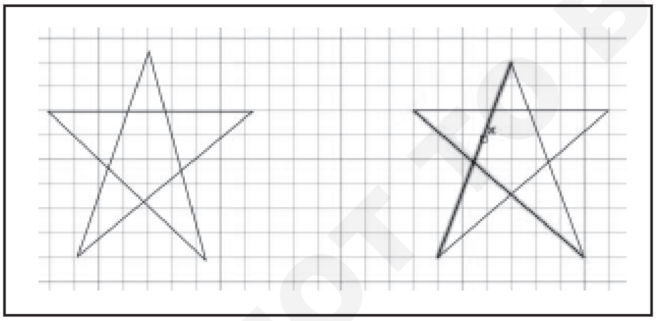

2. Left - cllick the SNAP MODE button on the Status bar to turn OFF the SNAP MODE option so that we can more easily move the cursor on top of objects. We can toggle the Status Bar options ON or OFF in the middle of another command.




3. Select any two lines on the screen; the selected lines are displayed as dashed lines as shown in the figure below.

To Deselect an object from the selection set, hold down the [SHIFT] key and select the object again.

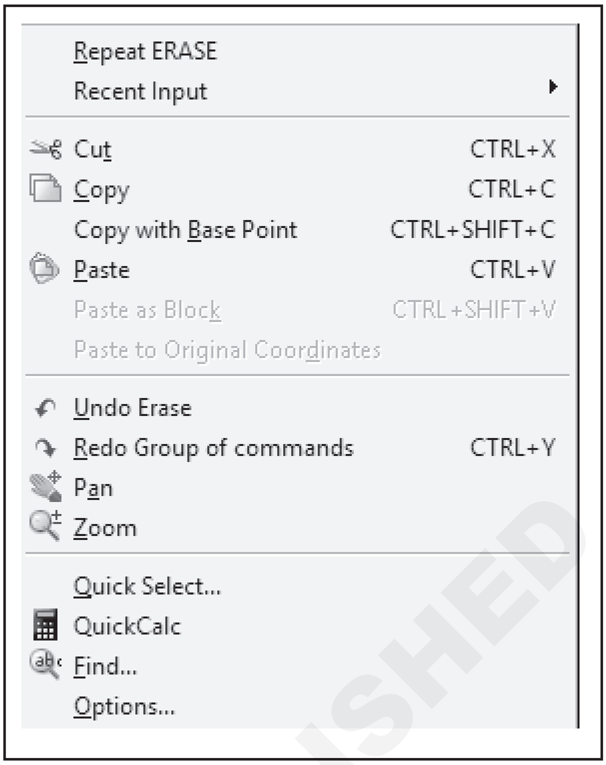
4. Right - mouse - click once to accept the selections. The selected two lines are erased.



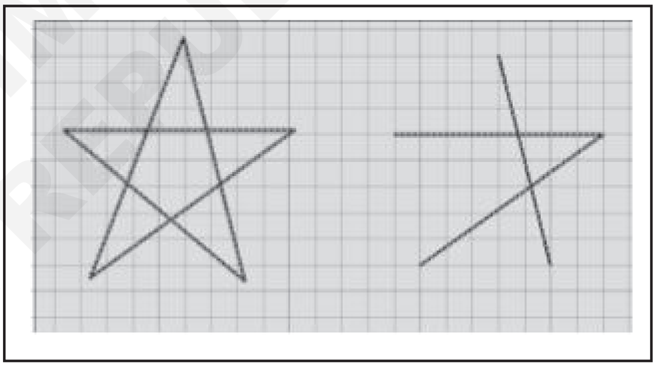
**The last command**

1. Inside the graphics window, click once with the right - mouse - button to bring up the popup option menu.

2. Pick Repeat Erase, with the left - mouse - button, in the popup menu to repeat the last command. Notice the other options available in the popup menu.



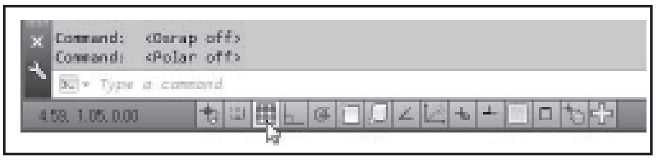

3. Move the cursor to a location that is above and toward the left side of the entities on the screen. Left - mouse - click once to start a corner of a rubber - band window.



Move the cursor toward the right and below the entities, and then left-mouse-click to enclose all the entities inside the selection window. Notice all entities that are inside the window are selected.

Inside the graphics window, right-mouse-click once to proceed with erasing the selected entities.

When your own create a free hand sketch of your choice using the line common. Experiment with using the different commands we have discussed so far, Reset the status button so that only the GRID DISPLAY option is turned ON as shown.



# Basic commands - III

**Objectives :** At the end of this exercise, you shall be able to,
- **point, rectangle, polyline**
- **revision cloud, spline, multiline**
- **construction line (xline), ray, hatch**

**1 Point**

This command is used to display a point on the screen [Drawing area]

Command : Point

Point : 5,6

Point :

Changing the point type

Normally the point appears as a dot on the screen, the style of the point can be changed by the PDMODE (point display mode) command.

Command : PDMODE

Pull down : Format, Point style

While using the pull - down menu, the point style dialogue box will appear select a point style in this dialog box by clicking the pointing device (mouse) then select the OK button.

Command : PDMODE

New value for PDMODE <current>: Enter new value (2)

Command : Point

Point : (2,2)

**2 Rectangle**

This command is used to draw Rectangle

Example:

Command : RECTANGLE / REG

First comer or [Chamfer / Elevation / Fillet / Thickness / Width]: 2,1

Other corner [Area / Dimension / Rotation] : 5,6

Chamfer - Used for chamfering the edges

Fillet - Used for filleting the edges

Width - to change the width

**Thickness** - allows to draw rectangle that projects in Z-direction by the specified value of thickness

**Elevation** - allows to draw a rectangle at a specified distance from the XY- plane along the Z-axis

**3 Poly line**

This command is used to draw poly lines. The PLINE command functions like the LIKE command with additional options like arc, length, width, etc.

Example:

Command : PLINE

Start point : select a point

Current the width is 0.0000

Next point or [Arc / Half width / Length / Undo / Width] : Select P1

Next point or [Arc / Close / Half width / Length/ Undo / Width]: Select P2

**Width** - To change the width of the poly line, enter W at last prompt. It asks you to enter the starting width and ending width of the poly line.

**Undo** - This erase the most recently drawn poly line seg ment. This can be invoked by entering U at the last prompt

**Length** - This asks you to enter the length of a new poly line segment. This can be invoked by entering L at prompt.

**Half width** - This is used to specify the starting and end ing half width or a poly line. This can be invoked by entering H at last prompt.

**Arc** - This is used to draw poly arcs from the previous point. It provides the various options for drawing poly arcs. The Arc option can be invoked by entering A last prompt.

**4 Revision cloud (Fig 1)**

This command is used to high light your mark-ups.

Example:

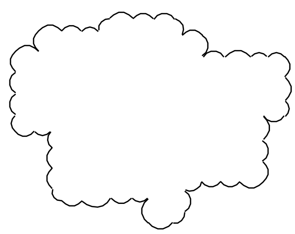
Command : REVCLOUD

Minimum arc length: 2.0000 Maximum arc length: 3.0000 Style: Normal specify start point or [Arc length / object / Style] <Object>: Specify start point

Guide crosshairs along cloud path...

Revision cloud finished.

Fig 1



REVISION CLOUD COMMAND

SUN256421

**5 Spline (Fig 2)**

Example

Command : SPLINE

Specify first point or [Object]: Click on the first point

Specify next point: <Ortho off>

Specify next point or [Close/Fit tolerance] <start tangent>: Click on the point

Specify next point or [Close/Fit tolerance] <start tangent>: Click on the point

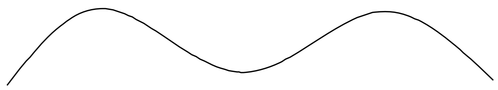
Specify next point or [Close/Fit tolerance] <start tangent>: Click on the point

Specify next point or [Close/Fit tolerance] <start tangent>: Click on the point

Specify next point or [Close/Fit tolerance] <start tangent>: Enter

Practice 1: Instructions

Fig 2



SPLINE COMMAND

SUN256422

1. Start a New file and select 1 workbook helper. Dwt
2. Draw the objects below using: (Fig 3)

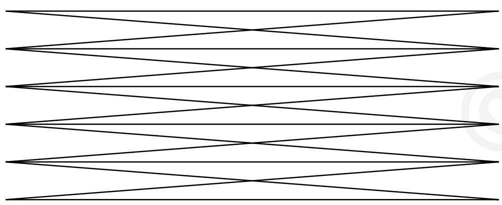
   DRAW / LINE

   ORTHO ON for Horizontal lines

   OBJECT SNAP = ENDPOINT
3. Save this drawing as:

Practice 2: Instructions

Fig 3



LINE COMMAND

SUN256423

1. Start a New file and select 1 workbook helper. Dwt
2. Draw the 2 vertical and 4 horizontal lines using: (Fig 3a)

   DRAW / LINE

   ORTHO (F8) = ON

   SNAP (F9) = OFF
3. Then draw the diagonal lines using:

   DRAW / LINE

   ORTHO & SNAP = OFF

   OBJECT SNAP = INTERSECTION
4. Save this drawing as:

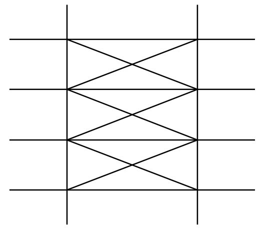
Practice 3: Instructions

1. Start a New file and select 1 workbook dwt.
2. Using FORMAT / UNITS:

   Set the units to DECIMALS

   Set the precision to 0.00

Fig 3a



LINE COMMAND

SUN256423A

3. Using FORMAT / DRAWING LIMITS set the drawing limits to :

   Lower left corner = 0,0

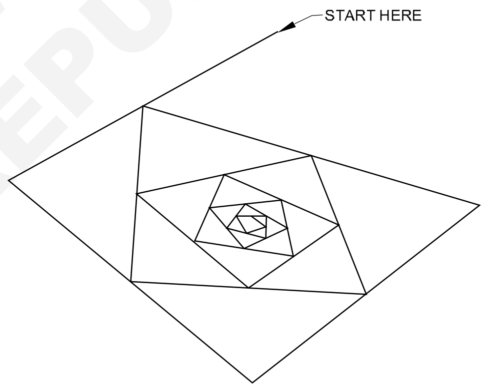
   Upper right corner = 12,9
4. Use VIEW / ZOOM / ALL to make the screen adjust to the new limits.
5. Turn OFF the GRIDS (F7) SNAP (F9) and ORTHO (F8)

   (Your screen should be blank and your crosshair should move freely)
6. Draw the Lines below using:

   DRAW / LINE

   OBJECT SNAP = MIDPOINT

Fig 4




LINE COMMAND

SUN256424

7. Save this drawing as: (Fig 4)

Practice 4: Instructions

1. Using a New file and select 1 workbook helper. dwt.
2. Using FORMAT / UNITS

   Set the units to ARCHITECTURAL

   Set the precision to ½"

**A warning may appear asking you if you "are sure you want to change the units"? Select the OK button.**

3. Using FORMAT / DRAWING LIMITS set the drawing limits to:

   Lower left corner = 0.0

   Upper right corner = 25, 20
4. Use VIEW / ZOOM / ALL to make the screen adjust to the new limits

5. Turn OFF the GRIDS (F7) SNAP (F9) and ORTHO (F8)

   (Your screen should be blank and your crosshair should move freely)

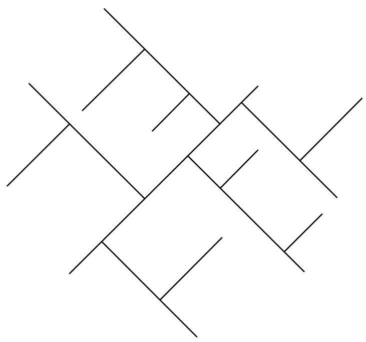
6. Draw the Lines below using:

   DRAW / LINE

   OBJECT SNAP = MIDPOINT

7. Save this drawing as: (Fig 4a)

Fig 4a



LINE COMMAND

SUN256424A

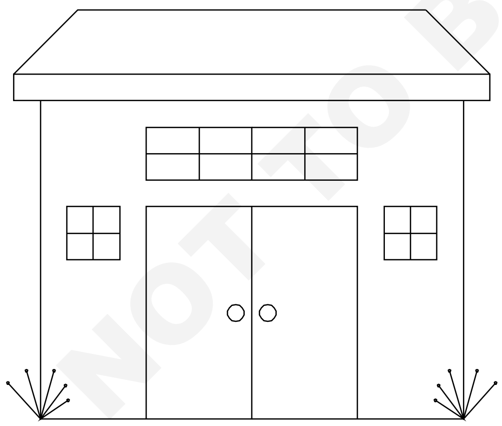
Practice 5: Instructions

1. Start a New file and select 1 workbook helper. dwt.
2. Draw the house below using at least 4 commands.
3. You can change the GRID and INCREMENT SNAP setting to whatever you like.
4. You decide when to turn Ortho and Snap On or Off.

   Have some fun with this one!

5. Save this drawing as: (Fig 5)

Fig 5



LINE COMMAND

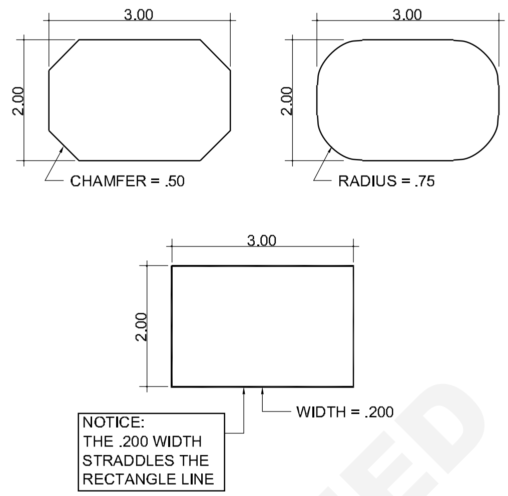
SUN256425

Practice 6: Instructions

1. Start a New file and select 1 workbook helper. dwt.
2. Draw the RECTANGLES below using the options: DIMENSION, CHAMFER, FILLET and WIDTH
3. Save this drawing as: (Fig 5a)

Practice 7: Instructions

Fig 5a




EXERCISE

SUN256425A

1. Start a New file and select 1 workbook dwt.
2. Using FORMAT / UNITS:

   Set the units to FRACTIONAL

   Set the precision to ¼"

3. Using FORMAT / DRAWING LIMITS set the drawing limits to:

   Lower left corner = 0,0

   Upper right corner = 12,9

4. Use VIEW / ZOOM / ALL to make the screen adjust to the new limits.
5. Turn OFF the GRIDS (F7) SNAP (F9) and ORTHO (F8)

   (Your screen should be blank and your crosshair should move freely)

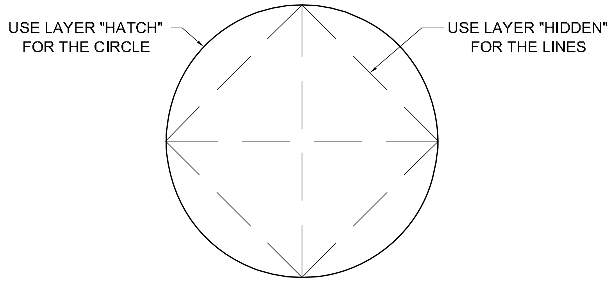
6. Draw the objects below using:

   DRAW / CIRCLE (CENTER, RADIUS) and LINE

   OBJECT SNAP = QUADRANT

7. Save this drawing as: (Fig 6)

Fig 6




HIDDEN COMMAND

SUN256426

Practice 8: Instructions

1. Start a New file and select 1 workbook dwt.

2. Using FORMAT / UNITS:

   Set the units to FRACTIONAL

   Set the precision to ½"

3. Using FORMAT / DRAWING LIMITS set the drawing limits to:

   Lower left corner = 0,0

   Upper right corner = 20,15

4. Use VIEW / ZOOM / ALL to make the screen adjust to the new limits

5. Turn OFF the GRIDS (F7) SNAP (F9) and ORTHO (F8)

   (Your screen should be blank and your crosshair should move freely)

6. Draw the objects below using:

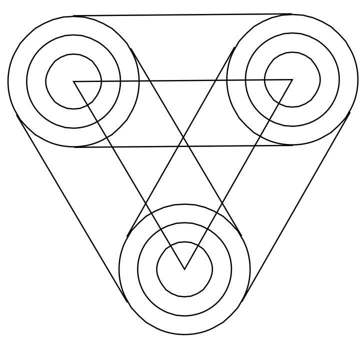
   DRAW / CIRCLE (CENTER, RADIUS) and LINE

   OBJECT SNAP = CENTER and TANGENT

   Very important: Use the Tangent option at each end of the line. AutoCAD needs to be told that you want each end of the line to be tangent to a circle.

7. Save this drawing as (Fig 6a)

Fig 6a



EXERCISE

SUN256426A

**6 MULTILINES:**

This command allows you to draw between 1 and 16 lines parallel to each other. You must tell AutoCAD the distance between the parallel lines.

Pull down menu: Draw, Multiline

Command: Draw multiline, ml

Once the command is issued, Autocad responds with

Current settings: Justification = Top, Scale = 1.00, Style = STANDARD

Specify start point or [Justification / Scale / STyle]:

Scale is the distance in units between the parallel lines. Justification determines where the start point of a vertex is. Both these settings are illustrated in the diagram below. Top, Zero and Bottom refer the justification

Multiline can be closed to form enclosed to form enclosed shapes (Fig 7). A closed multiline automatically joins the beginning and end of the shape. When you are drawing a multiline shape, the command option 'c' closes the shape otherwise just press enter to finish the command.

Editing multiline

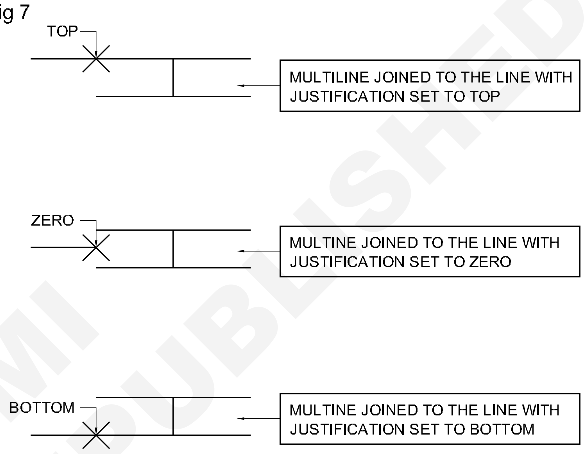
Command line: mledit

Menu: Modify, object, multiline

When the command is issued, the Multiline Edit tools dialogue box is displayed. The box is divided in to four columns. Each column helps you to edit a different type of intersection.

**7 Construction line (X line)**

Fig 7




MULTILINES COMMAND

SUN256427

X line is a linear object, which starts at infinite and ends at infinite, or we can say that it is a line, which has no start or end point but passes through a specified point. These lines are used for projections.

Command: X line

Specify a point or [hor/ver/ang/bisect/offset]: use one of the point fixing methods or enter

An option. Eg. H

Specify through point: Use one of the point fixing methods or

Specify through point: Use one of the point fixing methods or

**8 RAY**

Ray creates semi infinite lines commonly used as construction lines. A ray has a finite starting point and extends to infinity.

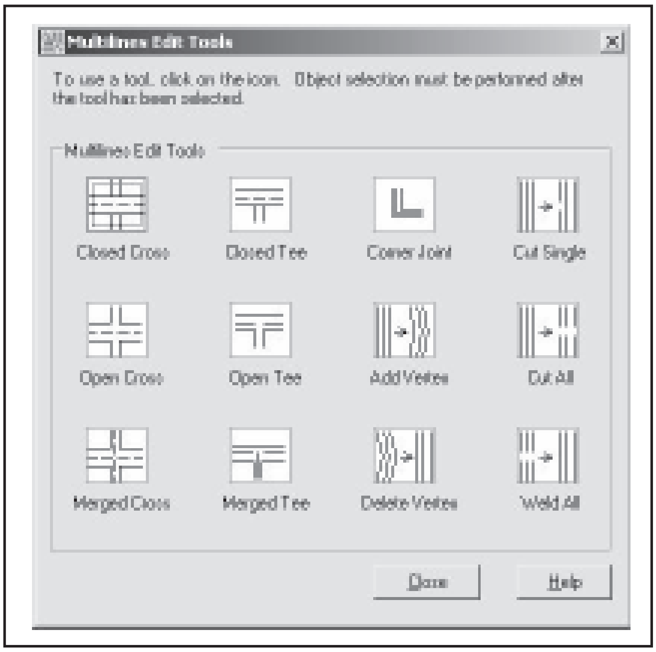
Command: RAY

Menu: Draw, Ray

Specify start point: Fix a point on the screen

Specify through point:

Specify through point:




AutoCAD draws a ray and continue to prompt for though points so you can create multiple rays. Press to end the command.

**9 Hatch**

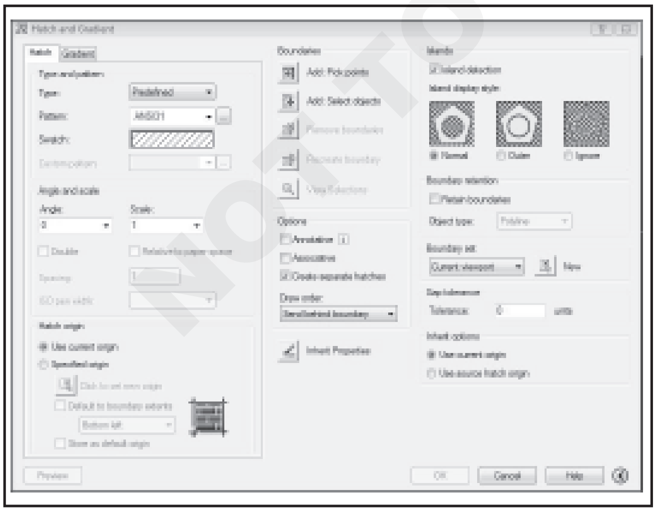
Hatch is used to fill an area defined by lines arcs, circles or poly line with either a predefined pattern, a user defined pattern or a simple hatch pattern. It is used to show the section of solids or objects.

Tool bar: Draw, Hatch

Pull down menu: Draw hatch B

Command: Hatch or H

This allows you to hatch a region enclosed within a boundary by selecting the objects to be hatched. When you invoke the HATCH command. The hatch and gradient dialogue box is displayed. This dialogue box has several options which give various aspects of hatching



**Command: Hatch or H**

1. Select type and pattern from predefined, user defined and customer select colour from gradients. (Fig 8)
2. Mouse click on add pick point.
3. Click inside ABCD.
4. Change angle and scale if you want click on preview.

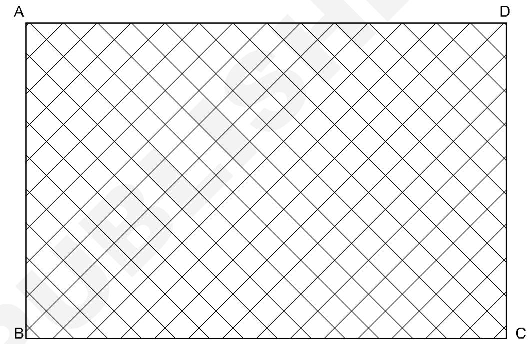
   If it is ok then click on in the dialogue.

Example:

**Command: Hatch, H**

1. Select type and pattern from predefined user defined cand custom or select colour from gradient (Fig 8)
2. Mouse click on add pick point
3. Mouse inside ABCD
4. Change angle and scale if you want
5. Click on preview
6. If it is ok then click on OK in the dialogue box.

Fig 8




HATCH COMMAND

SUN256428

**List :**

AutoCAD lists out the properties and the geometrical parameters of the selected objects.

Pull down menu :- Tools, inquiry, list

Command: list

Select objects: use any object selection method select rectangle ABCD

Select objects: 1 found

Select objects:

Properties of the rectangle ABCD = LWPOLYLINE layer: "0"

Space: Model space, Handle = d8a, Closed, Constant width 0.0000

Area 16486.7990, perimenter 551.6401

**Distance**

Pull down menu:- Tools, inquiry, distance

To measure the distance between two points

Command: Dist

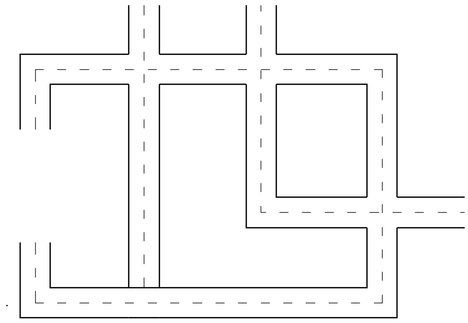
Specify first point: Select A

Specify second point: Select B

Distance = 118.6843, Angle in XY Plane = 0, Angle from XY Plane = 0

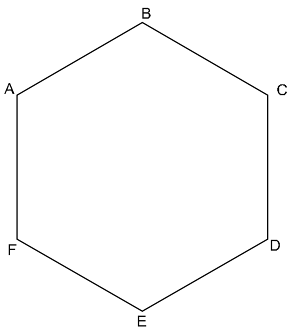
Delta X = 118.6743, Delta Y = 0.0000, Delta Z = 0.0000

Fig 9



MULTILINES

Fig 10




AREA COMMAND

**Area**

Calculate the area and perimeter of object or of defined areas

Pull down menu: Tools, Inquiry, area

Command Area

Specify first corner point or [ Object / Add / Subtract] first point A

Specify next corner point or press ENTER for total: Select next point B

Specify next corner point or press ENTER for total: Select next point C

Specify next corner point or press ENTER for total: Select next point D

Specify next corner point or press ENTER for total: Select next point E

Specify next corner point or press ENTER for total: Select next point F

Specify next corner point or press ENTER for total

Area = 8316.3401, Perimeter = 339.4622

REGEN

Command : Regen

This command makes Auto CAD to regenerate the entire drawing to update it. By using this commands, the circles and arcs can be smoothened.



## Dimensioning & Text

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

- **dimensioning**
- **text & text style**

### Dimensioning commands

While manufacturing an object, the drawing must contain size description such as the length, width, height, angle, radius, diameter and location of the object. These are added to the drawing with the help of dimensioning.

### 1 Dimension - linear

This command is used to measure horizontal and vertical dimensions between two points.

Tool bar : Dimension, Linear (Fig 1)

Pull Down : Dimension, Linear

Command : DIM LIN /DLI

Example:

Command : DIM LIN / DLI

Specify first extension line origin of : Selection point A

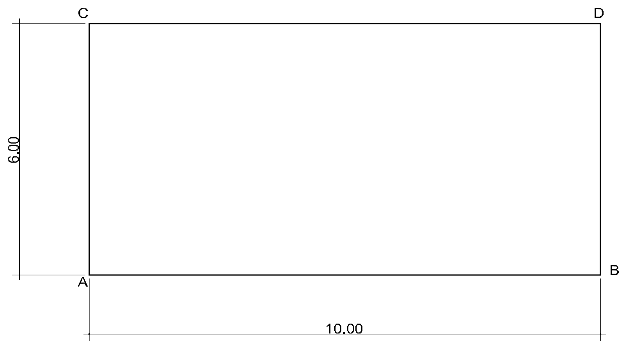
Specify second extension line original : Select point B

Specify dimension line location or

[Mtext/Text/Angle/Horizontal/Vertical/Rotated]: Mouse click on the position where the dimension is to be placed

Dimension text = 6.00

Fig 1




DIMENSION-LINEAR

DIMENSIONING COMMANDS

### 2. Dimension - aligned (Fig 2)

This command is used to measure inclined dimension between two points.

Tool bar : Dimension, Aligned

Pull down : Dimension, Aligned

Command : DIM ALI /DAL

Example:

Command : DIM ALI/DAL

Specify first extension line origin or : Select point A

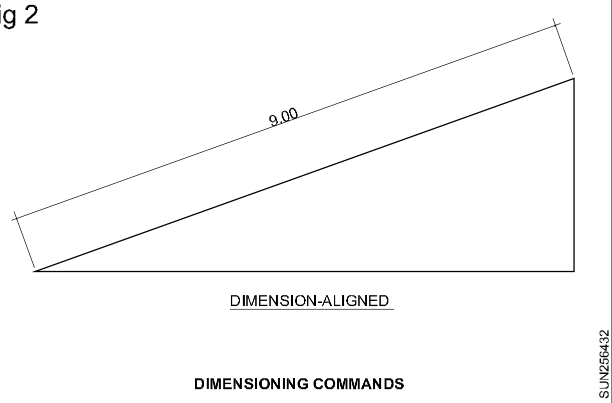
Specify first extension line origin : Select point B

Specify dimension line location or

[Mtext/Text/Angle/Horizontal/Vertical/Rotated]: Mouse click on the position where the dimension is to be placed

Dimension text = 9.00

Fig 2




### 3. Dimension - ARC length (Fig 3)

This command is used to measure the length of an arc.

Tool bar : Dimension, Arc length

Pull Down : Dimension, Arc length

Command : DIMARC/DAR

Example:

Command : DIM ARC / DAR

Command : DAR DIMARC

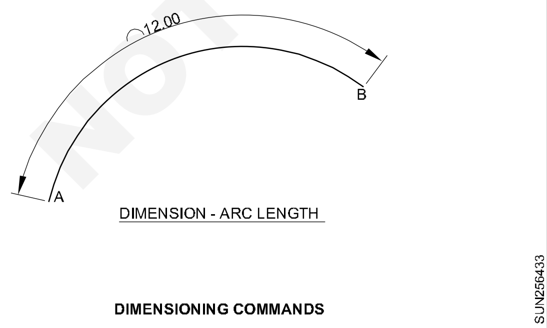
Select arc or polyline arc segment:

Specify arc length dimension location,

Or [Mtext/Text/Angle/Partial/Leader]: Mouse click on the position where the dimension is to be placed

Dimension text = 12.00

Fig 3




### 4. Dimension - radius (Fig 4)

This command is used to measure the radius of an arc or circle.

Tool bar : Dimension, Radius

Pull Down : Dimension, Radius

Command : DIM RA/DRA

Example:

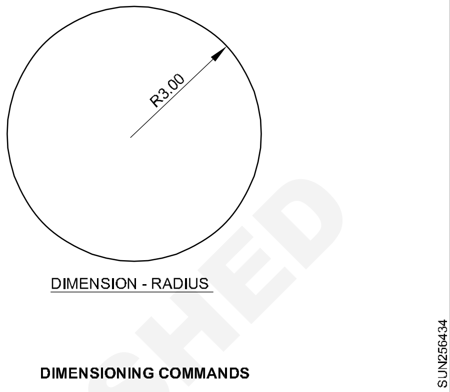
Command : DIM RA / DRA

Select arc or circle: Select the circle

Dimension text = 3.00

Specify dimension line location or [Mtext /Text/Angle]:

Fig 4




### 5. Dimension - jogged (Fig 5)

Tool bar : Dimension, Jogged

Pull Down : Dimension, Jogged

Command : DIM JO/DJO

Example:

Command : DIM JO/DJO

Select arc or circle: Select the circle

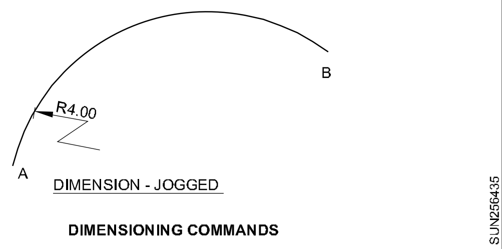
Specify center location override: Select center

Dimension text = 4.00

Specify dimension line location or [Mtext /Text/Angle]:

Specify jog location: Mouse click on the position where the dimension is to be placed.

Fig 5




### 6. Dimension - diameter (Fig 6)

This command is used to measure the Diameter of a circle.

Tool bar : Dimension, Diameter

Pull Down : Dimension, Diameter

Command : DIM DIA/DDI

Example:

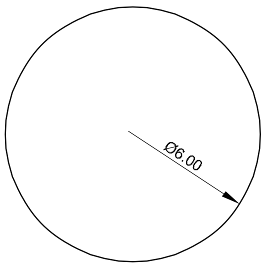
Command : DIM DIA/DDI

Select arc or circle: Select the circle

Dimension text = 6.00

Specify dimension line location or [Mtext /Text/Angle]: Mouse click on the position where the dimension is to be placed.

Fig 6




DIMENSION -DIAMETER

DIMENSIONING COMMANDS

SUN256436

**7. Dimension - Angular (Fig 7)**

This command is used to measure the Angle between two non parallel straight lines.

Tool bar : Dimension, Angular

Pull Down : Dimension, Angular

Command : DIM ANG/DAN

Example:

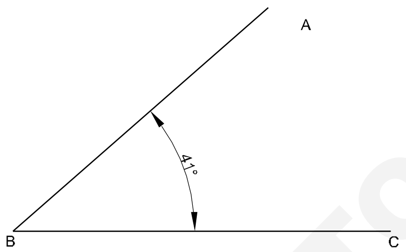
Command : DIM ANG/DAN

Select arc, circle, line, or <specify vertex>: Select AB

Specify dimension line location or [Mtext /Text/Angle]: Mouse click on the position where the dimension is to be placed.

Dimension text = 41

Fig 7




DIMENSION - ANGULAR

DIMENSIONING COMMANDS

SUN256437

**8. Dimension - continue (Fig 8)**

This command is used to continue dimensioning after the first dimensioning has been executed.

Tool bar : Dimension, Continue

Pull Down : Dimension, Continue

Command : DIM CON/DCO

Example:

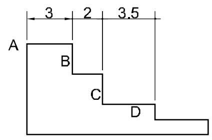
Command : DIM CON/DCO

Specify a second extension line origin or [Undo/Select] <Select>: Select C

Specify a second extension line origin or [Undo/Select] <Select>: Select D

Specify a second extension line origin or [Undo/Select] <Select>: * Cancel*

Fig 8




DIMENSION - CONTINUE

DIMENSIONING COMMANDS

SUN256438

**9. Dimension - base line (Fig 9)**

This command is used to give dimension when number or dimensions of a part have a common datum.

Tool bar : Dimension, Base line

Pull Down : Dimension, Base line

Command : DIM LEA/LE

Example:

Command: DIM LEA/LE

Specify first leader point, Select point A

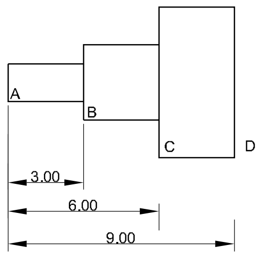
Specify next point: Select point B

Specify next point:

Specify text width <0.0000>:

Enter first line of annotation text <Mtext>: WOODEN BLOCK

Fig 9




DIMENSION -BASELINE

DIMENSIONING COMMANDS

SUN256439

**10. Dimension - leader (Fig 10)**

This command is used to give leader lines i.e. used to describe some features in the drawing.

Tool bar : Dimension Leader

Pull Down : Dimension Leader

Command : DIM LEA/LE

Example:

Command: DIM LEA/LE

Specify first leader point, Select point A

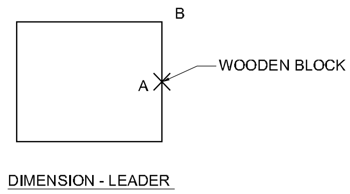
Specify next point: Select point B

Specify next point:

Specify text width <0.0000>:

Enter first line of annotation text <Mitest> WOODEN BLOCK

Fig 10




SUN25643A

DIMENSIONING COMMAND

11. DIMENSION - STYLE

Tool bar : Dimension, Dimension style

Pull Down : Dimension, Dimension style

Command : D

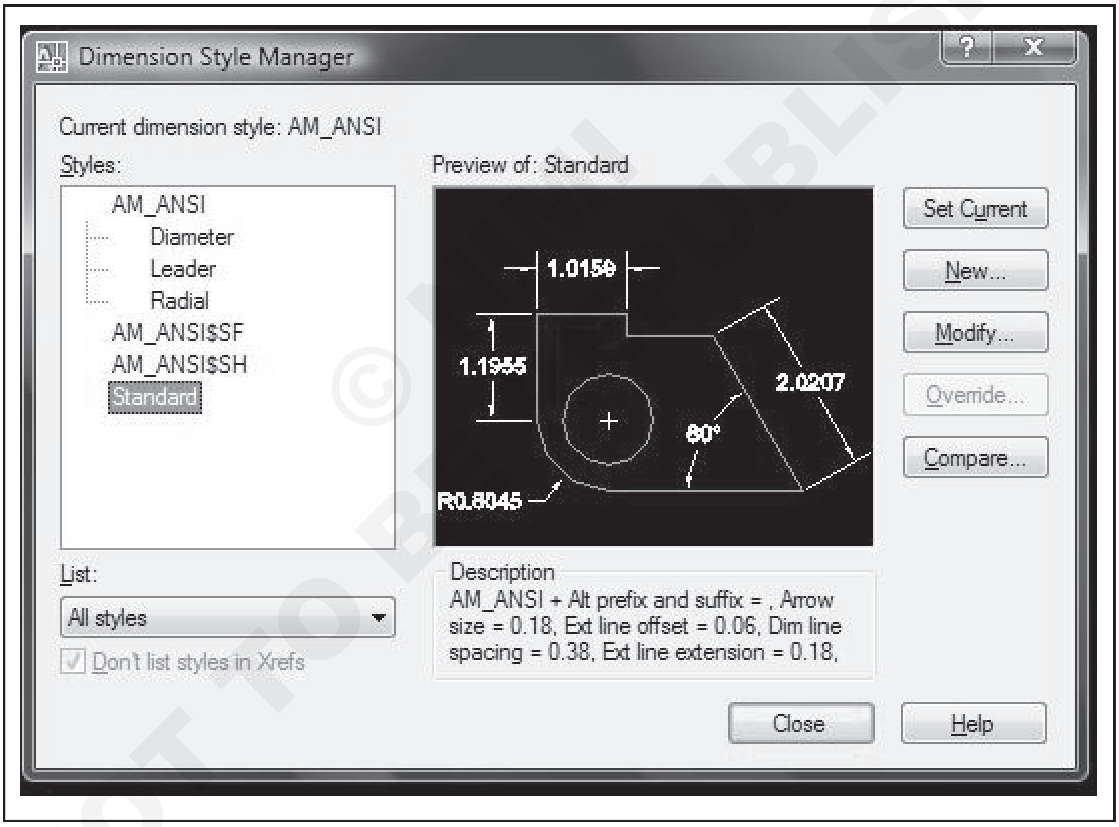
This command is used to select or change the properties of a dimension. When you enter this command the dimension style manager dialogue box will be displayed. This dialogue box provides various options for modifying the dimension. Click on modify and give the new values.

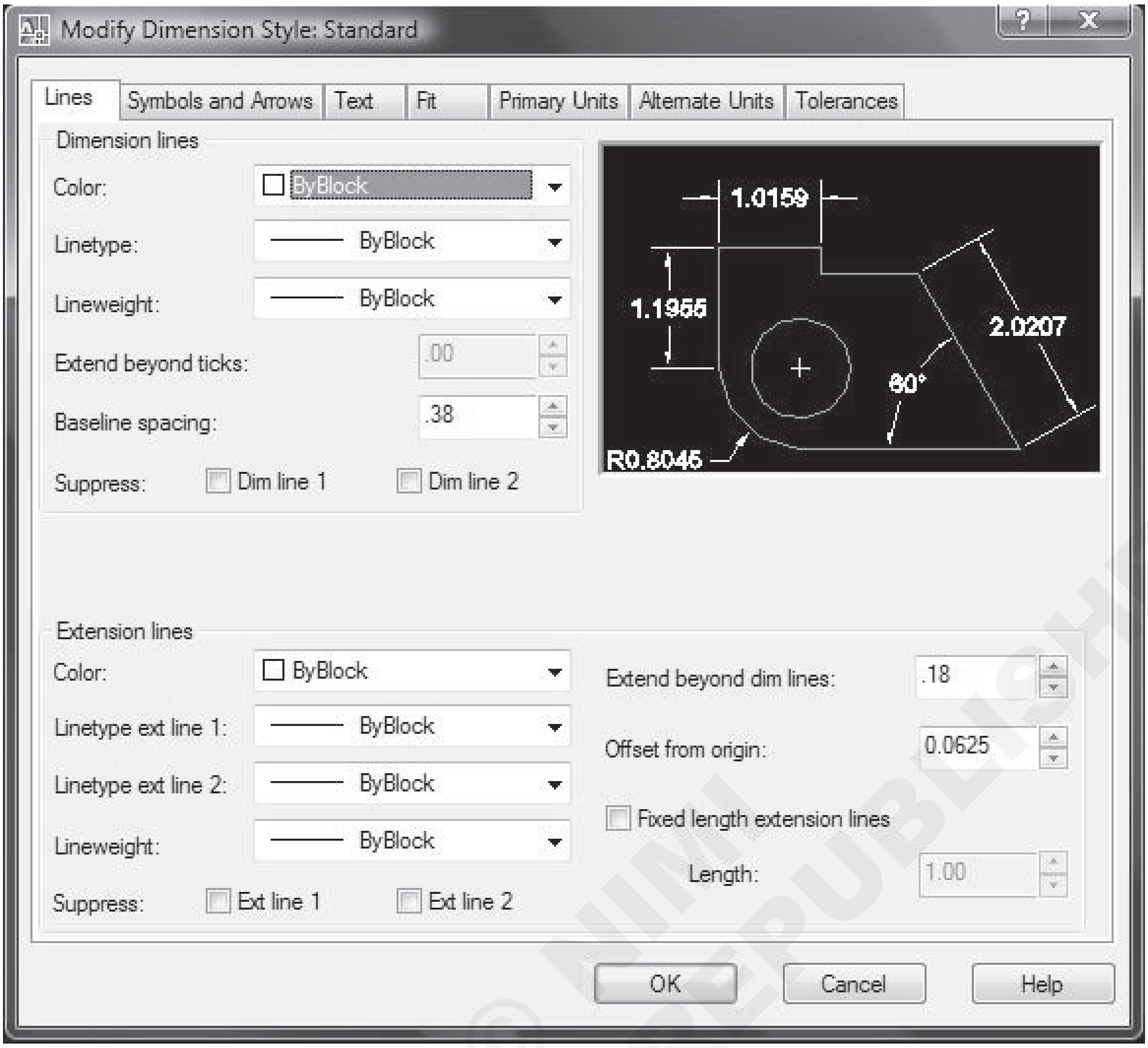
**Dimension sytle**

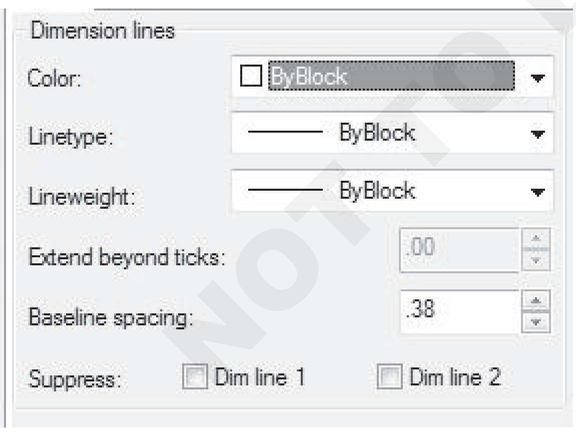
Pull down menu: Dimension, Dimension style

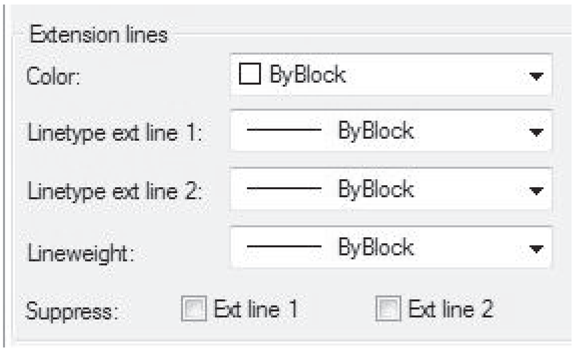
When you select this, a dimension style manager dialogue box will appear on the screen.

A dimension style is a saved set of dimension settings defining the appearance and behavior of the dimensions. By creating dimension styles. You can set all relevant dimension system variables and control the layout and appearance of all dimensions within a drawing.



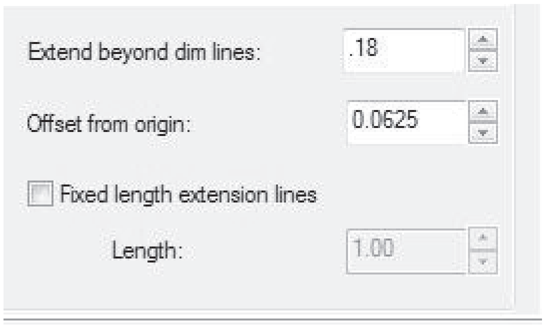



| | Description |
|---|---|
|   | Sets the dimension line properties<br>1. Colour displayed and Sets the colour for dimension line<br>2. Line type sets the type of the dimension line.<br>3. Line weight sets the line weight of the dimension line<br>4. Extend beyond ticks specifies a distance to extend the dimension line past the extension line when you use oblique, architectural, tick, integral, and no marks for arrow heads.<br>5. Base Line spacing sets the spacing between the dimension lines of a base line dimension. Enter a distance.<br>6. Suppress suppresses display of dimension line when they are outside. |



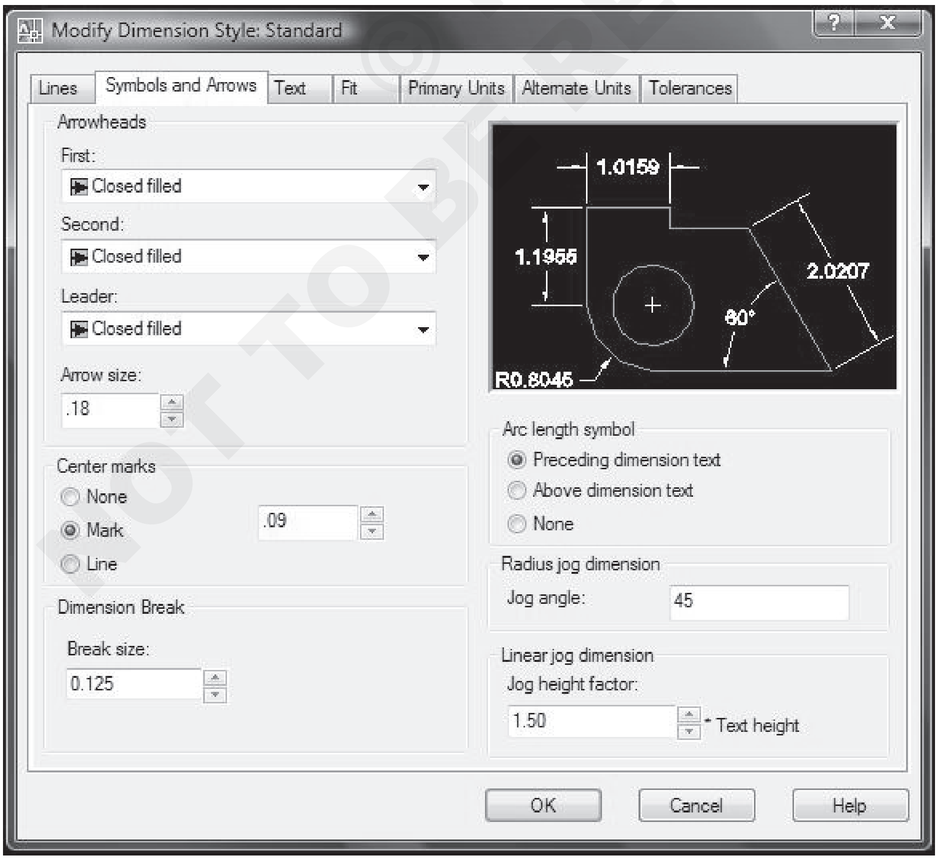

Set the Extension line properties

1. Colour displayed and Sets the colour for extension line
2. Line type sets the type of the Extension lines.
3. Line Weight sets the line weight of the Extension lines.
4. Suppress suppresses display of Extension lines.

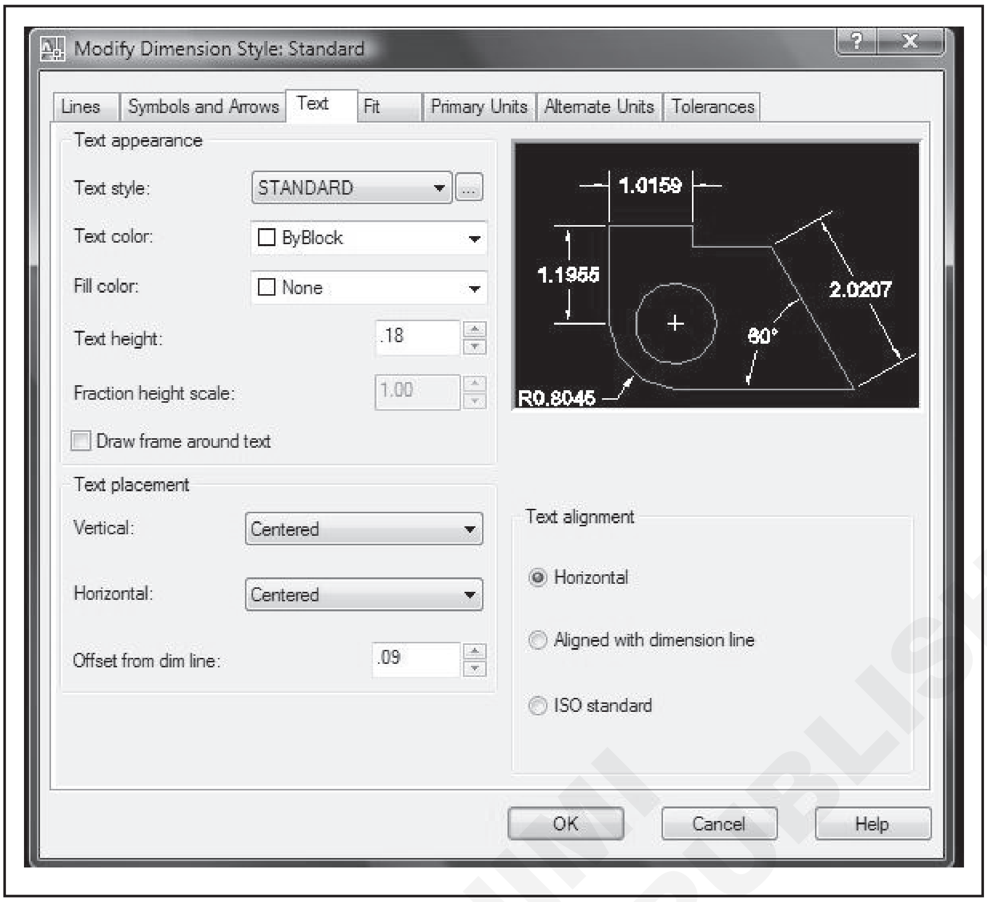


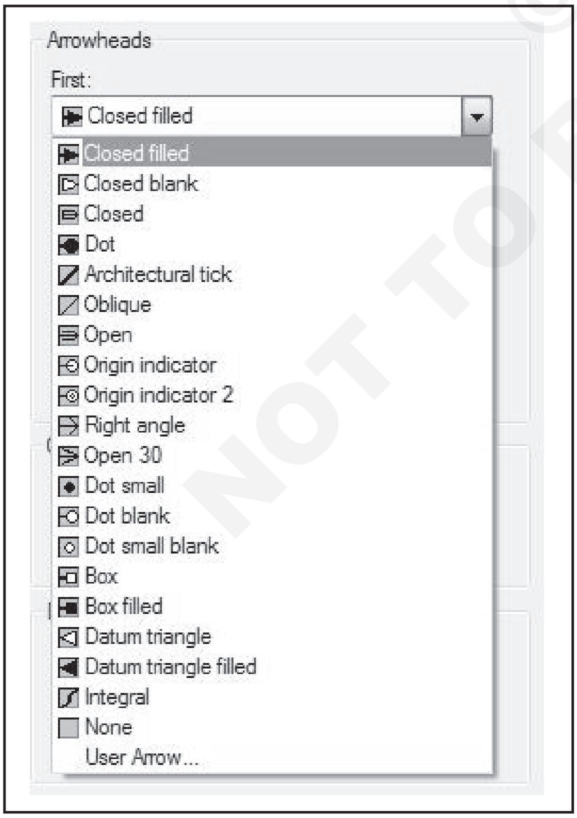

1. External Beyond Dim Lines specifies a distance to extend the extension lines.
2. Offset From Origin specifies the distance to offset the extension lines from the origin points that define the dimension.
3. Fixed length extension lines, set the length of the extension line.

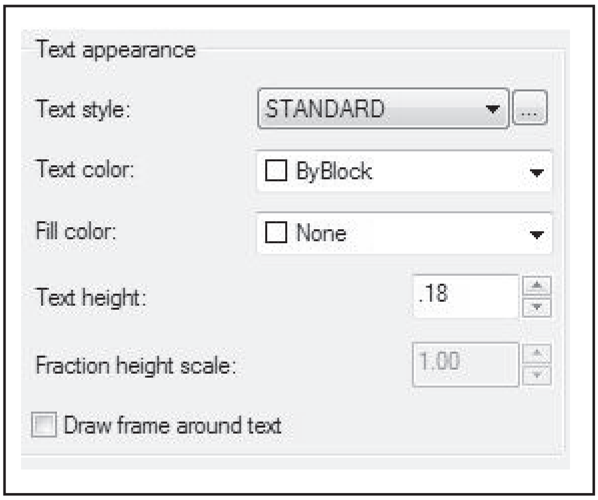
**Symbols and arrows tab**



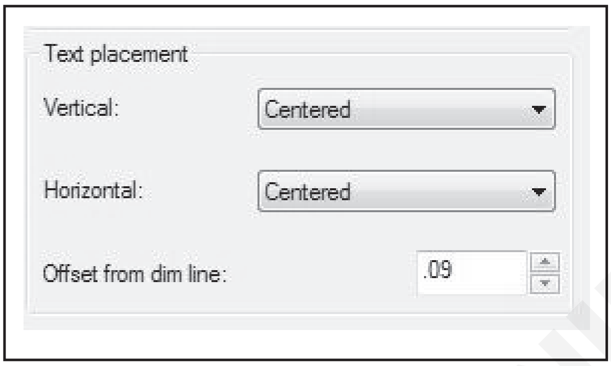
**Text tab**



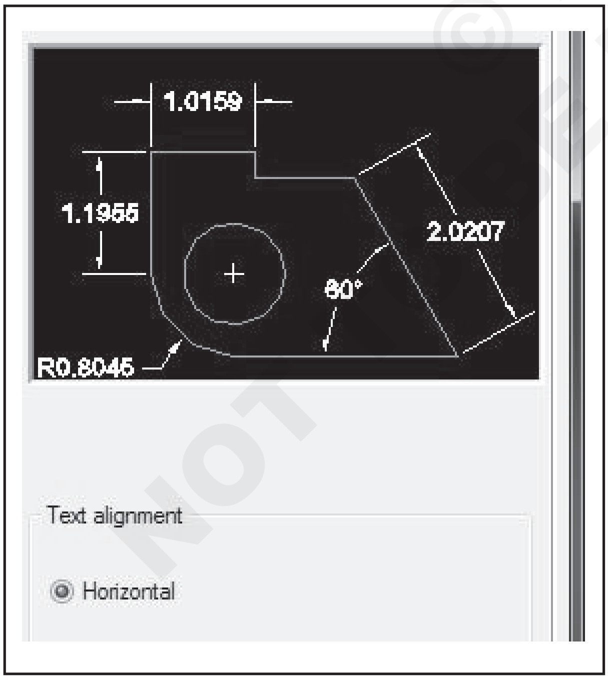

| | Description |
|---|---|
|  | 1. Here you can set the types of arrow heads<br>2. Arrow size sets the size of arrow |

<table>
<tr><th></th><th>Description</th></tr>
<tr><td>
</td><td>

1. Text style button displays the text style dialogue box, which you can use to define or modify text styles
2. Text colour displays and sets the colour for the dimension text.
3. Text Height displays and sets the current dimension text style.
4. Draw Frame Around Text draws a frame around dimension text.

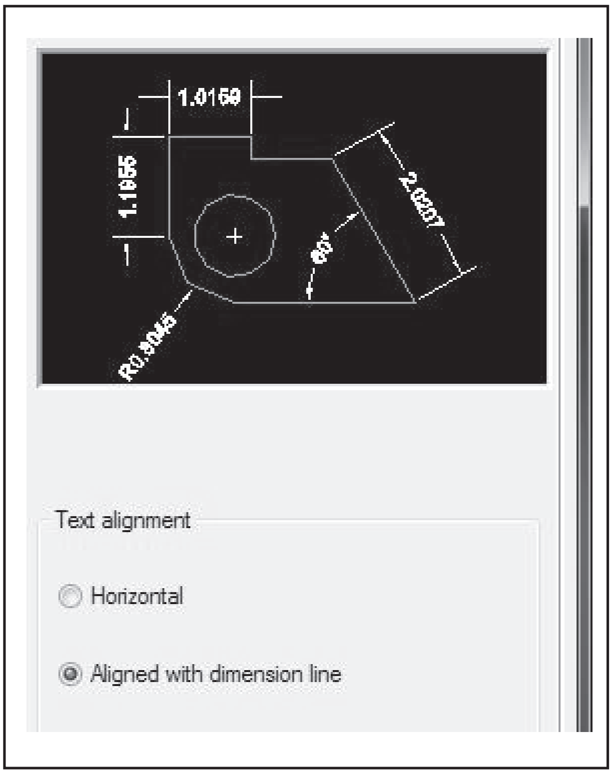
</td></tr>
<tr><td>
</td><td>

1. Vertical position controls the vertical justification of dimension text along the dimension line.
2. Horizontal position controls the horizontal justification of dimension text along the dimension line and extension line.
3. Offset from dimension line displays and sets the current text gap, which is the distance around the dimension text when the dimension line is broken to accommodate the dimension text.

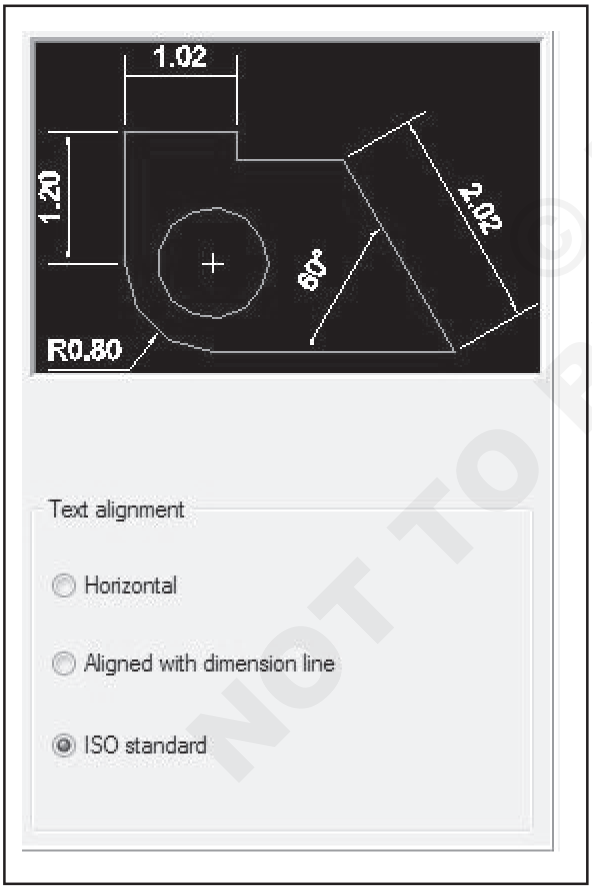
</td></tr>
<tr><td>
</td><td>

1. Horizontal places text in a horizontal position

</td></tr>
</table>

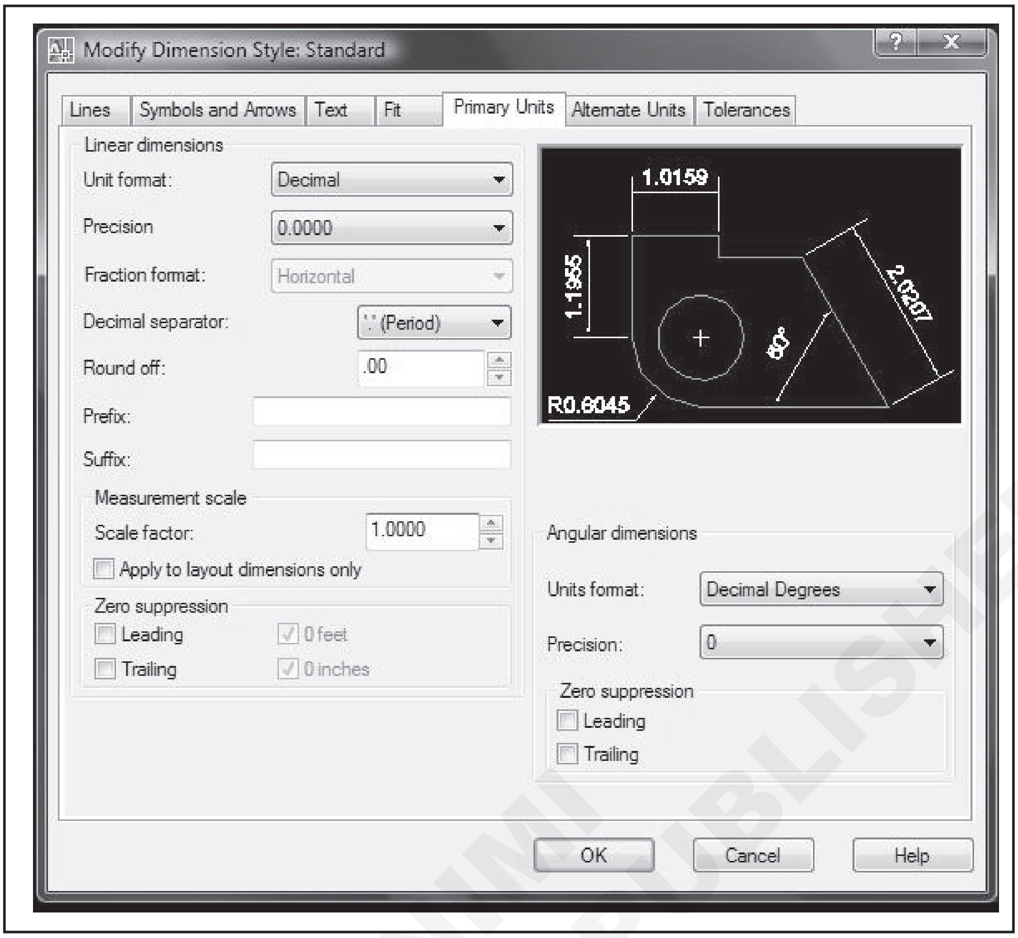



2. Aligned with dimension line aligns text with the dimension line

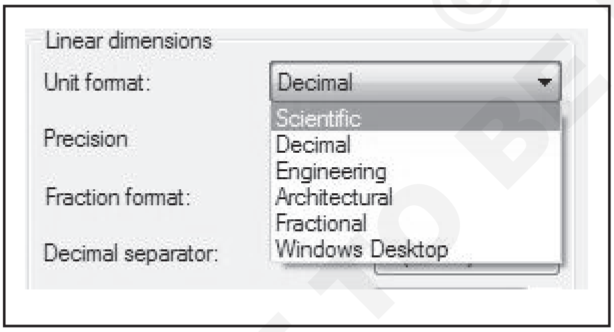



3. ISO Standards aligns text with the dimension line when the text is inside the extension lines, but aligns horizontally when text is outside the extension lines.

**Primary units tab**






| | Description |
|---|---|
|  | 1. Unit format sets the current for all dimension types accept angular. Options to select from include scientific, decimal, engineering, architectural, fractional etc.<br>2. Precision displays and sets the number of decimal places in the dimension text.<br>3. Fractional format sets the format for fractions. Options to select from include diagonal, horizontal, and not stacked<br>4. Decimal separator sets the separator for decimal formats. Options to select from include period (.), comma (.), or space |
|  | 1. Prefix includes the prefix you enter in the dimension text. You can enter text or use control codes to display special symbols. For example, entering the control code % %c displays the diameter symbol.<br>2. Suffix includes the suffix you enter in the dimension text. You can enter text or use control codes to display special symbols. For example, entering the text mm results in the dimension text similar to that shown in the illustration.<br>3. Measurement scale defines measurements scale options as follows: Linear scale factor sets a scale factor for linear dimension measurements for all dimension types except angular. |