UNIT-1
INTRODUCTION AND BASIC CONCEPTS

Surveying is defined as "taking a general view of, by observation and measurement determining the boundaries, size, position, quantity, condition, value etc. of land, estates, building, farms mines etc. and finally presenting the survey data in a suitable form". This covers the work of the valuation surveyor, the quantity surveyor, the building surveyor, the mining surveyor and so forth, as well as the land surveyor.

Another school of thought define surveying "as the act of making measurement of the relative position of natural and manmade features on earth‟s surface and the presentation of this information either graphically or numerically.

The process of surveying is therefore in three stages namely:

This part of the definition is important as it indicates the need to obtain an overall picture of what is required before any type of survey work is undertaken. In land surveying, this is achieved during the reconnaissance study.

Observation and Measurement

This part of the definition denotes the next stage of any survey, which in land surveying constitutes the measurement to determine the relative position and sizes of natural and artificial features on the land.

Presentation of Data:

The data collected in any survey must be presented in a form which allows the information to be clearly interpreted and understood by others. This presentation may take the form of written report, bills of quantities, datasheets, drawings and in land surveying maps and plan showing the features on the land.

Types of Surveying

On the basis of whether the curvature of the earth is taken into account or not, surveying can be divided into two main categories:

- Plane surveying
- Geodetic surveying

Plane surveying:

The type of surveying where the mean surface of the earth is considered as a plane All angles are considered to be plane angles. For small areas less than 250 km^2 plane surveying can safely be used. For most engineering projects such as canal, railway, highway, building, pipeline, etc constructions, this type of surveying is used. It is worth noting that the difference between an arc distance of 18.5 km and the subtended chord lying in the earth‟s surface is 7mm. Also the sum of the angles of a plane triangle and the sum of the angles in a spherical triangle differ by 1second for a triangle on the earth‟s surface having an area of 196km^2

Geodetic surveying:

It is that branch of surveying, which takes into account the true shape of the earth(spheroid).

Classification on the Basis of Instruments Used.

Based on the instrument used; surveys can be classified into;

- Chain tape surveys
- Compass surveys
- Plane table surveys
- Theodolite surveys

Classification based on the surface and the area surveyed

I. **Land survey:**

Land surveys are done for objects on the surface of the earth. It can be subdivided into:

II. **Topographic survey:**

This is for depicting the (hills, valleys, mountains, rivers, etc) and manmade features (roads, houses, settlements…) on the surface of the earth.

III. **Cadastral survey:**

It is used to determining property boundaries including those of fields, houses, plots of land, etc.

IV. **Engineering survey:**

It is used to acquire the required data for the planning, design and Execution of engineering projects like roads, bridges, canals, dams, railways, buildings, etc.

V. **City surveys:**

The surveys involving the construction and development of towns including roads, drainage, water supply, sewage street network, etc, are generally referred to as city survey.

VI. **Marine or Hydrographic Survey:**

Those are surveys of large water bodies for navigation, tidal monitoring, the construction of harbors etc.

VII. **Astronomical Survey:**

Astronomical survey uses the observations of the heavenly bodies (sun, moon, stars etc) to fix the absolute locations of places on the surface of the earth

CLASSIFICATION ON THE BASIS OF PURPOSE

- Engineering survey.
- Control Survey: Control survey uses geodetic methods to establish widely spaced vertical andhorizontal control points.
- Geological Survey: Geological survey is used to determine the structure and arrangement of rockstrata. Generally, it enables to know the composition of the earth.
- Military or Defense Survey: It is carried out to map places of military and strategic importance
- Archeological survey is carried out to discover and map ancient/relies of antiquity.

Classification Based On Instrument Used

- Chain/Tape Survey: This is the simple method of taking the linear measurement using a chain or tapewith no angular measurements made.
- Compass Survey: Here horizontal angular measurements are made using magnetic compass with the linear measurements made using the chain or tape.
- Plane table survey: This is a quick survey carried out in the field with the measurements and drawingsmade at the same time using a plane table.
- Leveling: This is the measurement and mapping of the relative heights of points on the earth‟s surface showing them in maps, plane and charts as vertical sections or with conventional symbols.
- Theodolite Survey: Theodolite survey takes vertical and horizontal angles in order to establishcontrols.

CLASSIFICATION BASED ON THE METHOD USED

Triangulation Survey

In order to make the survey, manageable, the area to be surveyed is first covered with series of triangles. Lines are first run round the perimeter of the plot, then the details fixed in relation to the established lines. This process is called triangulation. The triangle is preferred as it is the only shape that can completely over an irregularly shapedarea with minimum space left.

Traverse survey:

If the bearing and distance of a place of a known point is known: it is possible to establish the position of that point on the ground. From this point, the bearing and distances of other surrounding points may be established. In the process, positions of points linked with lines linking them emerge. The traversing is the process of establishing these lines, is called traversing, while the connecting lines joining two points on the ground. Joining two while bearing and distance is known as traverse A traverse station is each of the points of the traverse, while the traverse leg is the straight line between consecutive stations.

Traverses may either be open or closed.

Closed Traverse:

When a series of connected lines forms a closed circuit, i.e. when the finishing point coincides with the starting point of a survey, it is called as a „closed traverse‟, here ABCDEA represents a closed traverse. (Fig 2.1 (a))

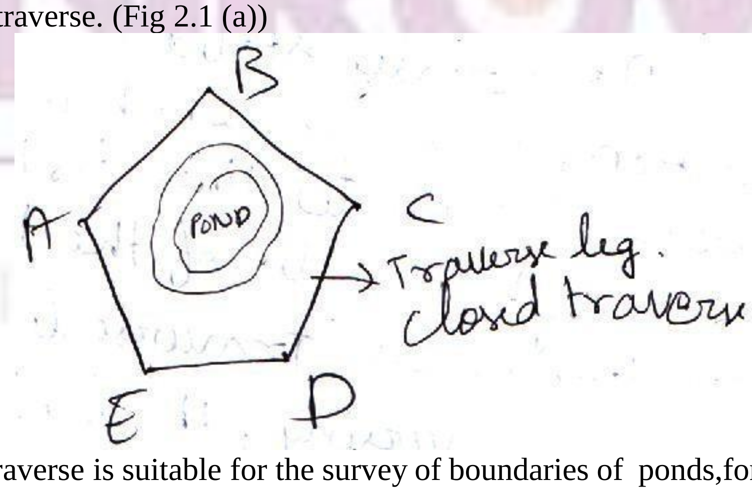
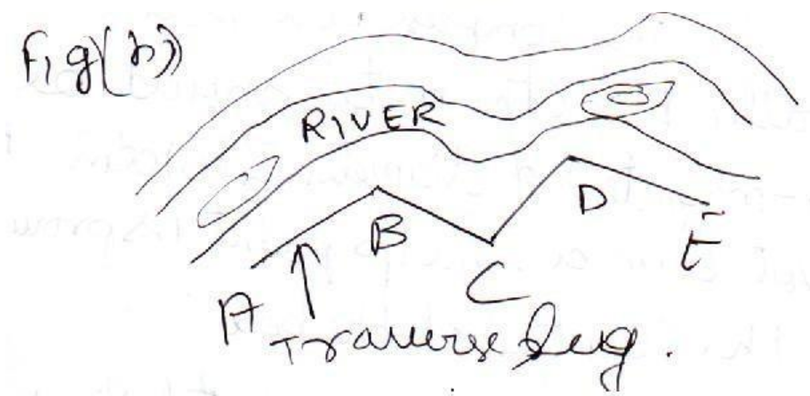


Fig 2.1 (a) Closed traverse is suitable for the survey of boundaries of ponds,forests etc.

Open Traverse:

When a sequence of connected lines extends along a general direction and does not return to the starting point, it is known as „open traverse" or (unclosed traverse). Here ABCDE represents an open traverse.



CLASSIFICATION OF SURVEYORS

Surveying is made up of various specializations known as sectors or classes as shownbelow:

- **General Practice Surveyors:**
  Surveyors under this class are mostly concerned with valuation and investment. Valuation surveyors deal with property markets, land and property values, valuation procedures and property law. Investment surveyors help investors to get the best possible return form property. They handle a selection of properties for purchase or sale by pension funds, insurance companies, charities and other major investors. They also specialize in housing policy advice, housing development and management.
- **Planning and Development Surveyors**
  They are concerned with preparing planning applications and negotiating with local authorities' planners to obtain planning permission.
- **Building Surveyors**
  Their work involves advising on the construction, maintenance, repair of all types of residential and commercial property. The analysis of building defects is an important part of a building surveyor'sdiscipline.
- **The Quantity Surveyors**
  They evaluate project cost and advice on alternative proposals. They also mensure that each element of a project agrees with the cost plan allowance and that the overall project remains within budget.
- **Rural Practice Surveyors:**
  Surveyors in rural practice advice land owners, farmers and others with interests in the countryside. They are responsible for the management of country estates and farms, the planning and execution of development schemes for agriculture, forestation, recreation, sales of properties and livestock.
- **Mineral Surveyors**
  They plan the development and future of mineral workings. They work with localauthorities and the land owners on planning applications and appeals, mininglaws and working rights, mining subsidence and damage, the environmentaleffects of land and deep underground mines.

- **Land surveyors:**

They measure land and its physical features accurately and record them in the form of a map or plan for the purpose of planning new building and by local authorities in managing roads, housing estates, and other facilities.They also undertake the positioning and monitoring for construction works.

<u>**BRANCHES OF SURVEYING**</u>

Aerial Surveying:

Aerial surveys are undertaken by using photographs taken with special cameras mounted in an aircraft viewed in pairs. The photographs produce three- dimensional images of ground features from which maps or numerical data can be produced usually with the aid of stereo plotting machines and computers.

Hydrographic Surveying (Hydro-Survey):

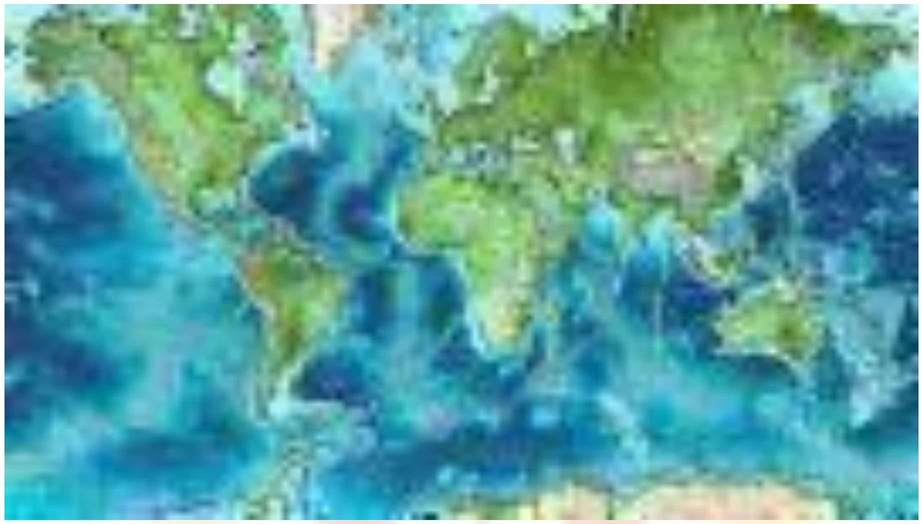
Hydro survey is undertaken to gather information in the marine environment such as mapping out the coast lines and sea bed in order to produce navigational charts.

It is also used for off shore oil exploration and production, design, construction and maintenance of harbors, inland water routes, river and sea defense, and pollution control and ocean studies.

Geodetic Survey:

In geodetic survey, large areas of the earth surface are involved usually on national basis where survey stations are precisely located large distances apart. Account is taken of the curvature of the earth, hence it involves advanced Mathematical theory and precise measurements are required to be made.

Geodetic survey stations can be used to map out entire continent, measure the size and shape of the earth or in carrying out scientific studies such as determination of the Earth"s magnetic field and direction of continental drifts.



Plane Surveying:

In plane surveying relatively small areas are involved and the area under consideration is taken to be a horizontal plane. It is divided into three branches.

- Cadastral surveying
- Topographical surveying
- Engineering surveying

Cadastral surveying:

These are surveys undertaken to define and record the boundary of properties, legislative area and even countries. It may be almost entirely topographical where features define boundaries with the topographical details appearing on ordinance survey maps. In the other hand, markers define boundaries corner or line points and little account may be taken of the topographical features.

Topographical Survey:

These are surveys where the physical features on the earth are measured and maps/plans prepared to show their relative positions both horizontally and vertically. The relative positions and shape of natural and man –made features over an area are established usually for the purpose of producing a map of the area of for establishing geographical information system.

Engineering Survey

These are surveys undertaken to provide special information for construction of Civil Engineering and building projects.

Reconnaissance:

This is an exhaustive preliminary survey of the land to be surveyed. It may beeither ground reconnaissance or aerial reconnaissance survey.

Reconnaissance is made on arrival to site during which an overall picture or viewof the area is obtained. The most suitable position of stations is selected, the purpose of the survey and the accuracy required will be drawn, and finally the method of observation will be established.

Objectives of reconnaissance

- To ascertain the possibility of building or constructing route or track through thearea.
- To choose the best one or more routes and record on amp.
- To estimate probable cost and draft airport.
- The basic principles and process surveyingIntroduction.
- So far, we have discussed the meaning, object and major classifications of surveying. Now let us move further to discuss the basic principles and process of surveying.
- Objectives**.**
- To enable students understand the basic principles of surveying.
- To expose the students to the process of surveying.

BASIC PRINCIPLES IN SURVEYING

PRINCIPLE OF WORKING FROM WHOLE TO PART

It is a fundamental rule to always work from the whole to the part. This implies a precise control surveying as the first consideration followed by subsidiary detail surveying.
This surveying principle involves laying down an overall system of stations whose positions are fixed to a fairly high degree of accuracy as control, and then the survey of details between the control points may be added on the frame by less elaborate methods.

Once the overall size has been determined, the smaller areas can be surveyed in the knowledge that they must (and will if care is taken) put into the confines of the main overall frame.
Errors which may inevitably arise are then contained within the framework of the control points and can be adjusted to it.

Surveying is based on simple fundamental principles which should be taken into consideration to enable one get good results.
Working from the whole to the part

It is achieved by covering the area to be surveyed with a number of spaced out control point called primary control points called primary control points whose pointing have been determined with a high level of precision using sophisticated equipments. Based on these points as theoretic, a number of large triangles are drawn. Secondary control points are then established to fill the gaps with lesser precision than the primary control points. At a more detailed and less precise level, tertiary control points at closer intervals are finally established to fill in the smaller gaps. The main purpose of surveying from the whole to the part is to localize the errors as working the other way round would magnify the errors and introduce distortions in the survey. In partial terms, this principle involves covering the area to be surveyed with large triangles. These are further divided into smaller triangles and the process continues until the area has been sufficiently covered with small triangles to a level that allows detailed surveys to be made in a local level. Error is in the whole operation as the vertices of the large triangles are fixed using higher precision instruments.
Using measurements from two control parts to fix other points.

Given two points whose length and bearings have been accurately determined, a line can be drawn to join them hence surveying has control reference points. The locations of various other points and the lines joining them can be fixed by measurements made from these two points and the lines joining them. For an example, if A and B are the control points, the following operations can be performed to fix other points.

Using points A and B as the centers ascribe arcs and fix (where they intersect). Draw a perpendicular from D along AB to a point C.

To locate C, measure distance AB and use your protractor to equally measure angle ABC.

To locate C the interior angles of triangle ABC can be measured. The lengths of the sides AC and BC can be calculated by solving the triangle.

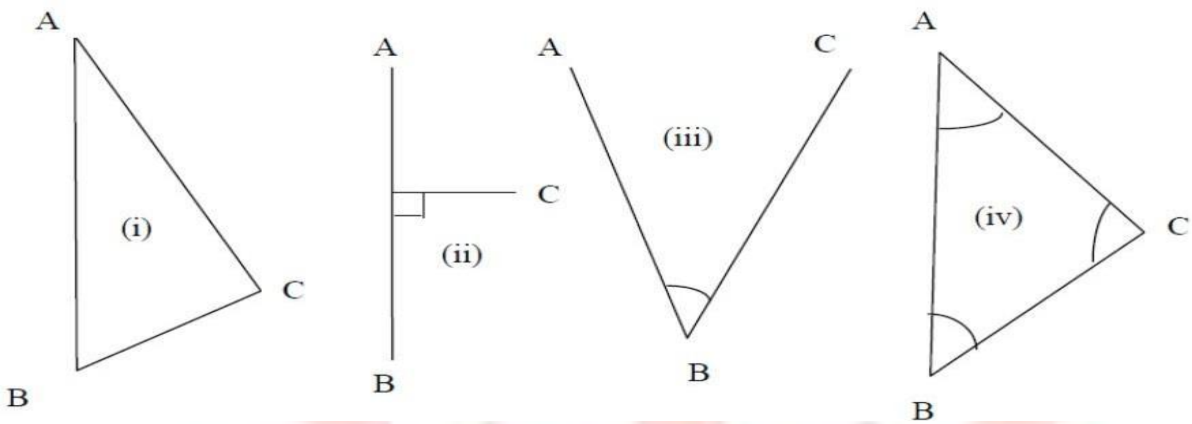


Fig. 6.1: Fixing the third points using two pointsThe process of surveying:

The survey process passes through 3 main phases – the reconnaissance, field work and measurements, and, the office work.

Reconnaissance survey

This is a pre-field work and measurement phase. It requires taking an overall inspection of the area to be surveyed to obtain a general picture before commencement of any serious survey. Walking through the site enables one to understand the terrain and helps in determining the survey method to be adopted, and the scale to be used. The initial information obtained in this stage helps in the successful planning and execution of the survey.

Field work and measurement:

This is the actual measurements in the field and the recordings in the field notebook. To get the best results in the field, the surveyor must be acquainted with the functions of the equipments and take good care of them.

Office work:

This is the post field work stage in which data collected and recordings in the field notebooks are decoded and used to prepare the charts, planes and maps for presentation to the clients and the target audience.

CHECK ON MEASUREMENTS

The second principle is that; all survey work must be checked in such a way that an error will be apparent before the survey is completed.
Concentration and care are necessary in order to ensure that all necessary measures are taken to the required standard of accuracy and that nothing is omitted. Hence they must be maintained in the field at all times.

Surveyor on site should be checking the correctness of his own work and that of others which is based on his information.
Check should be constantly arranged on all measurements wherever possible. Check measurements should be conducted to supplement errors on field. Pegs can be moved, sight rails etc

Survey records and computations such as field notes, level books, field books, setting out record books etc must be kept clean and complete with clear notes and diagrams so that the survey data can be clearly understood by others. Untidy and anonymous figures in the field books should be avoided.

Like field work, computations should be carefully planned and carried out in a systemic manner and all field data should be properly prepared before calculations start. Where possible, standardized tables and forms should be used to simplify calculations. If the result of a computation has not been checked, it is considered unreliable and for this reason, frequent checks should be applied to every calculation procedure.

As a check, the distances between stations are measured as they are plotted, to see that there is correspondence with the measured horizontal distance. Failure to match indicates an error in plotting or during the survey. If checks are not done on observations, expensive mistake may occur. It is always preferable to take a few more dimensions on site to ensure that the survey will resolve itself at the plotting stage.

Horizontal Distance Measurement

One of the basic measurements in surveying is the determination of the distance between two points on the earth's surface for use in fixing position, set out and in scaling. Usually spatial distance is measured. In plane surveying, the distances measured are reduced to their equivalent horizontal distance either by the
procedures used to make the measurement or by applying numerical corrections for the slope distance (spatial distance). The method to be employed in measuring distance depends on the required accuracy of the measurement, and this in turn depends on purpose for which the measurement is intended.

Pacing:

Where approximate results are satisfactory, distance can be obtained by pacing (the number of paces can be counted by tally or pedometer registry attached to one leg) Average pace length has to be known by pacing a known distance several times and taking the average. It is used in reconnaissance surveys& in small scale mapping

Odometer of a vehicle:

Based on diameter of tires (no of revolutions X wheel diameter); this method gives a fairly reliable result provided a check is done periodically on a known length. During each measurement a constant tyre pressure has to be maintained.

Tachometry:

Distance can be can be measured indirectly by optical surveying instruments like Theodolite. The method is quite rapid and sufficiently accurate for many types of surveying operations.

Taping (chaining):

This method involves direct measurement of distances with a tape or chain. Steel tapes are most commonly used .It is available in lengths varying from 15m to 100m. Formerly on surveys of ordinary precision, lengths of lines were measured with chains.

Electronic Distance Measurement (EDM):

Electronic Distance Measurement (EDM) are indirect distance measuring instruments that work using the invariant velocity of light or electromagnetic waves in vacuum. They have high degree of accuracy and are effectively used for long distances for modern surveying operations.

CHAIN SURVEYING

This is the simplest and oldest form of land surveying of an area using linear measurements only. It can be defined as the process of taking direct measurement, although not necessarily with a chain.

EQUIPMENTS USED IN CHAIN SURVEYING

These equipments can be divided into three, namely

- Those used for linear measurement. (Chain, steel band, linear tape)
- Those used for slope angle measurement and for measuring right angle (Eg. Abney level, clinometers, cross staff, optical squares)
- Other items (Ranging rods or poles, arrows, pegs etc).

Chain:

The chain is usually made of steel wire, and consists of long links joined by shorter links. It is designed for hard usage, and is sufficiently accurate for measuring the chain lines and offsets of small surveys.

Chains are made up of links which measure 200mm from centre to centre of each middle connecting ring and surveying brass handless are fitted at each end. Tally markers made of plastic or brass are attached at every whole metre position or at each tenth link. To avoid confusion in reading, chains are marked similarly form both end (E.g. Tally for 2m and 18m is the same) so that measurements may be commenced with either end of the chain

- There are three different types of chains used in taking measurementnamely:

Engineer's chain

Günter's chain

Steel Bands:

This may be 30m, 50m or 100m long and 13mm wide. It has handles similar to those on the chain and is wound on a steel cross. It is more accurate but less robust than the chain. The operating tension and temperature for which it was graduated should be indicated on the band.

Tapes:

Tapes are used where greater accuracy of measurements are required, such as the setting out of buildings and roads. They are 15m or 30m long marked in metres, centimeter and millimeters.

Tapes are classified into three types:

- **Linen or Linen with steel wire woven into the fabric:**
  These tapes are liable to stretch in use and should be frequently tested for length. They should never be used on work for which great accuracy is required.

- **Fibre Glass Tapes:**
  These are much stronger than lines and will not stretch in use.
- **Steel tapes:**
  These are much more accurate, and are usually used for setting out buildings and structural steel works. Steel tapes are available in various lengths up to 100m (20m and 30m being the most common) encased in steel or plastic boxes with a recessed winding lever or mounted on open frames with a folding winding lever.

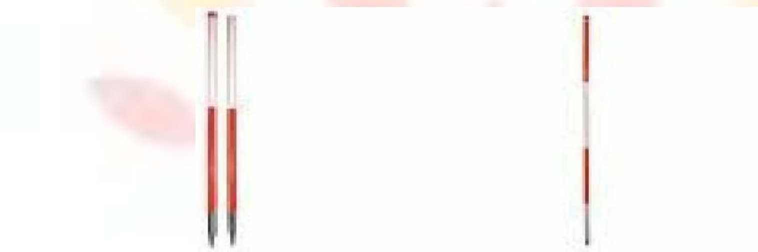
Arrows:

Arrow consists of a piece of steel wire about 0.5m long, and is used for marking temporary stations. A piece of colored cloth, white or red ribbon is usually attached or tied to the end of the arrow to be clearly seen on the field.

Pegs:

Pegs are made of wood 50mm x 50mm and some convenient length. They are used for points which are required to be permanently marked, such as intersection points of survey lines. Pegs are driven with a mallet and nails are set in the tops.

Ranging Rod:



These are poles of circular section 2m, 2.5m or 3m long, painted with characteristic red and white bands which are usually 0.5m long and tipped with a pointed steel shoe to enable them to be driven into the ground. They are used in the measurement of lines with the tape, and for marking any points which need tobe seen.

Optical Square:

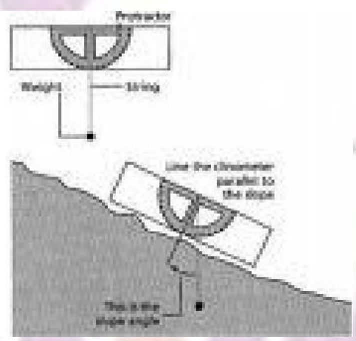
This instrument is used for setting out lines at right angle to main chain line. It is used where greater accuracy is required. There are two types of optical square, one using two mirrors and the other a prism.

The mirror method is constructed based on the fact that a ray of light is reflected from a mirror at the same angle as that at which it strikes the mirror.
The prism square method is a simplified form of optical square consisting of a single prism. It is used in the same way as the mirror square, but is rather more accurate.

Cross Staff:

This consists of two pairs of vanes set at right angle to each other with a wide and narrow slit in each vane. The instrument is mounted upon a pole, so that when it is set up it is at normal eye level. It is also used for setting out lines at right angle to themain chain line.

Clinometers :



This instrument is used for measuring angles of ground slopes (slope angle). They are of several form, the common form is the WATKING"S CLINOMETER, which consist of a small disc of about 60mm diameter. A weighted ring inside the disc can be made to hang free and by sighting across this graduated ring angle of slopes can be read off. It is less accurate than Abney Level.
Abney Level:

This instrument is generally used to obtain roughly the slope angle of the ground. It consists of a rectangular, telescopic tube (without lenses) about 125mm long with a graduated arc attached. A small bubble is fixed to the vernier arm, once the image of the bubble is seen reflected in the eyepiece the angle of the line of sight can be read off with the aid of the reading glass.

NECESSARY PRECAUTIONS IN USING CHAIN SURVEYINGINSTRUMENTS

- After use in wet weather, chains should be cleaned, and steel tapes should bedried and wiped with an oily rag.
- A piece of colored cloth should be tied to arrow (or ribbon – attached) to enablethem to be seen clearly on the field.
- Ranging rods should be erected as vertical as possible at the exact station point.
- The operating tension and temperature for which steel bands/tapes are graduatedshould be indicated.
- Linen tapes should be frequently tested for length (standardized) and always afterrepairs.
- Always keep tapes reeled up when not in use.

GENERAL PROCEDURE IN MAKING A CHAIN SURVEY

Reconnaissance: Walk over the area to be surveyed and note the general layout, the position of features and the shape of the area.

Choice of Stations: Decide upon the framework to be used and drive in the stationpegs to mark the stations selected.

Station Marking: Station marks, where possible should be tied - in to a permanent objects so that they may be easily replaced if moved or easily found during the survey. In soft ground wooden pegs may be used while rails may be used on roadsor hard surfaces.

Witnessing: This consists of making a sketch of the immediate area around the station showing existing permanent features, the position of the stations and its description and designation. Measurements are then made from at least three surrounding features to the station point and recorded on the sketch. The aim of witnessing is to re-locate a station again at much later date even byothers after a long interval.

Offsetting: Offsets are usually taken perpendicular to chain lines in order to dodgeobstacles on the chain line.

Sketching: The layout on the last page of the chain book, together with the date and the name of the surveyor, the longest line of the survey is usually taken as the base line and is measured first.

CRITERIA FOR SELECTING A SURVEY LINES/OFFSETS

During reconnaissance, the following points must be borne in mindas the criteria to provide the best arrangement of survey lines,

- **Few survey lines:** The number of survey lines should be kept to a minimum but must be sufficient for the survey to be plotted and checked.

- **Long base line:** A long line should be positioned right across the site to form a baseon which to build the triangles.

- **Well conditioned triangle with angles greater than 30º and not exceeding 150º:** It is preferable that the arcs used for plotting should intersect as close as 90º in order to provide sharp definition of the stations point.

- **Check lines:** Every part of the survey should be provided with check lines that are positioned in such a way that they can be used for off- setting too, in order to save any unnecessary duplication of line.Obstacles such as steep slopes and rough ground should be avoided as far aspossible.

- **Short offsets to survey lines (close feature preferably 2m) should be selected:** So that measuring operated by one person can be used instead of tape which needs two people.Stations should be positioned on the extension of a check line or triangle. Suchpoints can be plotted without the need for intersecting arcs.
- **Ranging:** Ranging involves placing ranging poles along the route to be measures so as to get a straight line. The poles are used to mark the stations and in between the stations.

ERRORS IN SURVEYING

Surveying is a process that involves observations and measurements with a wide range of electronic, optical and mechanical equipment some of which are very sophisticated. Despite the best equipments and methods used, it is still impossible to take observations that are completely free of small variations caused by errors which must be guided against or their effects corrected.

TYPES OF ERRORS

Gross Errors:

These are referred to mistakes or blunders by either the surveyor or his assistants due to carelessness or incompetence. On construction sites, mistakes are frequently made by in – experienced Engineers or surveyors who are unfamiliar with the equipment and method they are using.

These types of errors include miscounting the number of tapes length, wrong booking, sighting wrong target, measuring anticlockwise reading, turning instruments incorrectly, and displacement of arrows or station market.

Gross errors can occur at any stage of survey when observing, booking, computing or plotting and they would have a damaging effect on the results if left uncorrected. Gross errors can be eliminated only by careful methods of observing booking and constantly checking both operations.

Systematic or Cumulative Errors:

These errors are cumulative in effect and are caused by badly adjusted instrument and the physical condition at the time of measurement must be considered in this respect. Expansion of steel, frequently changes in electromagnetic distance (EDM) measuring instrument, etc are just some of these errors.

Systematic errors have the same magnitude and sign in a series of measurements that are repeated under the same condition, thus contributing negatively or positively to the reading hence, makes the readings shorter or longer. This type of error can be eliminated from a measurement using corrections (e.g. effect of tension and temperature on steel tape).

Another method of removing systematic errors is to calibrate the observing equipment and quantify the error allowing corrections to be made to further observations. Observational procedures by re-measuring the quantity with an entirely different method using different instrument can also be used to eliminate the effect of systematic errors.

Random or Compensating Errors:

Although every precaution may be taken certain unavoidable errors always exist in any measurement caused usually by human limitation in reading/handling of instruments. Random errors cannot be removed from observation but methods can be adopted to ensure that they are kept within acceptable limits.

In order to analyze random errors or variable, statistical principles must be used and in surveying their effects may be reduced by increasing the number of observations and finding their mean. It is therefore important to assume those random variables are normally distributed.

Corrections to Linear Measurement and their Application:

The following corrections are to be applied to the linear measurements witha chain or a tape where such accuracy is required.

- Pull correction,
- Temperature correction
- Standard length correction
- Sag correction
- Slope correction
- Mean sea level correction.

Pull Correction:-

A chain or tape of nominal length „L‟ having cross sectional area of the link or that of a tape, as the case may be, equal to A and standardized under a pull P_s isemployed to measure a length at a pull P_F.

If Young‟s modulus of elasticity of the material is E the extension of its length is = $\frac{(P_F - P_S)L}{AE}$

The recorded length is less than the actual by this extension. The error is here, -ve, the actual length is obtained by adding the extension to L. The correction is + ve. If P_F is less than P_S the error will be +ve and correction –ve.

Temperature Correction:-

A chain or a tape of nominal length „L‟ standardized at temperature T_S and having cross sectional area A is employed to measured length at temperature T_F being the coefficient of linear expansion of the material of the chain or tape per unit rise of temperature, the extension = □(T_F – T_S)L.

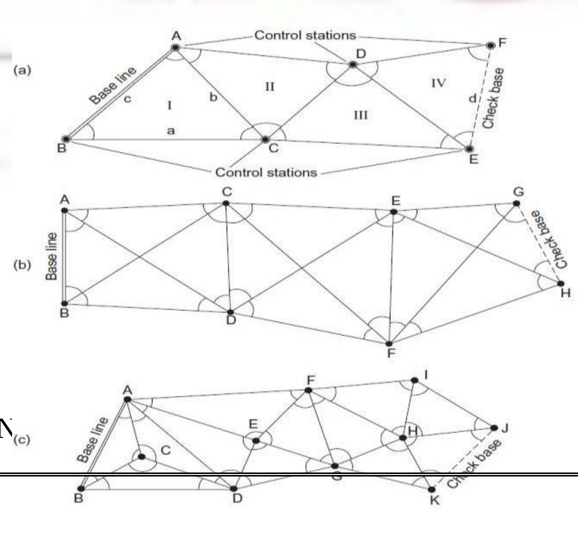
If T_F is more than T_S, recorded length is less than the actual by the amount of extension. The error is –ve and the correction to the length L is +ve by the amount of extension. If the field temperature T_F is less than T_S the error is =+ve and the corrections is–ve.

TRIANGULATION

Because, at one time, it was easier to measure angles than it was distance, triangulation was the preferred method of establishing the position of control points.

Many countries used triangulation as the basis of their national mapping system. The procedure was generally to establish primary triangulation networks, with triangles having sides ranging from 30 to 50 km in length. The primary trig points were fixed at the corners of these triangles and the sum of the measured angles was correct to ±3. These points were usually established on the tops of mountains to afford long, uninterrupted sight lines. The primary network was then noted with points at closer intervals connected into the primary triangles. This secondary network had sides of 10– 20 km with a reduction in observational accuracy. Finally, a third order net, adjusted to the secondary control, was established at 3–5- km intervals and fourth-order points fixed by intersection. Figure 12.2 illustrates such a triangulation system established by the Ordnance Survey of Great Britain and used as control for the production of national maps. The base line and check base line would be measured by invar tapes in catenary and connected into the triangulation by angular extension procedures. This approach is classical triangulation, which is now obsolete. The more modern approach would be to measure the base lines with EDM equipment and to include many more measured lines in the network, to afford greater control of scale error. Although the areas involved in construction are relatively small compared with national surveys (resulting in the term „micro triangulation‟) the accuracy required in establishing the control surveys is frequently of a very high order, e.g. long tunnels or dam deformation measurements.
The principles of the method are illustrated by the typical basic figures shown in Figure
If all the angles are measured, then the scale of the network is obtained by the measurement of one side only, i.e. the base line. Any error, therefore, in the measurement of the base line will result in scale error throughout the network. Thus, in order to control this error, check baseline should be measured at intervals the scale

Error is defined as the difference between the measured and computed check base. Using the base line and adjusted angles the remaining sides of the triangles may be found and subsequently the coordinates of the control stations. Triangulation is best



suited to open, hilly country, affording long sights well clear of intervening terrain. In urban areas, roof- top triangulation is used, in which the control stations are situated on the roofs of accessible buildings. (a) Chain of simple triangles, (b) braced quadrilaterals and (c) polygons with central points

General procedure:
Reconnaissance of the area, to ensure the best possible positions for stations and baselines.
Construction of the stations.
Consideration of the type of target and instrument to be used and also the method ofobservation.
All of these depend on the precision required and the length of sights involved.
Observation of angles and base-line measurements.
Computation: base line reduction, station and figural adjustment, coordinates of stations by direct methods.

A general introduction to triangulation has been presented, aspects of which will now be dealt with in detail.

Reconnaissance is the most important aspect of any well-designed surveying project. Its main function is to ensure the best positions for the survey stations commensurate with well-conditioned figures, ease of access to the stations and economy of observation. A careful study of all existing maps or plans of the area is essential. The best position for the survey stations can be drawn on the plan and the overall shape of the network studied. While chains of single triangles are the most economic to observe, braced quadrilaterals provide many more conditions of adjustment and are at their strongest when square shaped. Using the contours of the plan, profiles between stations can be plotted to ensure indivisibility. Stereo-pairs of aerial photographs, giving a three- dimensional view of the terrain, are useful in this respect. Whilst every attempt should be made to ensure that there are no angles less than 25°, if a small angle cannot be avoided it should be situated opposite a side which does not enter into the scale computation. When the paper triangulation is complete, the area should then be visited and the site of every station carefully investigated. With the aid of binoculars, indivisibility between stations should be checked and ground-grazing rays avoided. Since the advent of EDM, base-line sitting is not so critical. Soil conditions should be studied to ensure that the ground is satisfactory for the construction of long-term survey stations. Finally, whilst the strength of the network is a function of its shape, the purposeof the survey stations should not be forgotten and their position located accordingly.

Stations must be constructed for long-term stability .A complete referencing of the station should then be carried out in order to ensure its location at a future date.

As already stated, the type of target used will depend on the length of sight involved and the accuracy required for highly precise networks, the observations may be carried out at night when refraction is minimal. In such a case, signal lamps would be the only type of target to use. For short sights it may be possible to use the precise targets shown in *Figure 13.1* Whatever form the target takes, the essential considerations are that it should be capable of being accurately centered over the survey point and afford the necessary size and shape for accurate bisection at the observation distances used.

In triangulation the method of directions would inevitably be used and the horizon closed. An appropriate number of sets would be take non each face. The base line and
check base would most certainly be measured by EDM, with all the necessary corrections made

to ensure high accuracy.

Since the use of computers is now well established, there is no reason why a least squares adjustment using the standard variation of coordinates method should not be carried out. Alternatively the angles may be balanced by simpler, less rigorous methods known as „equal shifts‟. On completion, the sides may be computed using the sine rule and finally the coordinates of each survey point obtained. If the survey is to be connected to the national mapping system of the country, then all the baseline measurements must be reduced to MSL and multiplied by the local scale factor. As many of the national survey points as possible should be included in the scheme.

COMPASS SURVEYING

Introduction:
Another type of survey instrument that forms the subject of this section is the compass. Here, we will explain the meaning, types of compass survey and also introduce and discus the concept of bearing.
Objectives
To introduce the students to the meaning and types of compass survey
To enable students understand the concept ofbearing

Meaning and types of compass survey

In compass survey, the direction of the survey line is measured by the use of a magnetic compass while the lengths are by chaining or taping. Where the area to be surveyed is comparatively large, the compass survey is preferred, whereas if the area is small in extent and a high degree of accuracy is desired, then chain survey is adopted. However, where the compass survey is used, care must be taken to make sure that magnetic disturbances are not present. The two major primary types of survey compass are: the prismatic compass and surveyors compass

Compass surveys are mainly used for the rapid filling of the detail in larger surveys and for explanatory works. It does not provide a very accurate determination of the bearing of a line as the compass needle aligns itself to the earth‟s magnetic field which does not provide a constant reference point.

THE PRISMATIC COMPASS

This is an instrument used for the measurement of magnetic bearings. It is small and portable usually carried on the hand. This Prismatic Compass is one of the two main kinds of magnetic compasses included in the collection for the purpose of measuring magnetic bearings, with the other being the Surveyor's Compass. The main difference between the two instruments is that the surveyor's compass is usually larger and more accurate instrument, and is generally used on a stand or tripod.

The prismatic compass on the other hand is often a small instrument which is held in the hand for observing, and is therefore employed on the rougher classes of work. The graduations on this prismatic compass are situated on a light aluminum ring fastened to the needle, and the zero of the graduations coincides with the south point of the needle. The graduations therefore remain stationary with the needle, and the index turns with the sighting vanes. Since the circle is read at the observer's (rather than the target's) end, the graduations run clockwise from the south end of the needle (0º to 360º), whereas in the surveyor's compass, the graduations run anti-clockwise from north.

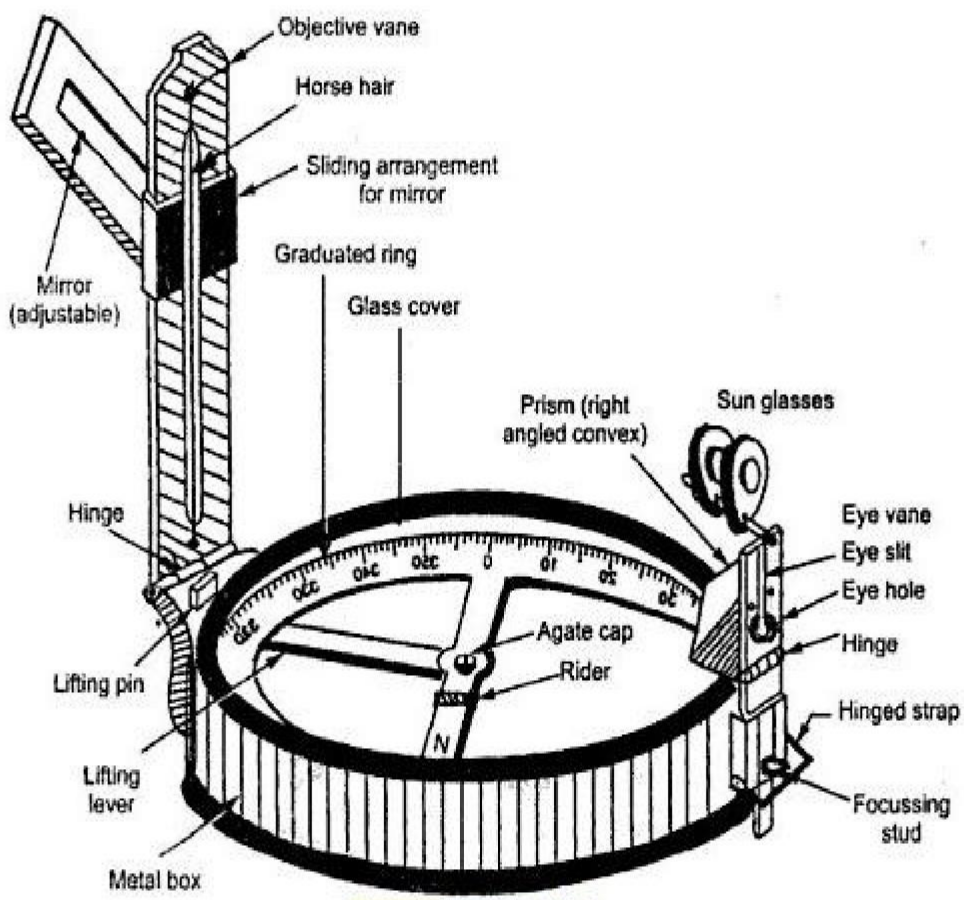
The prismatic attachment consists of a 45º reflecting prism with the eye and reading faces made slightly convex so as to magnify the image of the graduations. The prism is carried on a mounting which can be moved up and down between slides fixed on the outside of the case.

The purpose of this up-and-down movement is to provide an adjustment for focusing. The image of the graduations is seen through a small circular aperture in the prism mounting, and immediately above this aperture is a small V cut on top of the mounting, over which the vertical wire in the front vane may be viewed. Using the V cut, the vertical wire and the station whose bearing is required are viewed in one line, the bearing is directly read off the graduated arc at the point immediately underneath the vertical wire.

The mirror located in front of the forward vane slides up and down the vane, and is hinged to fold flat over it or to rest inclined at any angle with it. This mirror is used for solar observations, or for viewing any very high object, and is not a normal fitting to a compass. The two circular discs in front of the back vane are dark glasses which can be swung in front of the vane when solar observations are being taken.

COMPONENTS OF A PRISMATIC COMPASS

Prismatic compass consists of a non-magnetic metal case with a glass top andcontain the following:



Prismatic compass parts

Elements of prismatic compass

- Cylindrical metal box:

Cylindrical metal box is having diameter of 8to 12 cm. It protects the compass and forms entire casing or body of the compass. It protect compass from dust, rain etc.

◉ **Pivot:**

pivot is provided at the center of the compass and supports freely suspended magnetic needle over it.

◉ lifting pin and lifting lever:

lifting pin is provided just below the sight vane. When the sight vane is folded, it presses the lifting pin. The lifting pin with the help of lifting lever then lifts the magnetic needle out of pivot point to prevent damage to the pivoted.

◉ Magnetic needle:

Magnetic needle is the heart of the instrument. This needle measures angle of a line from magnetic meridian as the needle always remains pointed towards north South Pole at two ends of the needle when freely suspended on any support.

◉ Graduated circle or ring:

This is an aluminum graduated ring marked with 0^o to 360^o to measures all possible bearings of lines, and attached with the magnetic needle. The ring is graduated to half degree.

◉ **Prism :**

prism is used to read graduations on ring and to take exact reading by compass. It is placed exactly opposite to object vane. The prism hole is protected by prism cap to protect it from dust and moisture.

◉ Object vane:

Object vane is diametrically opposite to the prism and eye vane. The object vane is carrying a horse hair or black thin wire to sight object in line with eyesight.

◉ Eye vane:

Eye vane is a fine slit provided with the eye hole at bottom to bisectthe object from slit.

◉ Glass cover:

It covers the instrument box from the top such that needle andgraduated ring is seen from the top.

◉ Sun glasses:

These are used when some luminous objects are to be bisected.

◉ Reflecting mirror:

It is used to get image of an object located above or below the instrument level while bisection. It is placed on the object vane.

◉ Spring break or brake pin:

to damp the oscillation of the needle before taking a reading and to bring it to rest quickly, the light spring break attached to the box is brought in contact with the edge of the ring by gently pressing inward the

Temporary adjustment of prismatic compass

The following procedure should be adopted after fixing the prismatic compass on the tripod for measuring the bearing of a line.

◉ Centering :

Centering is the operation in which compass is kept exactly over the station from where the bearing is to be determined. The centering is checked by dropping a small pebble from the underside of the compass. If the pebble falls on the top of the peg then the centering is correct, if not then the centering is corrected by adjusting the legs of the tripod.

◉ Leveling :

Leveling of the compass is done with the aim to freely swing the graduated circular ring of the prismatic compass. The ball and socket arrangement on the tripod will help to achieve a proper level of the compass. This can be checked by rolling round pencil on glass cover.

◉ Focusing:

The prism is moved up or down in its slide till the graduations on the aluminum ring are seen clear, sharp and perfect focus. The position of the prism will depend upon the vision of the observer.

OPERATION PROCEDURE

Remove the corner and open out the prism and window, holding the compass as level as possible.

Then focus the prism by raising or lowering its case until the divisions appear sharp and clear.
If necessary with the needle on to its pivot.

Holding the compass box with the thumb under the prism and the forefinger near the stud, sight through the objector station lowering the eye to read the required bearing as soon as the needle comes to rest naturally.

The bearing read will be a forward bearing and normally a "whole circle" bearing clockwise angle between 0^o to360^o.

VARIATION IN DECLINATION

The position of the magnetic poles is not fixed and the North magnetic pole tendsto wander more than the south causing alterations in the positions of the isogonic lines from time to time. The angle of declination at any point is therefore not constant subject to the following variations;

Secular Variation:

This causes the largest variation in magnetic declination. It is a slow continuous swing with a cycle of about 400 to 500 years. Because of this large movement, the date, the declination and the approximate rate of annual change should be given for any magnetic orientation of survey.

Diurnal Variation:

This is a swing of the compass needle about its mean daily position.

Periodic Variation:

This is a minor variation of the magnetic meridian during the week, a lunarmonth, year, eleven years, etc.

Irregular Variation: These are caused by magnetic storms which canproduce sudden variations of the magnetic meridian.

Magnetic Bearing: The magnetic bearing of a survey line is the angle between the direction of the line and the direction of the magnetic meridian at the beginning of the line.

Magnetic Meridian: The magnetic meridian at any place is the direction obtained by observing the position of a freely supported magnetized needle when it comes to rest uninfluenced by local attracting forces.

Magnetic meridians run roughly north –south and follow the varying trend of the earth‟s magnetic field. The direction of a magnetic meridian does not coincide with the true or geographical meridian which gives the direction of the true North pole except in certain places.

Angle of Declination: : It is defined as the angle between the direction of the magnetic meridian and the truemeridian at any point.

Surveyor's Compass:

Similar to the prismatic compass but with few modifications, the surveyors compass isan old form of compass used by surveyors. It is used to determine the magnetic bearing of a given line and is usually used in connection with the chain or compass survey.

Bearing

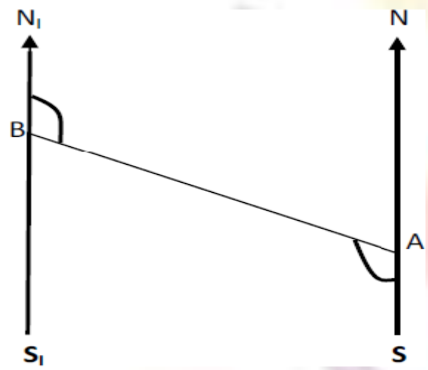
The bearing is the angular direction measured clockwise starting from North with reference to the observer. The reference North may be true or magnetic. While the true bearing is the angular direction measured in a place with the direction of true or geographical north; the magnetic bearing is the angle which it makes with the direction of Magnetic North measured in the clockwise direction.

Back and Fore bearing:

In this section, we will examine the back and fore bearing; and the steps to be taken when traversing with compass survey.

- **Back and fore bearing**

Fore bearing is the compass bearing of a place taken from a status to the other in the direction that the survey is being carried out. The back bearing in the other hand is the bearing in the opposite direction i.e. the bearing taken backwards from the next station to its preceding station that the fore bearing was taken. The difference between BB and FB is always 180^0.



- Back and fore bearing

If B is sighted from an observer at A, and the NS and N_1S_1 are the magnetic NS lines, then Forward bearing (FB) = < N A S + < S A B

Back bearing BA = < N1 B A

:. Back Bearing BA = Forward Bearing AB - 180^0

If the observer relocates to B and observers B, then forward bearing (FB) BA = < N1 BA and back bearing (AB) = < NAS + SAB. Hence, we can conclude that Forward Bearing = < N1 B A + 180^0. As a general rule, if the Fore Bearing is less than 180^0, add 180^0 to get the Back. Bearing, and if the Fore Bearing is greater than 180^0, then subtract 180^0 to get the Back Bearing.

Traversing and plotting with the compass survey:

Traversing with the compass involves taking the bearing along a series of connecting straight lines and in the same time measuring the distances with the tape. The compass is read at each point and a back bearing is equally taken to serve as a check. This continues until the traverse closes.

Observing Bearing of Line

- Consider a line AB of which the magnetic bearing is to betaken.
- By fixing the ranging rod at station B we get the magnetic bearing of needle with respect to North Pole.
- The enlarged portion gives actual pattern of graduations marked on ring. Designation of bearing

The bearing are designated in the following two system:-

1) Whole Circle Bearing System.(W.C.B)
2) Quadrant Bearing System.(Q.B)

Whole circle bearing system(W.C.B.)

The bearing of a line measured with respect to magnetic meridian in clockwise direction is called magnetic bearing and its value varies between 0^{O} to360^{O}.

The quadrant start from north and progress in a clockwise direction as the first quadrant is 0^{O} to 90^{O} in clockwise direction, $2^{nd}$$90^{O}$ to 180^{O}, $3^{rd}$$180^{O}$ to 270^{O}, andup to 360^{O} is 4^{th}one.

Quadrantal bearing system (Q.B.)

In this system, the bearing of survey lines are measured with respect to north line or south line whichever is the nearest to the given survey line and either in clockwise direction or in anti clockwise direction. It is also known as Reduced bearing (R.B)

values lies between 0^{O} to 90^{O}, but the quadrant should bementioned for proper designation.

The following table should be remembered for conversion of WCB to RB.

W.C.B OF ANYLINE	QUADRANT IN WHICH IT LIES	RULES FOR CONVERSION	QUADRANT
0 TO 90	I	RB=WCB	N-E
90 TO 180	II	RB=180-WCB	S-E
180 TO 270	III	RB =WCB-180^{O}	S-W
270 TO 360	IV	RB=360^{O} - WCB	N-W

Error in compass survey (Local attraction & observational error):

Local attraction is the influence that prevents magnetic needle pointing to magneticnorth pole

Unavoidable substance that affect are

Magnetic ore

- Underground iron pipes
- High voltage transmission line
- Electric pole etc.
- Influence caused by avoidable magnetic substance doesn‟t come under local attraction such as instrument, watch wrist, key etc

Detection of Local attraction

- By observing the both bearings of line (F.B. & B.B.) and noting the difference (180^{0} in case of W.C.B. & equal magnitude in case of R.B.)
- We confirm the local attraction only if the difference is not due toobservational errors.

If detected, that has to be eliminated two methods of elimination

- First method
- Second method

First method

Difference of B.B. & F.B. of each lines of traverse is checked to note ifthey differ by correctly or not. The one having correct difference means that bearing measured in those stations are free from local attraction

Correction is accordingly applied to rest of station.

If none of the lines have correct difference between F.B. & B.B., the one with minimum error is balanced and repeat the similar procedure.

Diagram is good friend again to solve the numerical problem.

Second method

Based on the fact that the interior angle measured on the affected stationis right.

All the interior angles are measured

Check of interior angle – sum of interior angles = (2n-4) x right angle,where n is number of traverse side

Errors are distributed and bearing of lines are calculated with the corrected angles from the lines with unaffected station.

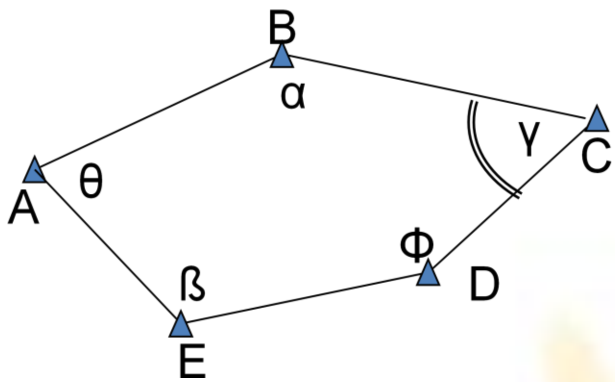
Checks in closed Traverse

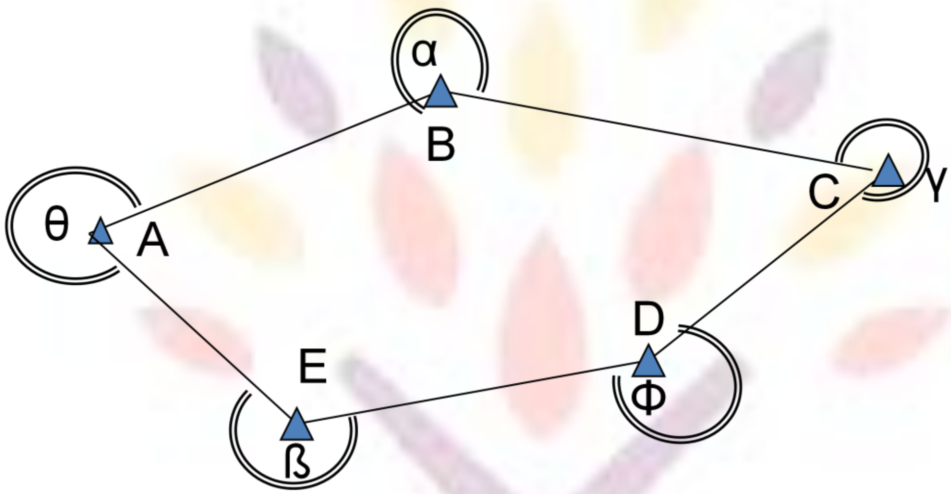
Errors in traverse is contributed by both angle and distance measurement

Checks are available for angle measurement but There is no check for distance measurement for precise survey, distance is measured twice, reverse direction secondtime

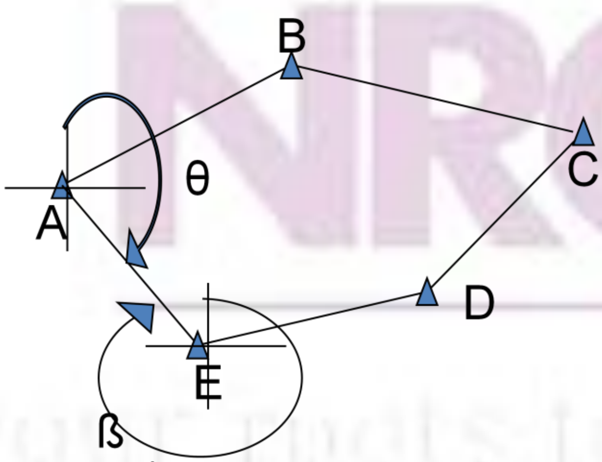
Checks for angular error are available

- Interior angle, sum of interior angles = (2n-4) x right angle, where n isnumber of traverse side
- Exterior angle, sum of exterior angles = (2n+4) x right angle, where n is numberof traverse side



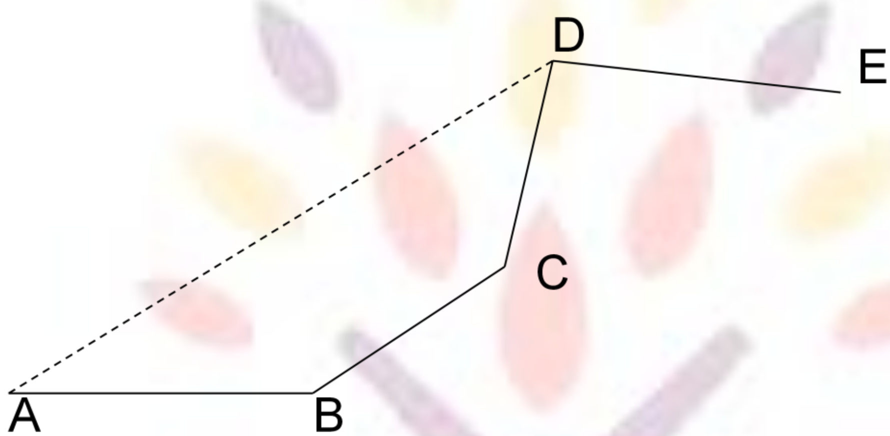


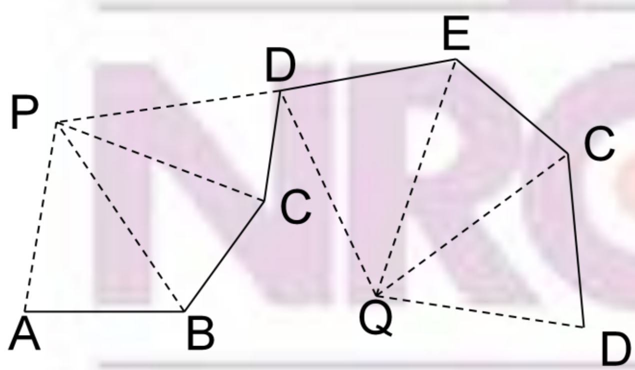
Deflection angle – algebraic sum of the deflection angle should be 0^0 or360^0.
Bearing – The fore bearing of the last line should be equal to its backbearing ± 180^0 measured at the initialstation.



ß should be = $\theta + 180^0$

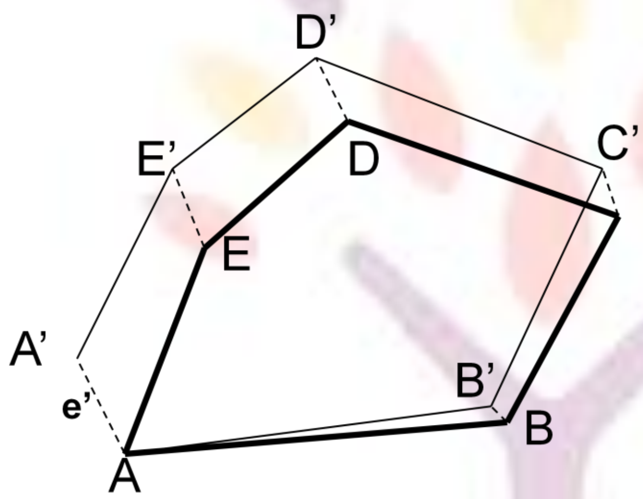
Checks in open traverse
No direct check of angular measurement is available
Indirect checks
Measure the bearing of line AD from A and bearing of DA fromD
Take the bearing to prominent points P & Q from consecutivestation and check in plotting.

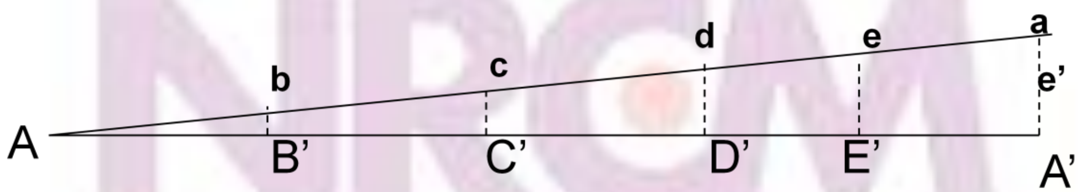




Methods
Compass rule(Bowditch)
When both angle and distance are measured with same precision
Transit rule
When angle are measured precisely than the length
Graphical method

Graphical rule
Used for rough survey
Graphical version of Bowditch rule without numerical computation
Geometric closure should be satisfied before this.





UNIT-2

LEVELLING

The branch of surveying which deals with the determination of elevations of points or establishing the points at known elevation with respect to a given or assumed datum is known as levelling.

APPLICATIONS OF LEVELLING

- Levelling is generally applied for the following civil engineering works:
- Preparation of topographical map.
- Setting up of gradient for sewer lines.
- Carrying out excavation upto prescribed depth for footing of a structure.
- Measurement of settlement of existing buildings.
- Laying out of highways and railways.

DEFINITIONS

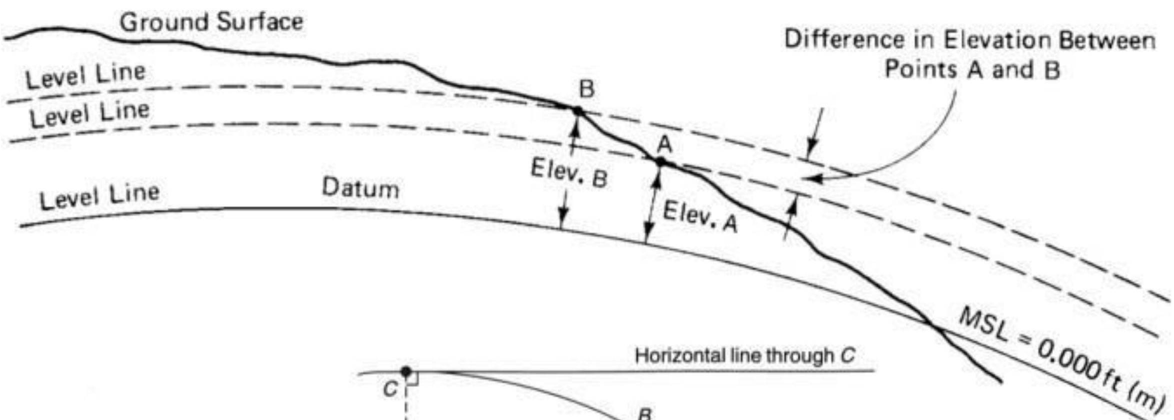
Datum: Any surface to which elevations are referred is known as datum. The mean sea level is a convenient datum used worldwide.

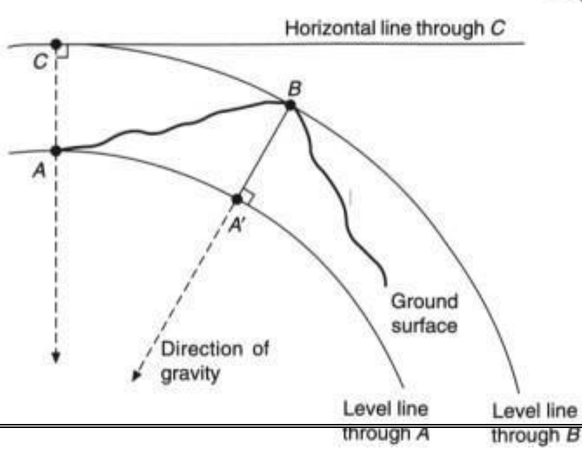
Mean Sea Level: It is the average height of the sea for all stages of the tides at several places. At anyparticular place it is derived by averaging the hourly tide heights over a long period of 19 years.

Level Surface: It is defined as a curved surface which at each point is perpendicular to the direction of gravity. The surface of a still water is truly level surface.

Level Line: It is a line lying in a level surface. It is, therefore, normal to the plumb line at all points.

Horizontal Plane: Horizontal plane through a point is a plane tangential to the level surface at that point.
It is, therefore, perpendicular to the plumb line through the point.





Horizontal Line: It is straight line tangential to the level line at a point. It is also perpendicular to the plumb line

Vertical Line: It is line normal to the level line at a point. It is commonly considered to be the line defined by a plumb line.

Elevation: Elevation of a point is the vertical distance of the point above or below an assumed level surface or datum. Elevation may be positive (e.g., top of pole) or negative (e.g., bottom level of sea) depending upon the position of point with respect to datum.
Alternative terms to elevation

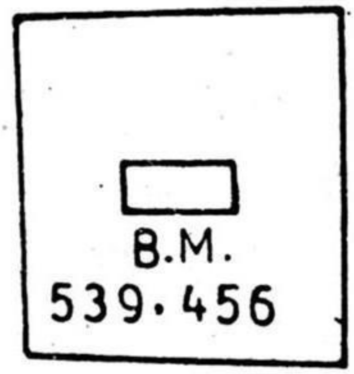
Grade: used in construction activities

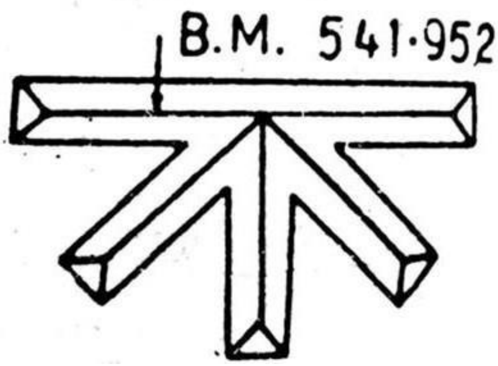
Altitude: used to specify a point in space

Bench mark: It is a relatively permanent point of reference whose elevation with respect to some assumed datum is known. It is used either as a starting point for leveling or as a point upon which to close a check.

TYPES OF BENCH MARKS

Depending upon permanency and precision, bench marks may be of the following types:
Great Trigonometric Survey (GTS) Bench Marks: These are established by the survey of India at an interval of about 100 km all over the country with respect to the mean sea level at Bombay Port as datum.
Permanent Bench Marks: These are established between the GTS bench marks by the government agencies like PWD on clearly defined and permanent points such as top of a parapet wall of a bridge or culvert, kilometer stone, railway plate form etc.



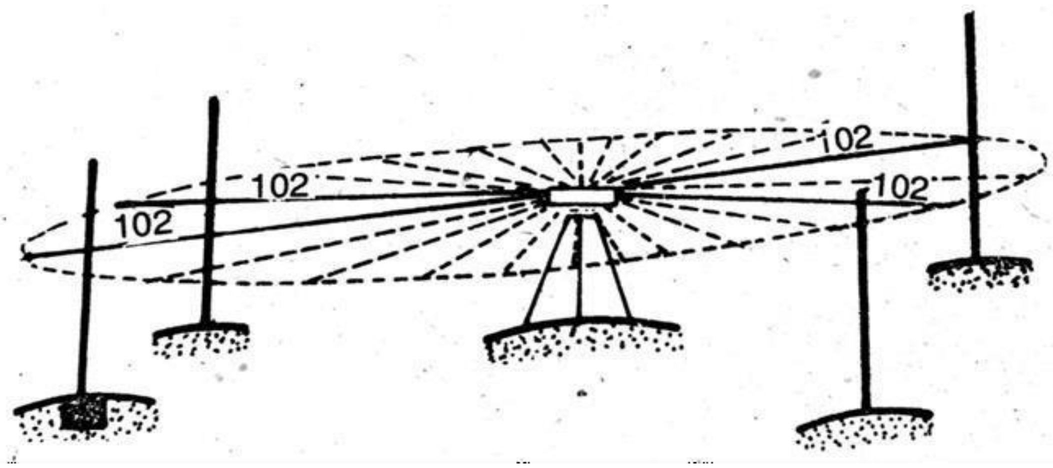


Arbitrary Bench Marks: These are reference points whose elevations are arbitrarily assumed for small leveling operations. Their elevations do not refer to any fixed datum.

Temporary Bench Marks: These are the reference points on which a day's work is closed and from where the leveling is continued the next day. Such a bench mark is carefully established generally on permanent objects like kilometer stones, parapets etc.

Axis of Telescope: It is the line joining the optical centre of objective and eye-piece.

Axis of Level Tube or Bubble Tube: It is an imaginary line tangential to the longitudinal curve of the tube at its mid-point.
Line of Sight: It is a line joining the intersection of the cross hairs to the optical centre of objective and its continuation. The line of sight when horizontal is called line of collimation.
Height of Instrument: It is the elevation of the plane of collimation when the instrument is leveled.



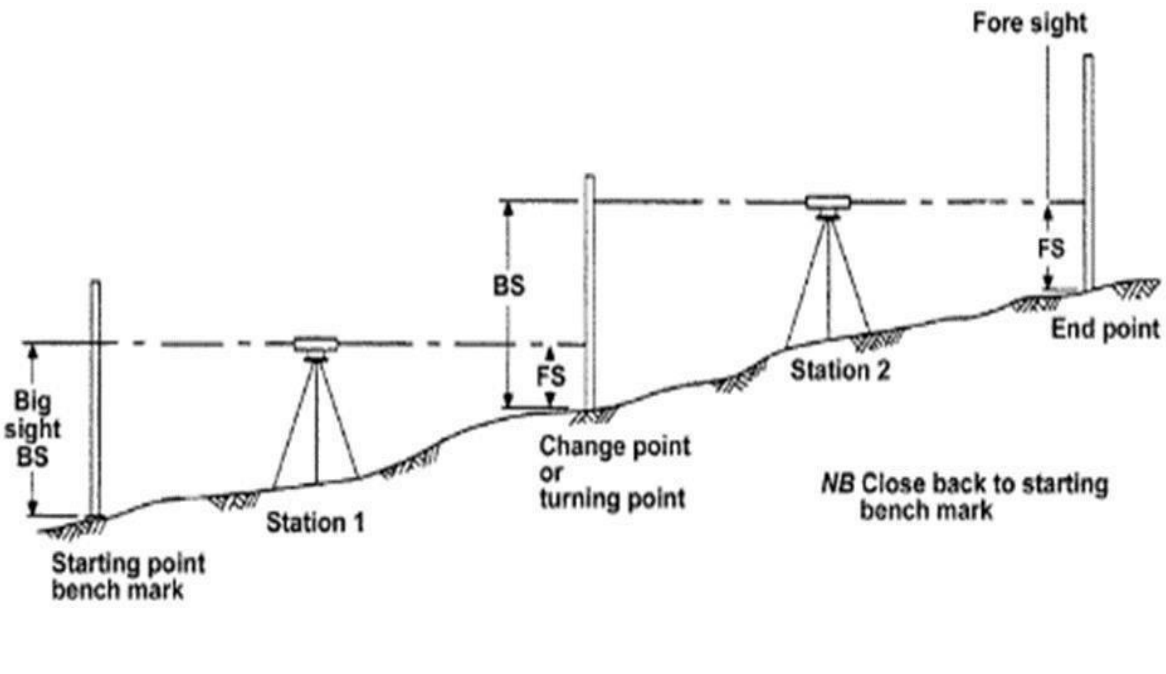
Back Sight (B.S): It is staff reading taken on a point of known elevation e.g. a sight on a bench markor change point. It is also called a plus sight.

Fore Sight (F.S): It is a staff reading taken on a point whose elevation is to be determined. It is also called a minus sight.

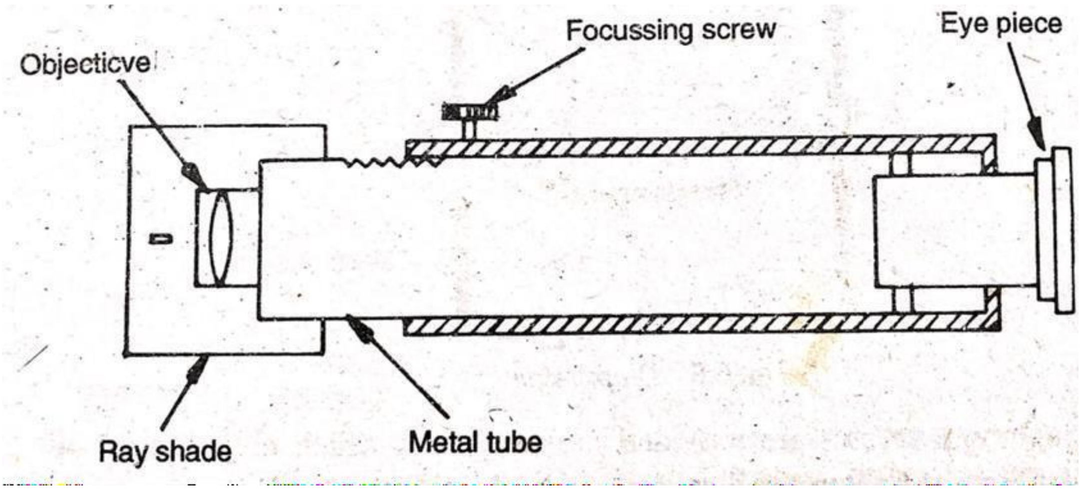
Intermediate Sight (I.S): It is staff reading taken on a point of unknown elevation between backsight and fore sight.

Change Point (C.P): It is point which denotes the sifting of the level. Here both B.S and F.S are observed. It is also known as turning point.

Station: A point whose elevation is to be determined is called station. It is the point where staff is kept.

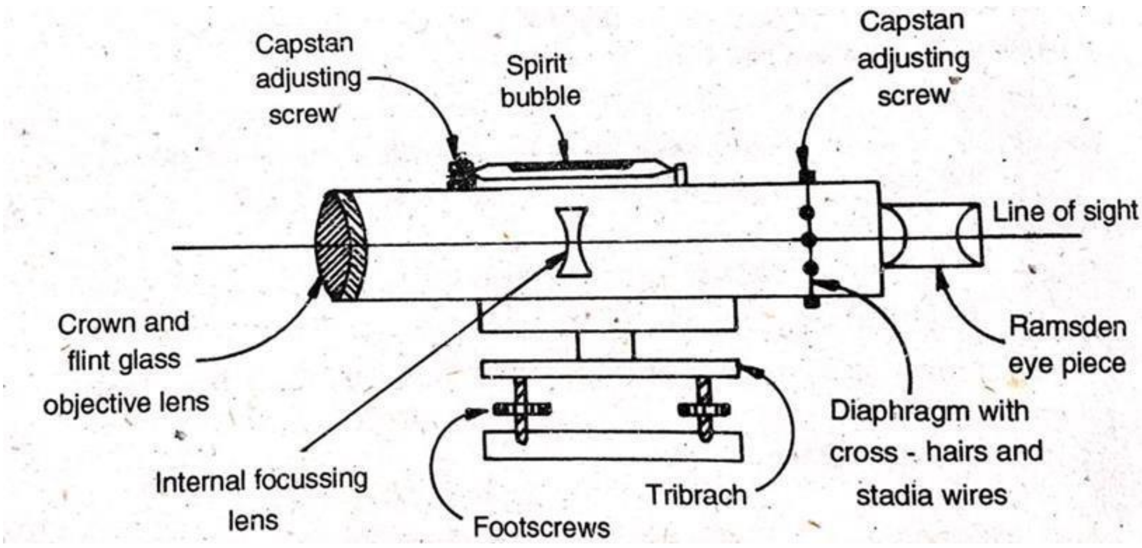


CONSTRUCTION OF LEVEL:



Objective:

- Optical defects, known as aberrations (results in distortion, unwanted colors and indistinctimage)
- These aberrations takes place, if single lens are used.
- To eliminate aberrations, two lenses are provided both in objective and eye piece inmodern telescopes
- Outer lens is a double convex lens and inner lens is concave-convex type cemented withBalsam

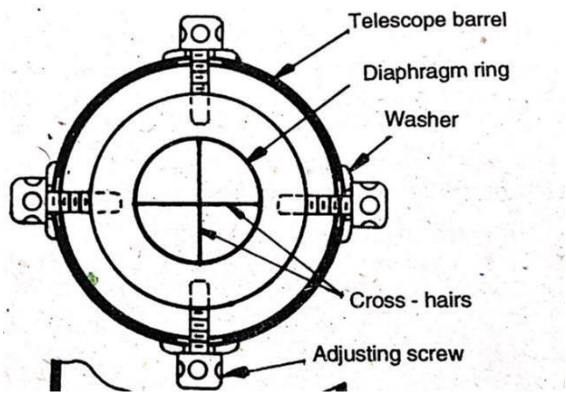


Eye piece:

- Consists of two Plano-convex lens placed together at a fixed distance of $\frac{2}{3}f$, where f is the focal length

Diaphragm:

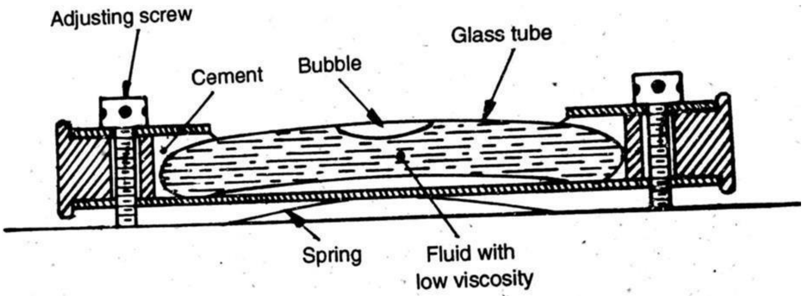
- It is the place where cross hairs / wires are provided
- These wires are made of platinum or silk



Level tube:

- It is a circular glass tube filled with alcohol / ether / sprit leaving enough space to form abubble.
- The liquid must be non-freezing, quick acting and stable under normal temperaturevariations.
- Purified synthetic alcohol is the best.

The tube is graduated on its upper surface. Linear distance between two consecutive graduations is generally kept as 2 mm.



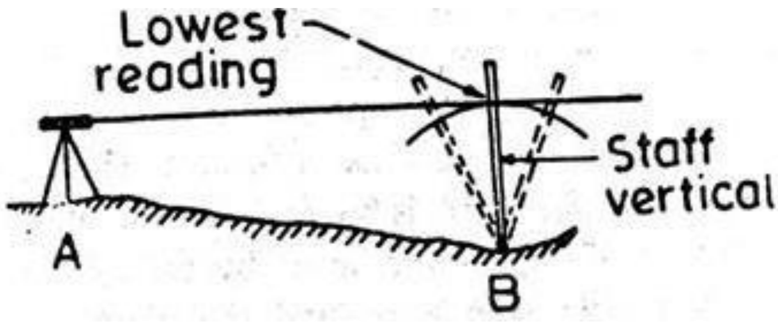
TYPES OF LEVELS

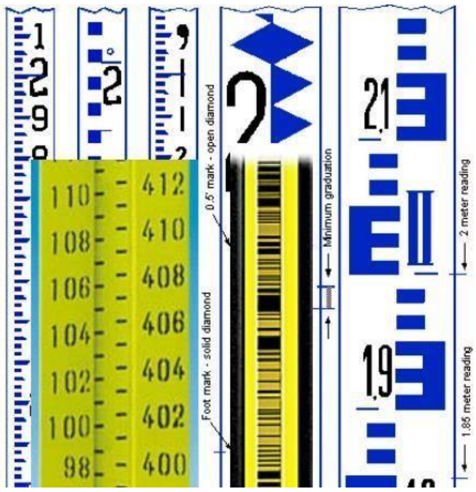
1. Dumpy levels
2. Tilting levels
3. Automatic levels

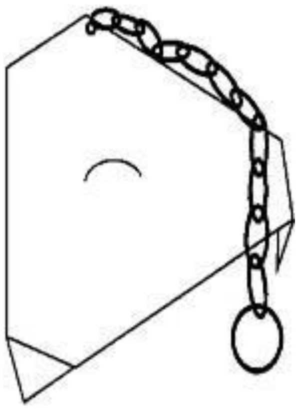
Both Dumpy and Tilting levels have the line of collimation (sight) set horizontal by means of a levelling tube (bubble). This will set the line of sight at 90° to the vertical axis i.e., to the direction ofgravity.
'Automatic' levels will still produce a horizontal line of sight if the telescope is almost horizontal which will put it in the range of the compensator. To level these instruments, the vertical axis is set vertical by centering the circular bubble.

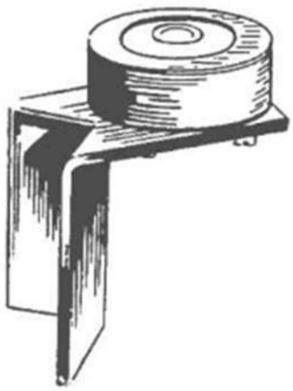
Levelling Staff and its accessories:

The Levelling Staff may be rigid, telescopic or hinged, and is usually made of metal or fibre glass. Most are either 3m or 5m in length when extended.
It is essential that a staff has a solid 'foot' or base. A staff must have some provision for attachment of a levelling bubble to ensure that the staff is held vertical.









Levelling Staff Change Plate Staff bubble

TEMPORARY ADJUSTMENTS OF A LEVEL

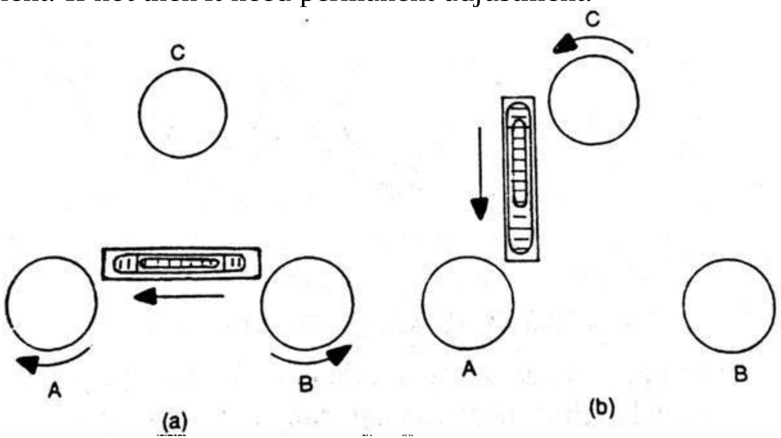
The temporary adjustments for a level consist of the following:

- Setting up the level
- Levelling up
- Elimination of parallax

Setting up the level: The operation of setting up includes (i) fixing the instrument on the stand, and (ii) levelling the instrument approximately by leg adjustment. To fix the level to the tripod, the clamp is released, instrument is held in the right-hand and is fixed on the tripod clamping screw. The tripod legs are so adjusted that the instrument is at the convenient height and the tribrach is approximately horizontal. It can be achieved by fixing any two legs firmly into the ground and the third leg is moved right or left in a circumferential direction until the bubble is approximately in the centre.
Levelling up: After having levelled the instrument approximately, accurate leveling is done with the help of foot screws and with reference to the plate level. The purpose of leveling is to make the vertical axis truly vertical. Levelling depends upon the number of foot screws.

(a) Levelling with three foot screw head

- Loose the clamp. Turn the instrument until the longitudinal axis of the plate level is roughlyparallel to a line joining any two of the leveling screws.
- Hold these two foot screws and turn uniformly towards each other or away from each other until the plate bubble is central.
- Swing the telescope through 90° so that it lies over the third foot screw.
- Turn this third screw till the plate bubble is central.
- Again swing the telescope by 90° through the same path to its original position and repeat the step 2 till the bubble remains central.
- Turn back the telescope again through 90° and repeat the step 4.
- Repeat steps 2 and 4 till the bubble remains central in both the positions.
- Now rotate the instrument through 180°. The bubble should remain in centre if the instrument is in correct adjustment. If not then it need permanent adjustment.



3. **Elimination of Parallax:** Parallax is a condition arising when the image formed by the objective is not in the plane of the cross-hairs. Unless parallax is eliminated, accurate sighting is impossible. Parallax can be eliminated in two steps: (i) by focusing the eye piece for distinct vision of the cross-hairs, and (ii) by focusing the objective to bring the image of the object in a plane of cross- hairs.

Focusing the eye-piece: To focus the eye-piece for distinct vision of the cross-hairs, point the telescope towards the sky or hold a sheet of white paper in front of the objective and move the eye-piece in or out till the cross-hairs are seen sharp and distinct.

Focusing of objective: The telescope now directed towards the staff and the focusing screw is turned till the image appears clear and sharp. The image so formed is in the plane of cross-hairs.

METHODS OF LEVELLING

There are following two principal methods which are used to determine the difference in elevation.

Indirect Levelling (Trigonometric Levelling, Barometric levelling and Hypsometry)

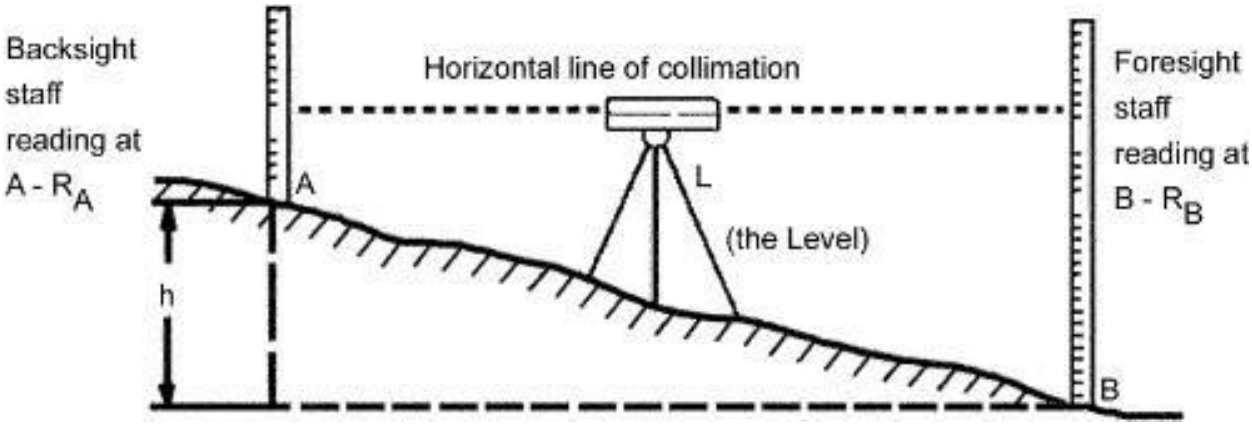
Direct Levelling (Spirit Levelling)

Indirect Levelling (Trigonometric Levelling): It is the process of leveling in which the elevations of points are computed from the vertical angles and horizontal distances measured in the field, just as the length of any side in any triangle can be computed from proper trigonometric relations.

Barometric Levelling: Barometric leveling makes use of the phenomenon that difference in elevation between two points is proportional to the difference in atmospheric pressures at these points. A barometer, therefore, may be used and the readings observed at different points would yield a measure of the relative elevations of those points. At a given point, the atmospheric pressure does not remain constant in the course of the day, even inthe course of an hour. This method is therefore, relatively inaccurate and is little used in surveying work.

Hypsometry: It is based on the principle of boiling point of water. Boiling point of water decreases as the pressure decreases.

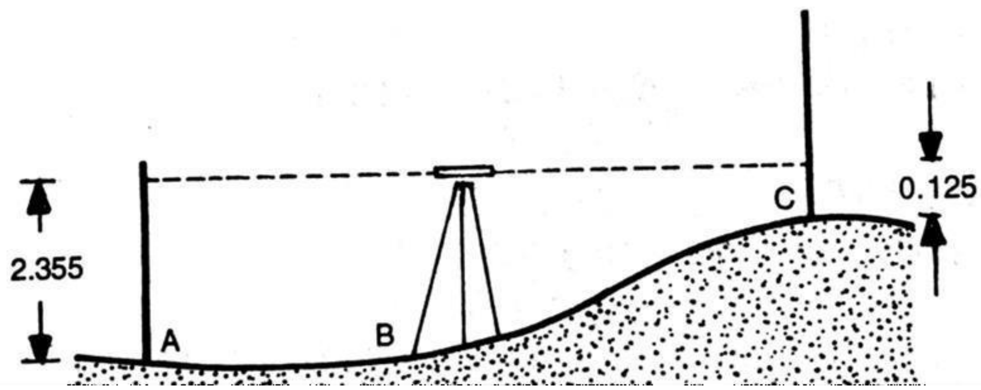
Direct Levelling (Spirit Levelling): In this method the elevations of different points are determinedwith respect to a horizontal line (perpendicular to the direction of gravity). The horizontal line is established by means of a spirit level. In spirit leveling, a spirit level and a sighting device (telescope) are combined and vertical distances are measured by observing on graduated rod placed on the points. It is also known as direct leveling and most commonly used in the survey work.



CLASSIFICATION OF SPIRIT LEVELLING

- Simple levelling
- Differential Levelling
- Profile Levelling
- Cross-sectioning
- Reciprocal Levelling
- Precise Levelling

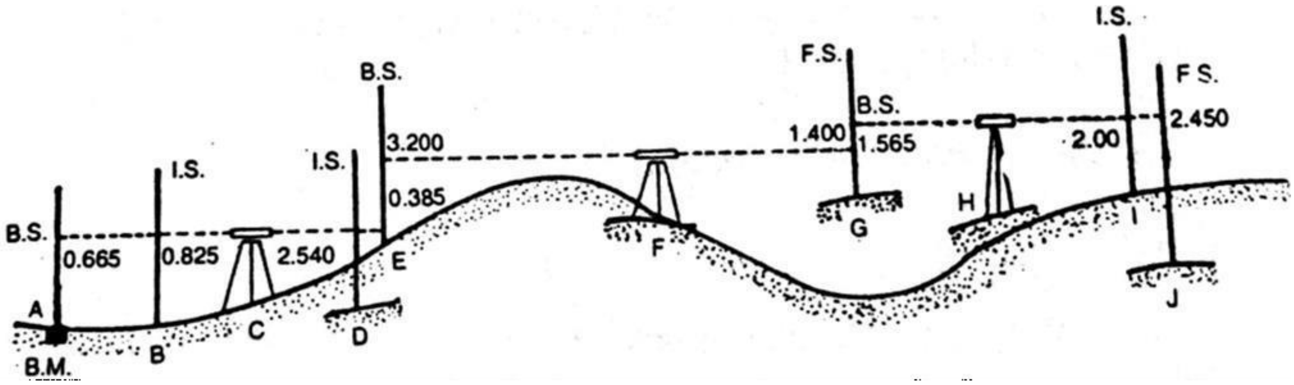
Simple levelling: used to find the difference in elevation between two points both of which are visible from a single position of the instrument.



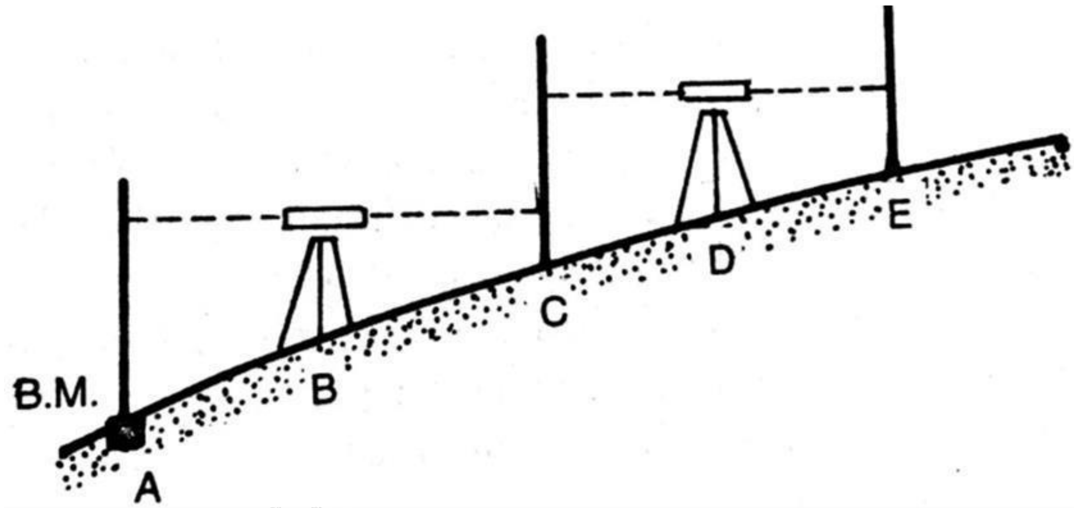
Differential levelling: used to find the difference in elevation between two points without any regard to the alignment of the points.

Uses:

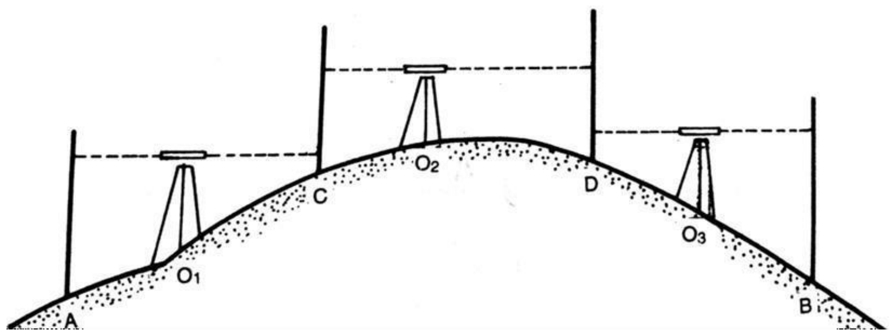
- Two points are at a large distance apart



- Difference in elevation between two points is large



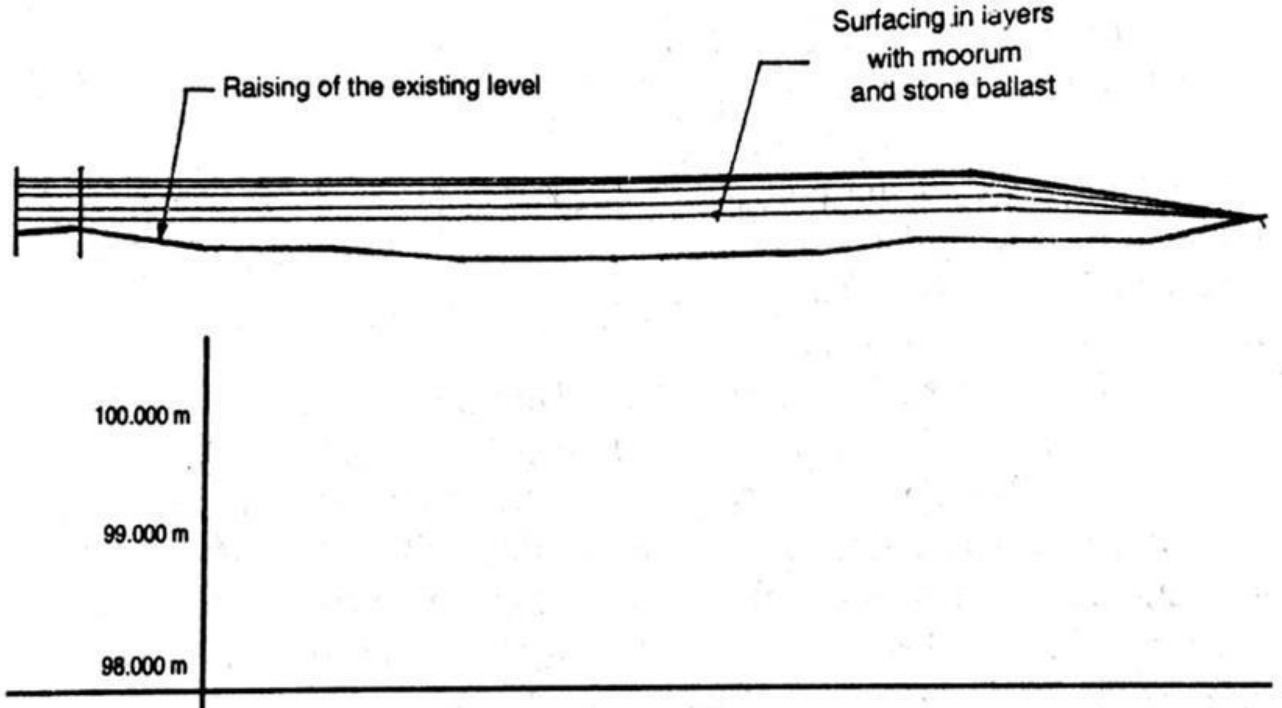
- Obstacle intervenes between points



Spot levels: these are elevations of the points depicted at different spots on the map. These are represented by a dot (•) or plus sign (+) with their elevations on the side. These are determined by fly levelling or profile levelling or x-sectioning.

Fly levelling: it is an operation of levelling in which a line of levels is run to determine the approximate elevations. It is carried out for reconnaissance of the area.

Profile levelling: it is used to run a longitudinal section along various proposed centre lines of highway, railway, canal, sewer etc. and to compare their costs to select a suitable one. Pegs are inserted at regular intervals along the proposed centre line, and the levels of the ground at these points are determined. Levels are also taken at where a change in direction occurs, and at critical points like culverts, bridges etc. crossing the alignment. It is also called longitudinal or L-sectioning.



Formation level (m)	100.325	—	100.325	100.325	100.325	100.325	100.325	100.325	100.325	100.325	99.975	99.675
Existing level (m)	99.585	99.770 99.610	99.515	99.515	99.475	99.455	99.400	99.400	99.530	99.490	99.505	99.670
Chainage (m)	725	750	775	800	825	850	875	900	925	950	975	26 km.

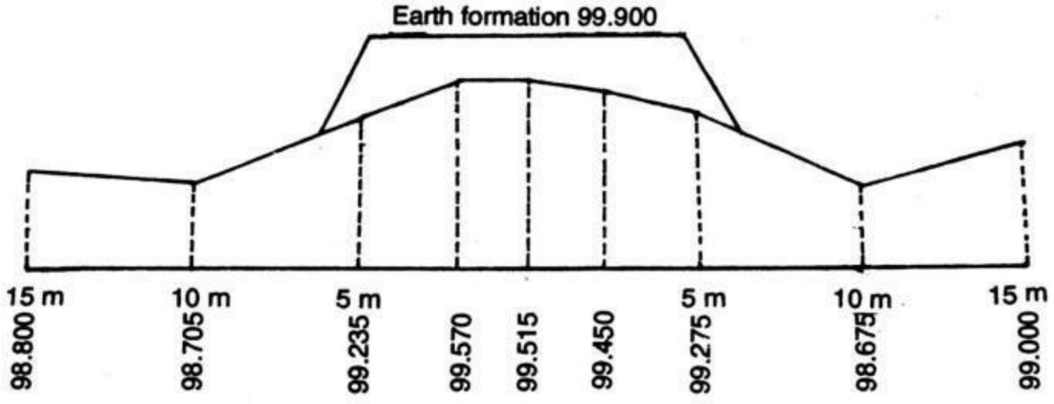
Levelling to establish grade points: This kind of levelling, often referred to as giving elevations is used in all kinds of engineering construction. After the profile has been plotted and the grade line has been established on the profile map, the grade elevation for each station is known. The amounts of cutting / filling at each point are thus determined before going into the field. The levelling operations starts from the BM and is carried forward by turning points. The grade point is established by measuring down from the H.I a distance equal to the grade rod reading, using the relation

Grade point elevation = H.I – grade rod reading

A grade stake is driven in the ground and grade rod is kept on the top of it and read with the help of level. The stake is driven in or put till the grade rod reading is the same as calculated.

Cross sectioning:

It is the operation of levelling to determine the elevation of the points at right angles on either side of the centre line of the proposed route and radially on curves. The observations must be recorded as being to left and right of centre line. The distance along the longitudinal section at which the cross section is taken must also be noted at the beginning of the levels corresponding to a section. Cross sections are plotted in the same way as profiles, but horizontal and vertical scales are made equal. The detailed information regarding the levels of the ground on either side of the L-section helps in computing the quantity of earthwork.



Cross-section at 25.775 km

PRECISE LEVELLING

It is very accurate form of differential levelling used for establishing bench marks. It is usually conducted by government agencies like Department of Survey of India. In principle, there is no difference between ordinary and precise levelling except that every effort is used to control all sources of errors. Similarly, instruments used for precise levelling work are more sophisticated.

BOOKING AND REDUCING LEVELS

There are two methods of booking and reducing the elevations of points from the observed staff readings:

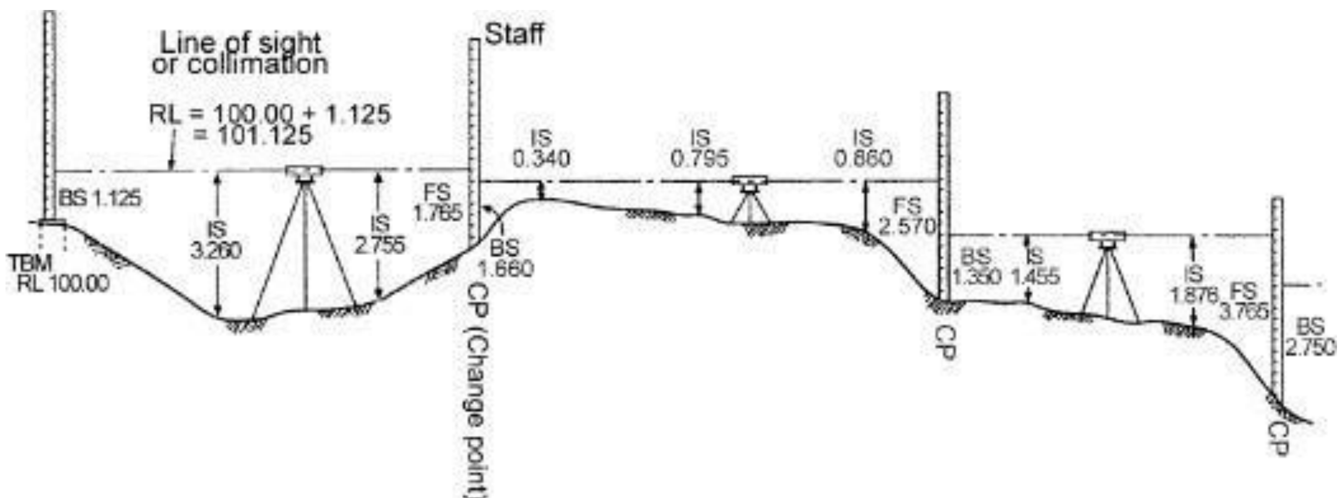
(i) Collimation or Height of Instrument Method;

(ii) Rise and Fall Method

HEIGHT OF INSTRUMENT METHOD OR COLLIMATION METHOD:

In this method, the height of the instrument (H.I) is calculated for each setting of the instrument by adding back sight to the elevation of the B.M. The elevation of the turning point is then calculated by subtracting the back sight from H.I. If there are some intermediate points, the reduced level of these points is calculated by subtracting the intermediate sights from the height of instrument. For the next setting of the instrument, the height of instrument is obtained by adding the back sight to the reduced level of the turning point. The process continues till the reduced level of the last point is obtained.

Arithmetic Check: $\sum$ B.S - $\sum$ F.S = Last R.L – First R.L



RISE AND FALL METHOD:

It consists of determining the difference of levels between the consecutive points by comparing their staff readings. The rise or fall is obtained by calculating the difference between the consecutive staff readings. A rise is indicated if the preceding reading is more than the forward reading, and a fall if the preceding reading is less than the forward reading. Then the reduced level of each point is obtained by adding the rise to, or by subtracting the fall from the reduced level of the preceding point.

Arithmetic Check: ∑ B.S – ∑ F.S = ∑ Rise – ∑ Fall = Last R.L – First R.L

Note: Arithmetical checks only verifies the arithmetic done to evaluate reduce levels of points but, it does not verify that the calculated RLs of any point is actually correct

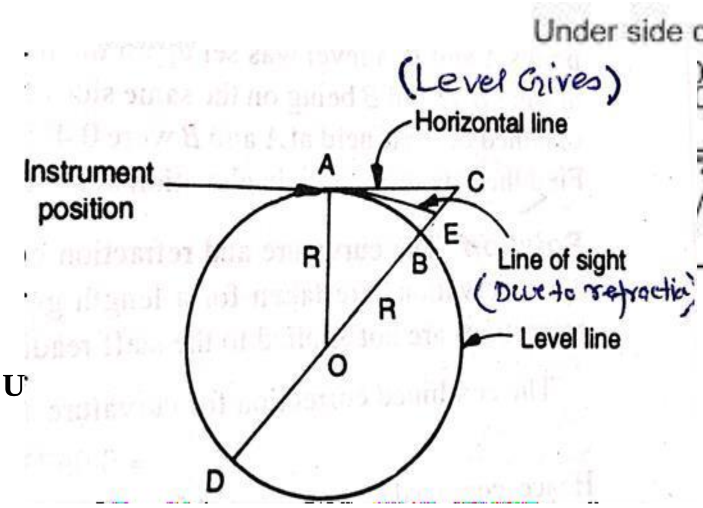
COMPARISION OF THE TWO METHODS

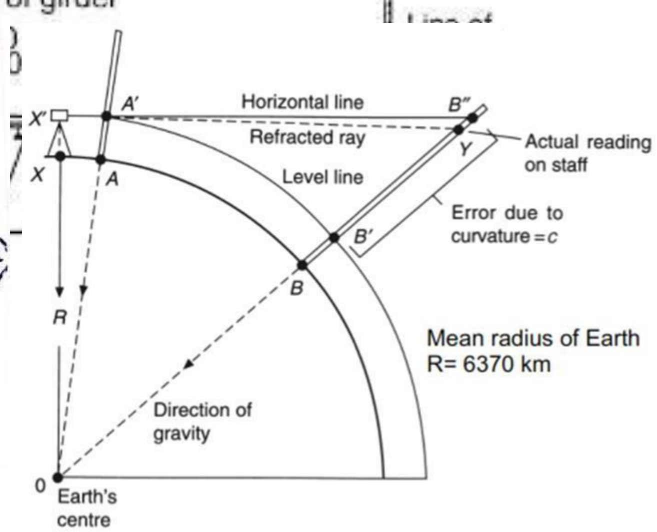
S.No.	**Collimation Method**	**Rise and Fall Method**
1.	It is rapid and simple.	It is slow.
2.	There are two arithmetical checks. ∑ B.S - ∑ F.S = Last R.L – First R.L	There are three arithmetical checks. ∑B.S–∑F.S=∑Rise –∑Fall=Last R.L–First R.L
3.	Since there is no check on R.L of intermediate stations, errors, if any, in the intermediate sights are not detected.	Since there is complete check on R.L of intermediate stations, errors, if any, in the intermediate sights are also detected.
4.	Most suited for longitudinal leveling, cross sectional leveling and contouring.	It is well suited for determining the difference of levels of two points where precision is required.

USE OF INVERTED STAFF

When the point, whose elevation is to be found, is above the line of sight (e.g., underside of beam, slab etc.), the staff is placed inverted with its zero end touching the point. The reading on the staff is taken in the usual manner. Such an observation is entered in the level page book with a minus sign, for convenience. The levels of these points can be obtained by simply adding the staff readings to theheight of instrument.

CU





If the distance between instrument station and staff is less then earth's surface is assumed as flat but if the distance is large then earth's surface is taken as it is i.e. curved. Since the level gives a horizontal line of sight therefore, for small distances level line and horizontal line may be treated as parallel but for large distances horizontal line departs from level line due to earth's curvature. Therefore, if the distance between instrument station and staff is large then observed staff readings will be more, thus the effect of curvature is that the objects sighted appear lower than they really are. The correction due to curvature in staff readings will be negative.

Curvature correction(C_C):

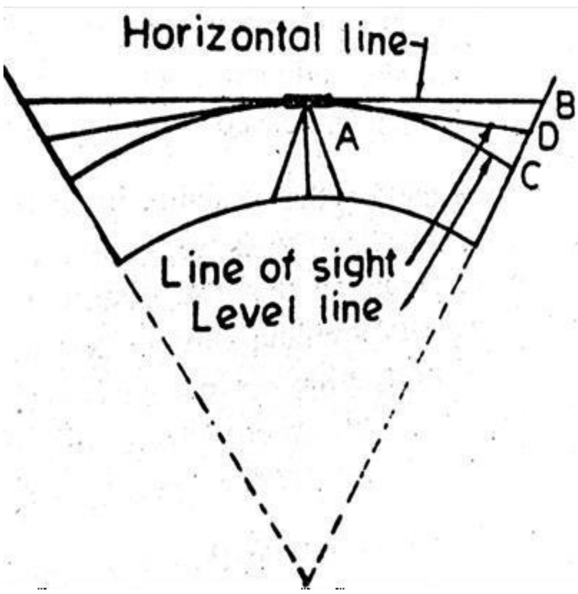
$$C_C = BC$$

In ΔAOC

$$OC^2 = OA^2 + AC^2$$
$$(R + C_C)^2 = R^2 + D^2$$
$$R^2 + 2RC_C + C_C^2 = R^2 + D^2$$
$$C_C(2R + C_C) = D^2$$
$$C_C = \frac{D^2}{2R + C_C}$$
$$\because C_C \ll R \ (Radius\ of\ the\ earth = 6370\ km)$$
$$\therefore C_C = \frac{D^2}{2R} = \frac{D^2}{2 \times 6370}$$
$$= 0.0000785D^2\ km\ (-ve)$$
$$C_C = 0.0785D^2 m,\ dis\ the\ distance\ in\ km$$

Effect of Curvature on levels:

$$h = 0.0785D^2\,(m)$$
$$For\ 1\ km,\ h = 7.8\ cm \sim 8\ cm$$
$$For\ 10\ km,\ h = 7.8\ m \sim 8\ m$$



Due to atmospheric refraction, the line of sight deflects little bit downwards thus the effect of refraction is to make the objects appear higher than they really are. The correction due to refraction in staff readings will be positive. These effects should also be accounted for in precise levelling work. These corrections are applied if the length of sights are more than 200 m.

Refraction correction(C_r):

$$C_r = CE = Amount\ of\ refraction\ correction$$

$$Average\ refraction\ correction = \frac{1}{7} \times Curvature\ correction$$

$$\therefore C_r = \frac{1}{7} \times 0.0785D^2$$

$$= 0.0112D^2\ (+ve)$$

Combined Correction(C):

$$C = BE = Combined\ correction\ (-ve)$$

$$Combined\ correction = 0.0785D^2 - 0.0112D^2 = 0.0673D^2$$

$$\therefore True\ staff\ reading = observed\ staff\ reading - 0.0673D^2$$

How to apply these corrections:

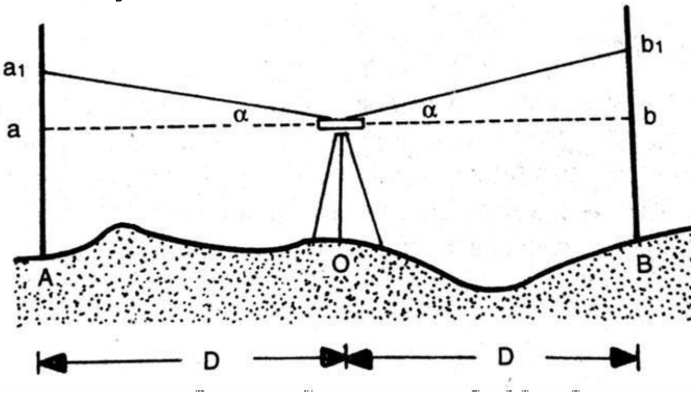
- Decrease each staff reading by combined correction before computing reduced levels
- Increase the RLs of the points by adding the combined correction to the computed RLs

Elimination of error:

- **Method 1:** Equalizing B.S and F.S distances. As the B.S is added and F.s is subtracted, the net effect is zero
- **Method 2:** if it is not possible to set the instrument to equalize B.S and F.S distances,reciprocal levelling can be done to neutralize the effect of curvature and refraction.

BALANCING BACKSIGHT AND FORESIGHT

When the difference in elevation between any two points is determined from a single set-up by back sighting on one point and fore sighting on the other, the error due to non-parallelism of line of collimation and axis of the bubble tube (when the bubble is in the centre of the run) and also the error due to curvature and refraction may be eliminated if the lengths of two sights can be made equal i.e. the instrument is exactly in the middle.



Let A and B be the two points at a distance D from the level as shown in the Figure. Let the line of collimation be inclined at an angle α with the true line of collimation aob.

Observed reading on staff at A = Aa_1
True reading on staff at A = Aa
Observed reading on staff at B = Ba_1
True reading on staff at B = Ba
∴ The errors at A and B are = aa_1 *and* bb_1
True reading at A is $Aa = Aa_1 - aa_1 = Aa_1 - D \tan \alpha$
True reading at B is $Bb = Bb_1 - bb_1 = Bb_1 - D \tan \alpha$
True difference of level between A and B is

$$Bb - Aa = (Bb_1 - D \tan \alpha) - (Aa_1 - D \tan \alpha) = Bb_1 - Aa_1$$

Therefore, it is seen that the error is completely eliminated by equalizing the B.S and F.S distances.

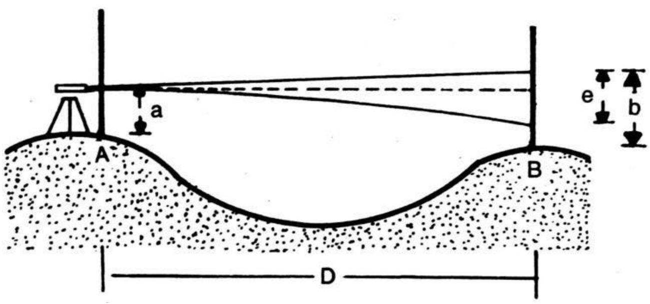
RECIPROCAL LEVELLING

It is the operation of levelling in which the difference in elevation between the two points is accurately determined by two sets of reciprocal observations. It is generally employed to determine the difference in elevation between two intervisible points situated (1) on the opposite banks of a large river (2) on either side of a deep gorge or valley (3) between which the instrument cannot be set up for balancing the sights

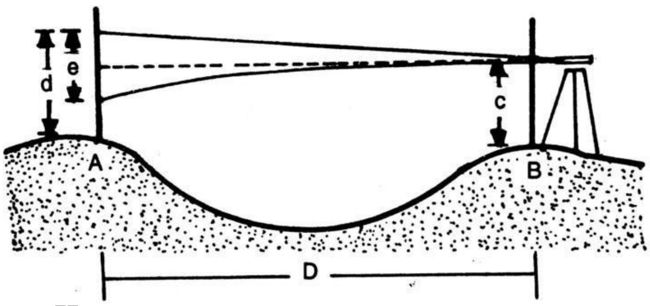
Advantages: It eliminates

- The error due to curvature and refraction
- The collimation error i.e., due to the line of collimation not being exactly parallel to the bubble line

Let h = true difference of level between A and B
e = total error due to curvature, refraction and imperfect collimation adjustment



Case I



Case II

Case I:
$h = (b - e) - a$ (1)

Case II:
$h = c - (d - e)$ (2)

Adding 1 and 2, we get

$$2h = (b - e) - a + c - (d - e)$$
$$or\ 2h = b - e - a + c - d + e$$
$$= (b - a) + (c - d)$$
$$h = \frac{1}{2}[(b - a) + (c - d)]$$

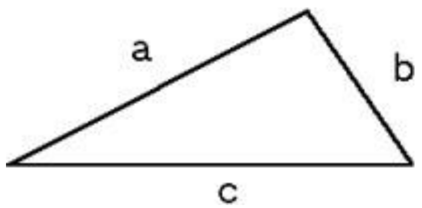
Subtracting 2 from 1, we get

$$0 = b - e - a - c + d - e$$
$$2e = (b - a) - (c - d)$$
$$e = \frac{1}{2}[(b - a) - (c - d)]$$

COMPUTATION OF AREAS AND VOLUMES

Areas and Volumes are often required in the context of design, eg. We might need the surface area of a lake, the area of crops, of a car park or a roof, the volume of a dam embankment, or of a road cutting. Volumes are often calculated by integrating the area at regular intervals eg. along a road centre line, or by using regularly spaced contours. We simply use what you already know about numerical integration from numerical methods). Objectives

After completing this topic you should be able to calculate the areas of polygons andirregular figures and the volumes of irregular and curved solid



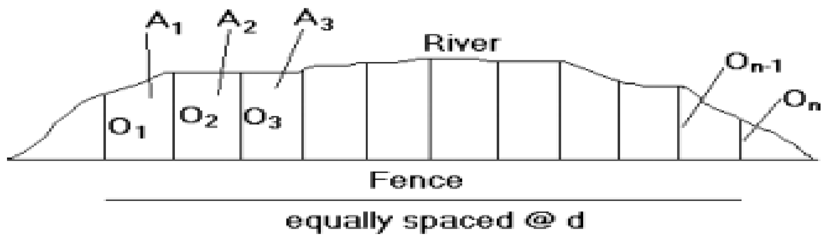
Triangles if s = (a + b + c) / 2 then area = S.(S-a)(S-b)(S-c)

Calculating area of a polygon from Coordinates: If the coordinate points are numbered clockwise: area = 1 2 ∑ i=1 n (Ni . Ei+1 - Ei . Ni+1) This formula is not easy to remember, so let's look at a practical application

The computation of volumes of various quantities from the measurements done in the field is required in the design and planning on many engineering works. The volume of earth work is required for suitable alignment of road works, canal and sewer lines, soil and water conservation works, farm pond and percolation pond consent. The computation of volume of various materials such as coal, gravel and is required to check the stock files, volume computations are also required for estimation of capacities of bins tanks etc. For estimation of volume of earth work cross sections are taken at right angles to a fixed line, which runs continuously through the earth work. The spacing of the cross sections will depend upon the accuracy required. The volume of earth work is computed once the various cross-sections are known, adopting Prismoidal rule and trapezoidal rule.

Calculating areas with the Trapezoidal Rule

(as used in integrating functions)



$$A_1 = d \,.\, (O_1 + O_2) / 2$$
$$A_2 = d \,.\, (O_2 + O_3) / 2$$
$$A_3 = d \,.\, (O_3 + O_4) / 2$$

Hence, the total area is:

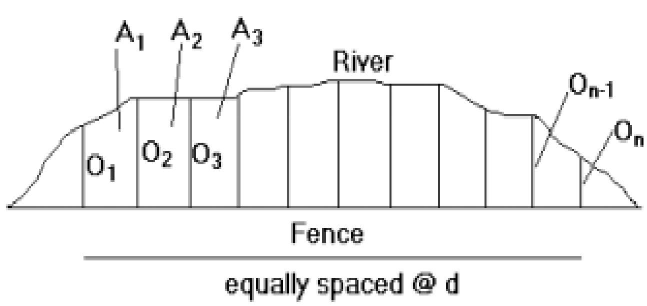
$$A = (d/2) \,.\, [O_1 + 2.O_2 + 2.O_3 + ... + 2.O_{n-1} + O_n]$$

The Trapezoidal Rule assumes **straight line segments** on the boundary.

Doing better with Simpson's Rule

Simpson's Rule assumes a parabola fitted to 3 adjacent points, rather than the straight lines between adjacent points assumed by the Trapezoidal Rule.

This may be more accurate than the Trapezoidal Rule because boundaries are often curved.



Volumes can be calculated in a number of ways. It is common to calculate the area of each of several equally spaced slices (either vertical cross-sections, or horizontal contours), and integrate these using Simpson's Rule or similar. A second method is to use spot levels, and calculate the volume of a series of wedges or square cells. Cross-sections are well suited for calculating volumes of roads, pipelines, channels, dam embankments, etc. Formulae are given below for the most common cross-section cases.

Computation of area using different methods

1. The following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m. 0, 2.50, 3.50, 5.00, 4.60, 3.20, 0 m. Compute the area between the chain line, the irregular boundary line and the end offsets by:

(a) Trapezoidal Rule

(b) Simpson's Rule

(a) Trapezoidal Rule

Here d = 10

$$\text{Area} = \frac{10}{2}\{0+0+2(2.50+3.50+5.00+4.60+3.20)\} = 5 * 37.60 = \mathbf{188\ m^2}$$

(b) Simpson's Rule

D = 10

$$\text{Area} = \frac{10}{3}\{0+0+4(2.50+5.00+3.20)+2(3.50+4.60)\} = \frac{10}{3} * 59.00 = \mathbf{196.66\ m^2}$$

2. The following offsets were taken from a survey line to a curved boundary line:

Distance (m)	0	5	10	15	20	30	40	60	80
Offset (m)	2.50	3.80	4.60	5.20	6.10	4.70	5.80	3.90	2.20

Find the area between the survey line, the curved boundary line and the first and last offsets by (a) Trapezoidal Rule and (b) Simpson's Rule.

Here, the intervals between the offsets are not regular throughout the length. Soothe section is divided into three compartments.

Let,

Δ_1 = Area of the 1st section

Δ_2 = Are of the 2nd section

Δ_3 = Area of the 3rd section

Here,

$d_1 = 5$ m

$d_2 = 10$ m

$d_3 = 20$ m

(a) Trapezoidal Rule:

$$\Delta_1 = \frac{5}{2}\{2.50 + 6.10 + 2(3.80 + 4.60 + 5.20)\} = 89.50 \text{ m}^2$$

$$\Delta_2 = \frac{10}{2}\{6.10 + 5.80 + 2(4.70)\} = 106.50 \text{ m}^2$$

$$\Delta_3 = \frac{20}{2}\{5.80 + 2.20 + 2(3.90)\} = 158.00 \text{ m}^2$$

Total Area = 89.50 + 106.50 + 158.00 = **354.00 m²**

(b) By Simpson's Rule

$$\Delta_1 = \frac{5}{3}\{2.50 + 6.10 + 4(3.80 + 5.20) + 2(4.60)\} = 89.66 \text{ m}^2$$

$$\Delta_2 = \frac{10}{3}\{6.10 + 5.80 + 4.70\} = 102.33 \text{ m}^2$$

$$\Delta_3 = \frac{20}{3}\{5.80 + 2.20 + 4(3.90)\} = 157.33 \text{ m}^2$$

Total area = 89.66 + 102.33 + 157.33 = **349.32 m²**

Simpson's rule

In this rule, the boundaries between the ends of ordinates are assumed to form an arc of a parabola. Hence Simpson's rule is sometimes called the parabolic rule.

Refer to Fig. 7.13.

Let

O_1, O_2, O_3 = three consecutive ordinates

d = common distance between the ordinates

Area AFeDC = area of trapezium AFDC + area of segment FeDEF

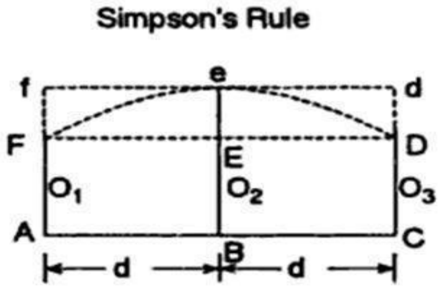


Fig. 7.13

Here,

$$\text{Area of trapezium} = \frac{O_1 + O_3}{2} \times 2d$$

$$\text{Area of segment} = \frac{2}{3} \times \text{area of parallelogram FfdD}$$

$$= \frac{2}{3} \times \text{Ee} \times 2d = \frac{2}{3} \times \left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$$

Trapezoidal rule

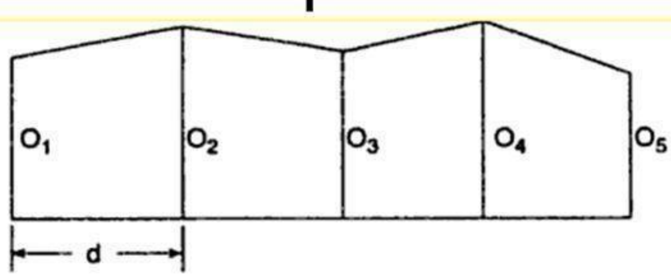


Fig. 7.12

Let $O_1, O_2, \ldots, O_n$ = ordinates at equal intervals

d = common distance

$$\text{1st area} = \frac{O_1 + O_2}{2} \times d$$

$$\text{2nd area} = \frac{O_2 + O_3}{2} \times d$$

$$\text{3rd area} = \frac{O_3 + O_4}{2} \times d$$

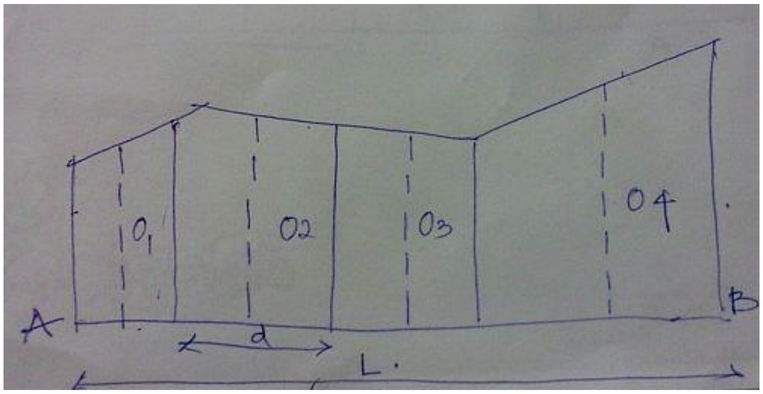
$$\text{Last area} = \frac{O_{n-1} + O_n}{2} \times d$$

$$\text{Total area} = \frac{d}{2}\{O_1 + 2O_1 + 2O_2 + \ldots + 2O_{n-1} + O_n\}$$

$$= \frac{\text{common distance}}{2}\{(\text{1st ordinate} + \text{last ordinate} + 2\ (\text{sum of other ordinate})\}$$

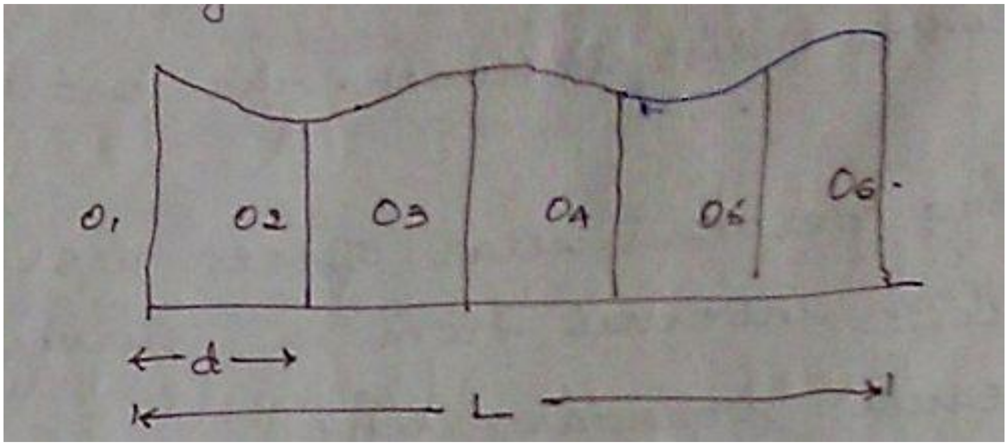
Midpoint-ordinate rule

The rule states that if the sum of all the ordinates taken at midpoints of each division multiplied by the length of the base line having the ordinates (9 divided by number of equal parts).



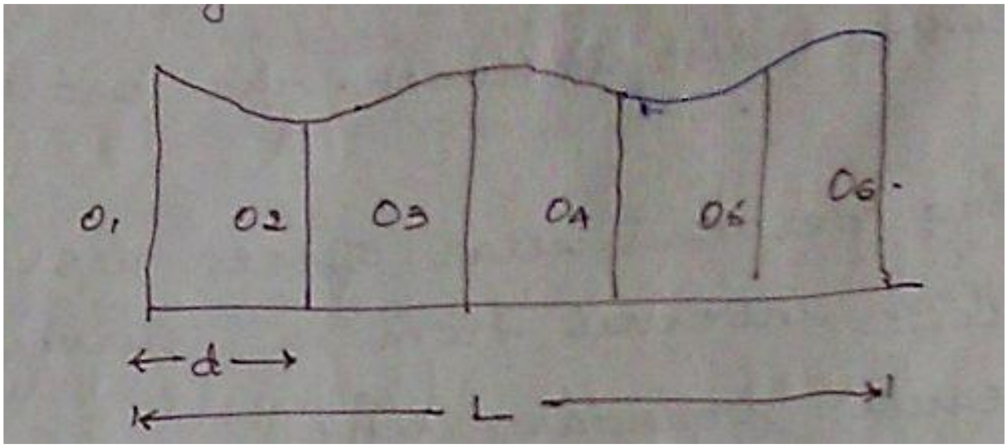
boundary line. The ordinates are measured at midpoint of the division are 10, 13, 17, 16, 19, 21, 20 and 18m. Calculate the are enclosed by the midpoint ordinate rule.
Given:
OrdinatesO1 = 10
O2 = 13
O3 = 17
O4 = 16
O5 = 19
O6 = 21
O7 = 20
O8 = 18
Common distance, d =10m
Number of equal parts of the baseline, n = 8 Length of baseline, L = n *d = 8*10 = 80m Area = [(10+13+17+16+19+21+20+18)*80]/8

The following perpendicular offsets were taken at 10m interval from a survey line to an irregular



Average Ordinate Rule

The rule states that (to the average of all the ordinates taken at each of the division of equal length multiplies by baseline length divided by number of ordinates)



Problems

The following perpendicular offsets were taken at 10m interval from a survey line to an irregular boundary line.

9, 12, 17, 15, 19, 21, 24, 22, 18

Calculate area enclosed between the survey line and irregular boundary line. Area = [(O1+ O2+ O3+ …. + O9)*L]/(n+1)

= [(9+12+17+15+19+21+24+22+18)*8*10]/(8+1)

= 139538sqm

Simpson's Rule Statement

It states that, sum of first and a last ordinate has to be done. Add twice the sum of remaining odd ordinates and four times the sum of remaining even ordinates. Multiply to this total sum by 1/3rd of the common distance between the ordinates which gives the required area.

Problem

Chainage	0	25	50	75	100	125	150
Offset „m"	3.6	5.0	6.5	5.5	7.3	6.0	4.0

The following offsets are taken from a chain line to an irregular boundary towards right side of the chain line.

Common distance, d = 25m

Area = d/3[(O_1+O_7) + 2 (O_3+O_5)+4(O_2+O4+O_6)]

= 25/3[(3.6+4)+2(6.5+7.3)+4(5+5.5+6)]

Area = 843.33sqm

COMPUTATIONS OF VOLUMES

The computation of volumes of various quantities from the measurements done in the field is required in the design and planning on many engineering works. The volume of earth work is required for suitable alignment of road works, canal and sewer lines, soil and water conservation works, farm pond and percolation pond consent. The computation of volume of various materials such as coal, gravel and is required to check the stock files, volume computations are also required for estimation of capacities of bins tanks etc.

For estimation of volume of earth work cross sections are taken at right angles to a fixed line, which runs continuously through the earth work. The spacing of the cross sections will depend upon the accuracy required. The volume of earth work is computed once the various cross-sections are known, adopting Prismoidal rule and trapezoidal rule

Measurement of Volume of Earth work from Cross-Sections

The length of the project along the centre line is divided into a series of solids known as Prismoidal by the planes of cross-sections. The spacing of the sections should depend upon the character of ground and the accuracy required in measurement. They are generally run at 20m or 30m intervals, but sections should also be taken at points of change from cutting to filling, if these are known, and at places where a marked change ofslop occurs either longitudinally or transversely. The areas of the cross-sections which have been taken are first calculated and the volumes of the Prismoidal between successive cross- sections are then obtained by using the Trapezoidal formula or the Prismoidal formula. The former is used in the preliminary estimates and for ordinary results, while the latter is employed in the final estimates and for precise results. The Prismoidal formula can be used directly or indirectly. In the indirect method, the volume is firstly calculated by trapezoidal formula and the Prismoidal correction is then applied to this volume so that the corrected volume is equal to that as if it has been calculated by applying the Prismoidal formula directly. The indirect method being simpler is more
commonly used.

When the centre line of the project is curved in plan, the effect of curvature is also taken into account specially in final estimates of earthwork where much accuracy is needed. It isthe common practice to calculate the volumes as straight as mentioned above and then to apply the correction for curvature to them.

Another method of finding curved volumes is to apply the correction for curvature to the areas of cross-sections, and then to compute the required volumes from the corrected areas from Prismoidal formula

The following are the various cross-sections usually met with whose areas are to becomputed:

- Level section.
- Two-level section.
- Side-hill two-level section.
- Three-level section.
- Multi-level section

1. Level-Section (Fig. 12.2):

In this case the ground is level transversely.

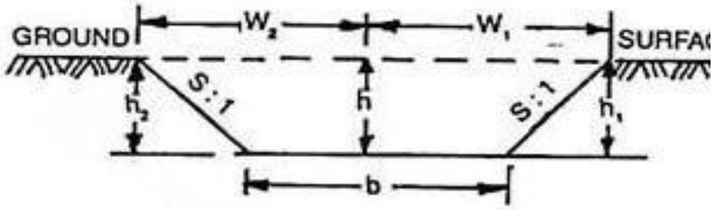


Fig. 12.2

$$h_1 = h_2 = h$$
$$w_1 = w_2$$
$$= \frac{b}{2} + sh$$
$$A = \frac{1}{2}[b + (b + 2sh)]h$$
$$= (b + sh)\,h \quad \ldots \quad \ldots \quad \ldots$$

2. Two-Level Section (Fig. 12.1):

In this case, the ground is sloping transversely, but the slope of the ground does not intersect the formation level.

$$w_1 = \frac{b}{2} + \frac{rs}{r-s}\left(h + \frac{b}{2r}\right)$$

$$w_2 = \frac{b}{2} + \frac{rs}{(r+s)}\left(h - \frac{b}{2r}\right)$$

$$h_1 = h + \frac{w_1}{r}$$

$$h_2 = h - \frac{w_2}{r}$$

$$A = \frac{1}{2}\left[(w_1 + w_2)\left(h + \frac{b}{2s}\right) - \frac{b^2}{2s}\right]$$

$$= \left[\frac{s(\frac{b}{2})^2 + r^2bh + r^2sh^2}{(r^2 - s^2)}\right] \quad \ldots \quad \ldots \quad \text{(Eqn. 12.2)}$$

4. Three-Level Section (Fig. 12.4):

In this case, the transverse slope of the ground is not uniform.

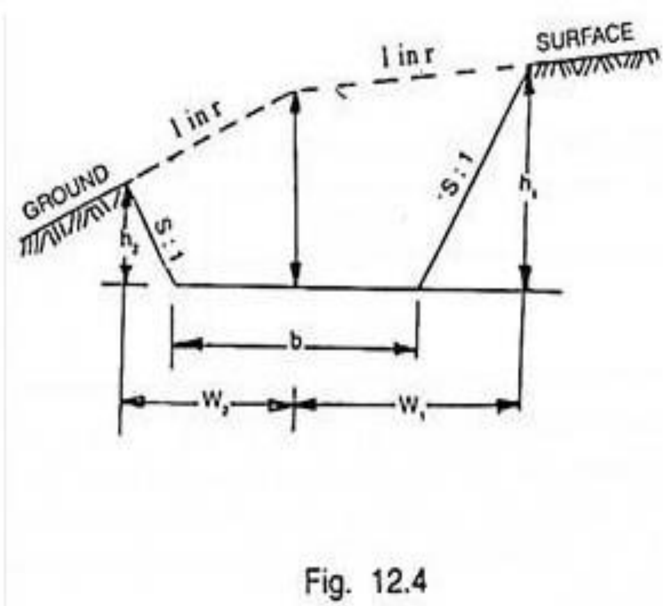


Fig. 12.4

$$w_1 = \frac{r_1 s}{(r_1 - s)}\left(h + \frac{b}{rs}\right)$$

$$w_2 = \frac{r_2 s}{(r_2 + s)}\left(h + \frac{b}{2s}\right)$$

The formulae for w_1 and w_2 may apply to both side widths according as the ground rises or falls from the centre to both sides.

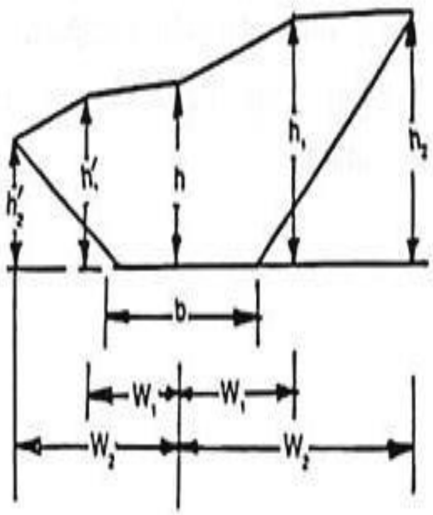
$$h_1 = \left(h + \frac{w_1}{r_1}\right)$$

$$h_2 = \left(h - \frac{w_2}{r_2}\right)$$

$$A = \left[\frac{1}{2}h(w_1 + w_2) + \frac{b}{4}(h_1 + h_2)\right] \quad \ldots \quad \ldots \quad \text{(Eqn. 12.5}$$

5. Multi-Level Section (Fig. 12.5):

In this case, the transverse slope of the ground is not uniform but-has multiple cross-slopes as is clear from the figure.



The notes regarding the cross-section are recorded as follows:

Left	*Centre*	*Right*
$\frac{\pm h'_2}{w'_2}\ \frac{\pm h'_1}{w'_1}$	$\frac{\pm h}{0}$	$\frac{\pm h_1}{w_1}\ \frac{\pm h_2}{w_2}$

The numerator denotes cutting (+ve) or filling (-ve) at the various points, and the denominator their horizontal distances from the centre line of the-section. The area of the section is calculated from these notes by coordinate method. The co-ordinates may be written in the determinant form irrespective of the signs.

$$\frac{0}{b/2} \times \frac{h'_2}{w'_2} \times \frac{h'_1}{w'_1} \times \frac{h}{0} \times \frac{h_1}{w_1} \times \frac{h_2}{w_2} \times \frac{0}{b/2}$$

Formula

Let Σ F= sum of the product of the co-ordinates joined by full lines.Σ D= sum of the products of the co-ordinates joined by dotted lines.Then, A= 1/2 (ΣF- ΣD)

Volume of a reservoir

Formulae for volume:

To calculate die volumes of the solids between sections, it must be assumed that they have some geometrical from. They must nearly take the form of Prismoidal and therefore, in calculation work, they are considered to be Prismoidal.

Let A_1, A_2, A_3…………….. A_n = the areas at the 1st, 2nd, 3rd… last cross-section.

D = the common distance between the cross-section.V = the volume of cutting or filling

Measurement of Volumes from contours:

Mass Diagram:

The mass diagram is a graph plotted between distances along centre line, taken as base and algebraic sum of the mass of the earth work, taken as ordinates. The volume of cutting is considered as positive where as that of filling as negative.

For determining in advance, the proper distribution of excavated material and the amount of waste and borrow, a mass diagram is commonly used. From the mass diagram, it is possible to determine by trial, the earthwork distribution plan that will result in the minimum cost of overhaul and the economical expenditure for overhaul and borrow

Lift and Lead:

Lift:

Vertical distance through which the excavated earth is lifted beyond a certain depth is called lift. Excavation up to 1.5m depth below ground level and excavated material deposited on the ground shall be included in the item of work as specified. The lift shall be measured from the C.G. of the excavated earth to that of the deposited earth. Extra lift shall be measured in unit of 1.5m or as per pre-accepted condition.

Lead:

The horizontal distance from borrow pit to the site of work is called lead. It shall be measured from the centre of the area of excavation to the centre of the placed earth. Normally a lead up to 30m or as per pre- accepted condition is not paid- extra.

Beyond a lead of 30m and lift of 1.5m rates will be different for every unit of 30m lead and 1.5m lift or fraction thereof

Converting Lift into lead:

The lift is converted into lead by the following rules:

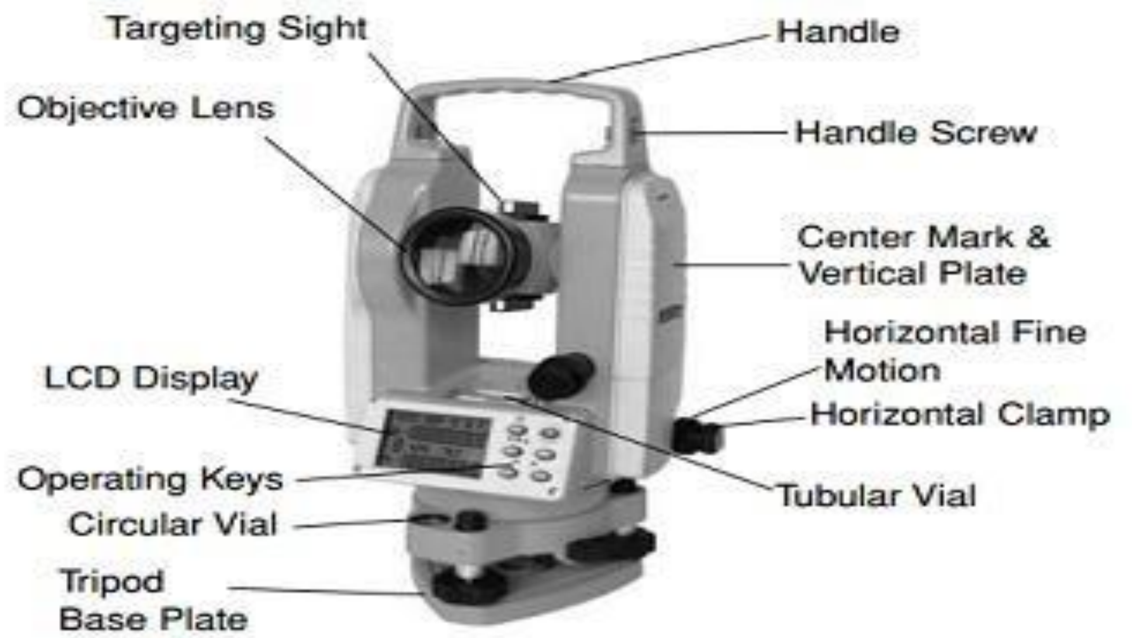
1. The lift up to 3 .6m is multiplied by 10
2. Lift more than 3.6m and less than 6m is squared and multiplied by 3.3.Lift more than 6m is multiplied by 20

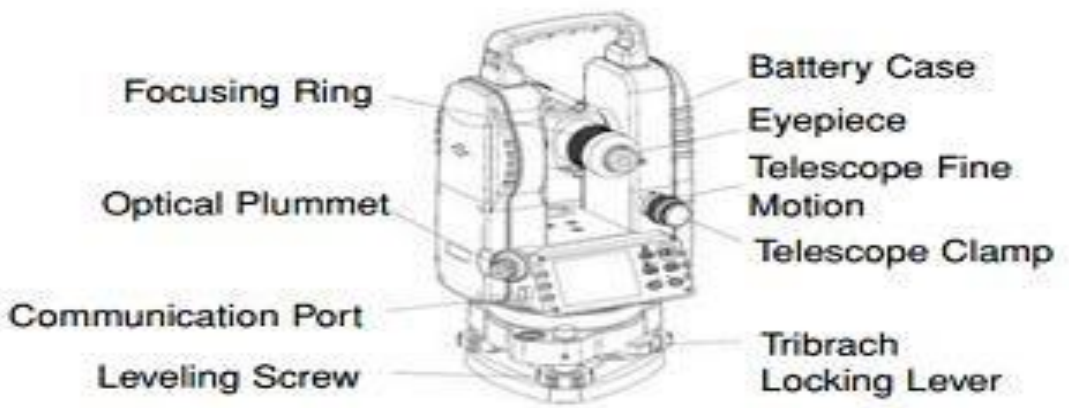
UNIT-3

THEODOLITE AND TRAVERSE SURVEYING

Types of Theodolite

There are two different kinds of Theodolite: digital and non digital. Non digital Theodolite are rarely used anymore. Digital Theodolite consists of a telescope that is mounted on a base, as well as an electronic readout screen that is used to display horizontal and vertical angles. Digital Theodolite are convenient because the digital readouts take the place of traditional graduated circles and this creates more accurate readings.





How Does a Theodolite Work

A Theodolite works by combining optical plummets (or plumb bobs), a spirit (bubble level), and graduated circles to find vertical and horizontal angles in surveying. An optical plummet ensures the Theodolite is placed as close to exactly vertical above the survey point. The internal spirit level makes sure the device is level to the horizon. The graduated circles, one vertical and one horizontal, allow the user to actually survey for angles

Theodolite is mainly used for surveying, but they are also useful in theseapplications:

- Navigating
- Meteorology
- Laying out building corners and lines
- Measuring and laying out angles and straight lines
- Aligning wood frame walls
- Forming panels
- Plumbing a column or building corner
- Terminology of Theodolite
- It is important to clearly understand the terms associated with the Theodolite and its use and meaning. The following are some important terms and their definitions.

Vertical axis

It is a line passing through the centre of the horizontal circle and perpendicular to it. The vertical axis is perpendicular to the line of sight and the trunnion axis or the horizontal axis. The instrument is rotated about this axis for sighting different points

Horizontal axis

It is the axis about which the telescope rotates when rotated in a vertical plane. Thisaxis is perpendicular to the line of collimation and the vertical axis.

Telescope axis It is the line joining the optical centre of the object glass to the centre ofthe eyepiece

Line of collimation

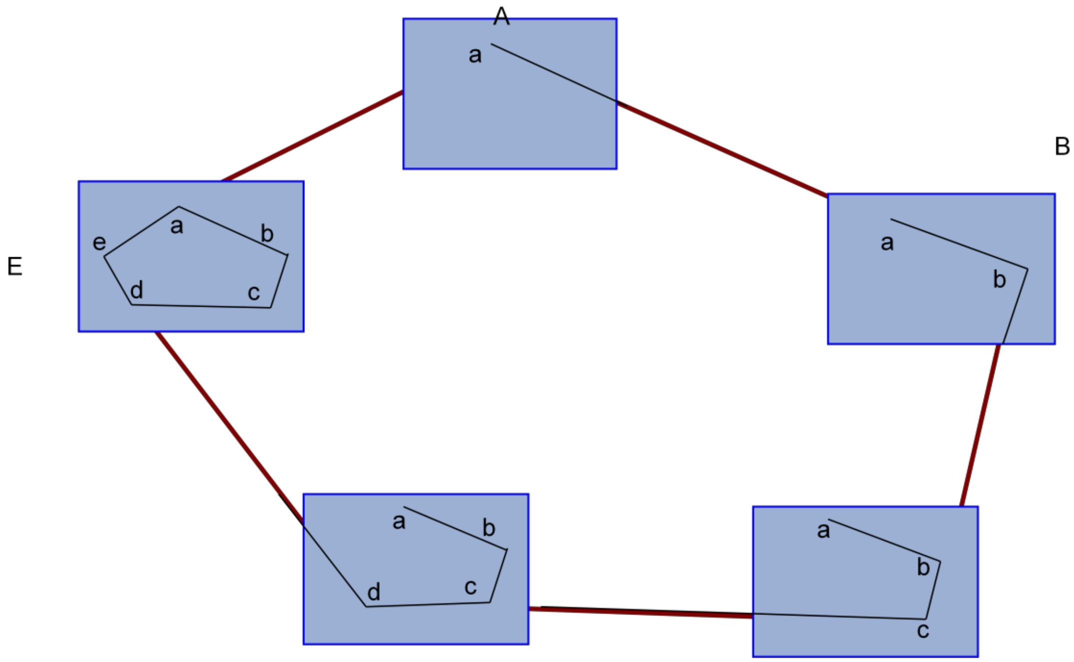
It is the line joining the intersection of the cross hairs to the optical centre of the object glass and its continuation. This is also called the line of sight.

Axis of the bubble tube

It is the line tangential to the longitudinal curve of the bubble tube at its centre

TRAVERSING METHOD

This is similar to that of Compass Survey or Transit Traversing. It is used for running survey lines between stations, which have been previously fixed by other methods of survey, to locate the topographic details. It is also suitable for the survey of roads, rivers,etc.



Plane Tabling using Traversing Method Resection :-

Resection is the process of determining the plotted position of the station occupied by the plane table, by means of sights taken towards known points, locations ofwhich have been plotted.

The method consists in drawing two rays to the two points of known location on the plan after the table has been oriented. The rays drawn from the un-plotted location of the station to the points of known location are called resectors, the intersection of which gives the required location of the instrument stations. If the table is not correctly oriented at the station to be located on the map, the intersection of the two resectors will not give the correct location of the station

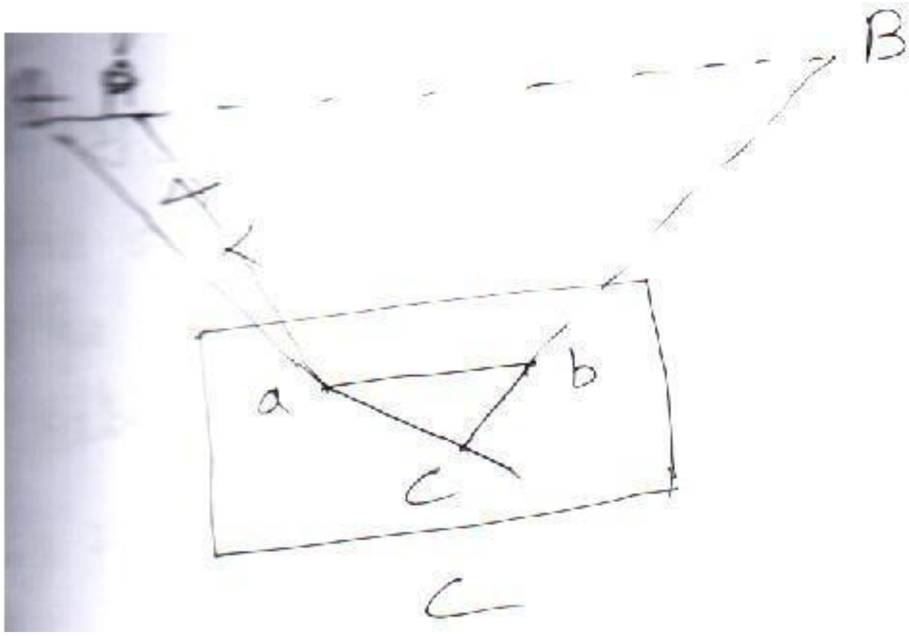
. The problem, therefore, lies in orienting table at the stations and can be solved by the following four methods of orientation.

- Resection after orientation bycompass.
- Resection after orientation by back sighting.
- Resection after orientation by three point problem.
- Resection after orientation by two-point problem.

Resection after orientation by compass:-

The method is utilized only for small scale or rough mapping for which the relatively large errors due to orienting with the compass needle would not impair the usefulness of the map.

The method is as follows

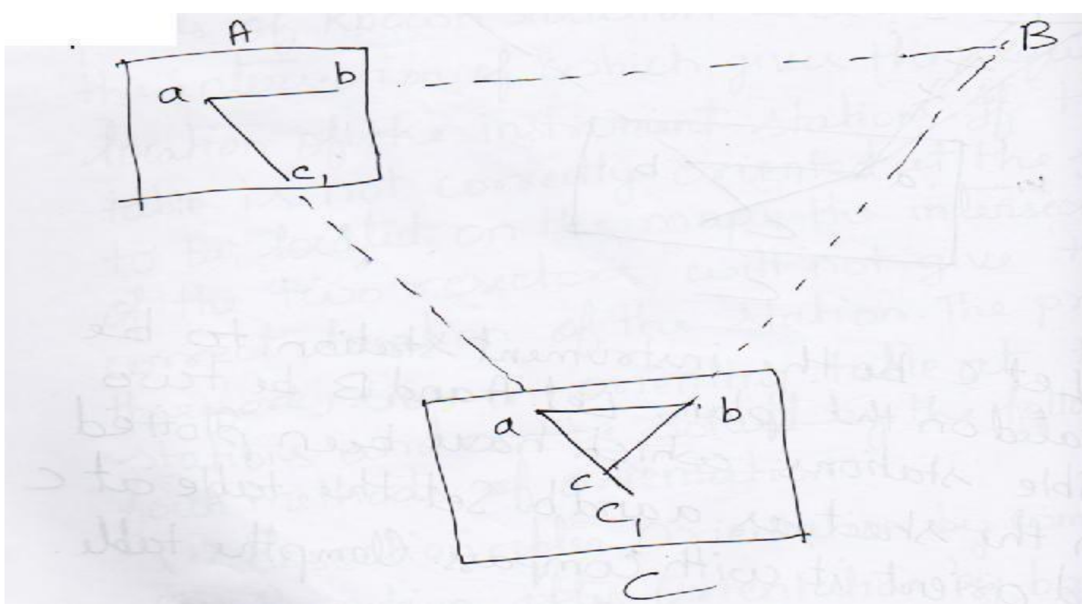


Let „C" be the instrument station to be located on the plan. Let „A" and „B" be two visible stations which have been plotted on the sheet as „a" and „b". set the table at
„c" and orient it with compass. Clamp the table.
Pivoting the alidade about „a", draw a resector (ray) towards „A"; similarly, sight „B"from „b" and draw a resectors. The intersection of the two resectors will give „C", therequired point.

Resection after orientation by back sighting:-

If the table can be oriented by back sighting along a previously plotted back sight line, the station can be located by the intersection of the back sight line and the resectors drawn through another known point.

The method is as follows :



Let „C‟ be the station to be located on the plan and „A‟ and „B‟ be two visible points which have been plotted on the sheet as „a‟ and „b‟. Set the table at „A‟ and orient it by back sighting „B‟ along „ab‟.
Pivoting the alidade at „a‟. sight „C‟ and draw a ray. Estimate roughly the position of „C‟ on this ray as C_1.
Shift the table to „C‟ and centre it approximately with respect to C_1.Keep the alidade on the line c_1a and orient the table by back sight to „A‟, Clamp the table which has been oriented.
Pivoting the alidade about „b‟, sight „B‟ and draw the resectors „bB‟ to intersect the ray „c_1a‟ in „C‟. Thus, „C‟ is the location of the instrument station.

The Three-Point Problem:

Statement :-

Location of the position, on the plan of the station occupied by the plane table by means of observations to three well-defined points whose positions have been previously plotted on the plan.

The following are some of the important methods available for the solution of the problem.

- Mechanical Method (Tracing Paper Method)
- Graphical Method
- Lehmann‟s Method (Trial and Error Method)

- Mechanical Method (Tracing Paper method)

- The method involves the use of a tracing paper and is, therefore also known as tracing paper method

Procedure :

Let A, B, C be the known points and a, b, c be their plotted positions. Let „P‟ be the position of the instrument station to be located on the map.
Set the table on P. Orient the table approximately with eye so that „ab‟ is parallel to AB.
Fix a tracing paper on the sheet and mark on it P‟ as the approximately location of „P‟ with the help of plumbing fork.

Pivoting the alidade at „P‟, sight A, B, C in turn and draw the corresponding lines P‟a‟, P‟b‟ and P‟c‟ on the tracing paper. These lines will not pass through a, b and c as the orientation is approximate.
Loose the tracing paper and rotate it on the drawing paper in such a way that the lines p‟a‟, p‟b‟ and p‟c‟ pass through a, b and c respectively. Transfer p‟ on to the sheet and represent it as p. Remove the tracing paper and join pa, pb and pc.

Keep the alidade on pa. The line of sight will not pass through „A" as the orientation has not yet been corrected. To correct the orientation, loose the clamp and rotate the plane table so that the line of sight passes through „A". Clamp the table. The table is thus oriented.
To test the orientation keep the alidade along pb. If the orientation is correct, the line of sight will pass through B. similarly, the line of sight will pass through
„C" when the alidade is kept on pc.

Lehmann's Method:-

This is the easiest and quickest solution. The principles of the method are as follows:

When the board is properly oriented and the alidade sighted to each control signals A, B and C, rays drawn from their respective signals will interest at a unique point.
When rays are drawn from control signals, the angles of their intersections are true angles whether or not the board is properly oriented.

Procedure :-

Set the table over new station p and approximately orient it.
With alidade on a sight A, similarly sight B and C. The three rays Aa, Bb and Cc will meet at a point if the orientation is correct. Usually, however, they will not meet but will form a small triangle known as the triangle of error.
To reduce the triangle of error to zero, another point „p" is chosen as per Lehmann"s rule.
Keep the alidade along p"a and rotate the table to sight A. Clamp the table. This will give next approximate orientation (but more accurate than the previous one).

much smaller.
The method has to be repeated till the triangle of error reduces to zero.

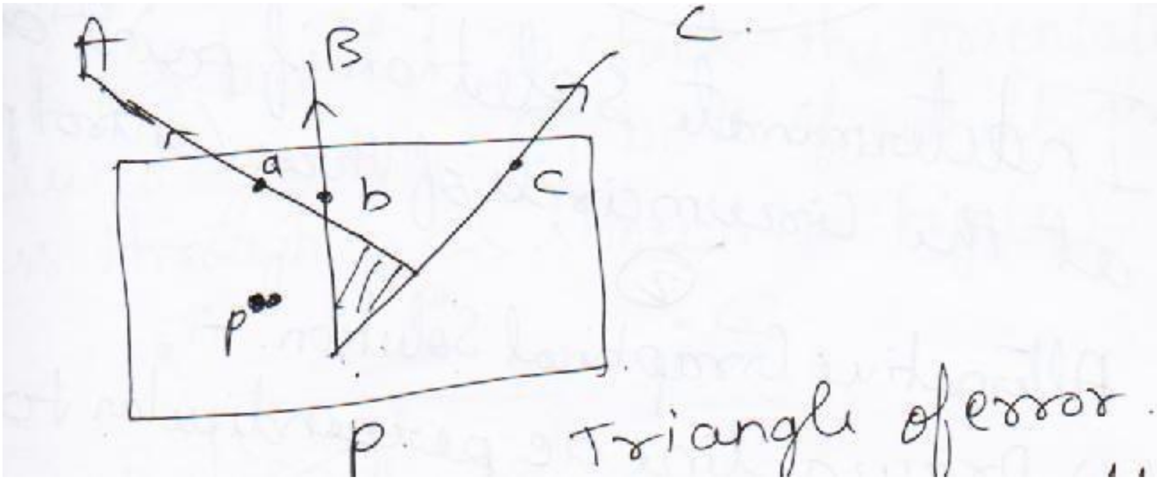
Lehmann's Rules :-

There are three rules to help in proper choice of the point p".

If the plane table is set up in the triangle formed by the three points (i.e. p lies within the triangle ABC) then the position of the instrument on the plan will be inside the triangle of error, if not it will be outside.
The point P" should be so chosen that its distance from the rays Aa, Bb and Cc is proportional to the distance of p from A, B and C respectively. Since the rotation of the table must have the same effect on each ray.
The point p" should be so chosen that it lies either to the right of all three rays or to the left of all three rays, since the table is rotated in one direction to locate P.

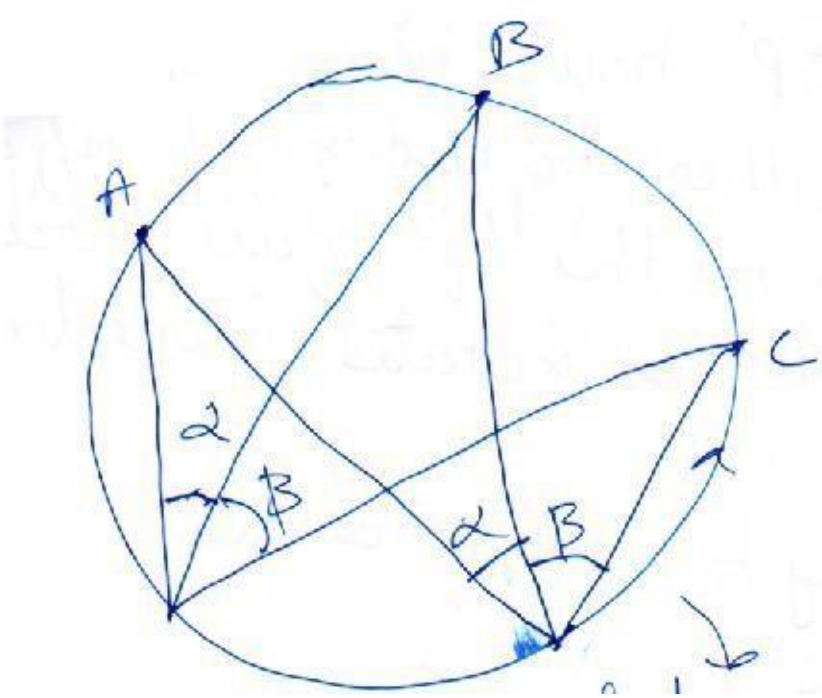
Referring to the figure below :

Then sight „B" with alidade at b and „C" with alidade at c. The rays will againform a triangle of error but



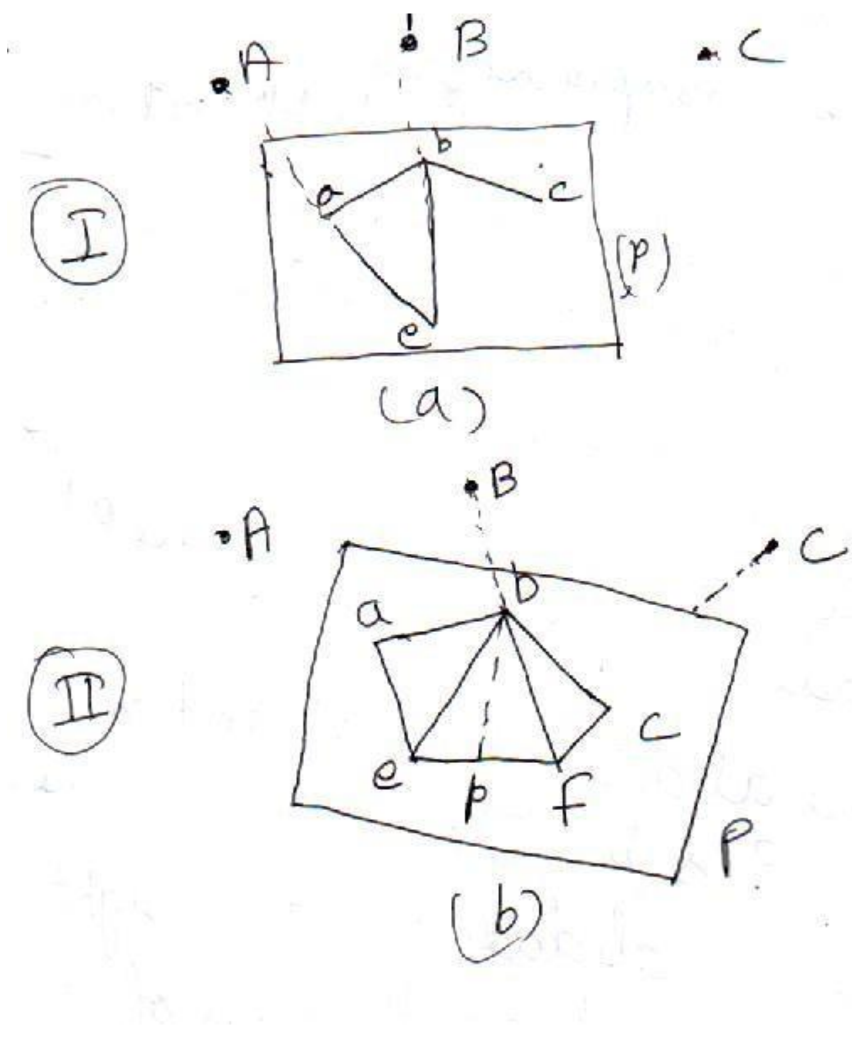
By rule 1 p is outside the small triangle as p is outside the triangle ABC.

By rule 2, using the proportions for the perpendiculars given by scaling thedistances PA, PB and PC, it must be in the left hand sector as shown.
By rule 3, it cannot be in either of the sectors contained by the rays PA, PBand PC.



Indeterminate solution if point occupied at the circum circle of the threecontrol points :-
Alternative Graphical Solution :-

Draw a line „ae‟ perpendicular to „ab‟ at „a‟. Keep the alidade a long „ea‟ and rotate the plane Table till „A‟ is bisected. Clamp the table with „b‟ as centre, directthe alidade to sight B and draw the ray be to cut „ae‟ in „e‟ Fig 28.1(a)
Similarly, draw „cf‟ perpendicular to „bc‟ at „c‟. Keep the alidade along „FC‟ and rotate the plane table till „c‟ is bisected clamp the table. With „b‟ as centre, direct the alidade to sight „B‟ and draw the ray „bf‟ to cut „cf‟ in F Fig 28.1(b)
Join „e‟ and „F‟. Using a set set square, draw „bp‟ perpendicular to „ef‟. Then „p‟ represents on the plane the position „p‟ of the table on the ground.
To orient the table, keep the alidade along „pb‟ rotate the plane table till „B‟ is bisected. To check the orientation draw rays aA, cC both of which should pass through „p‟ as shown in Fig. 28.1(c).



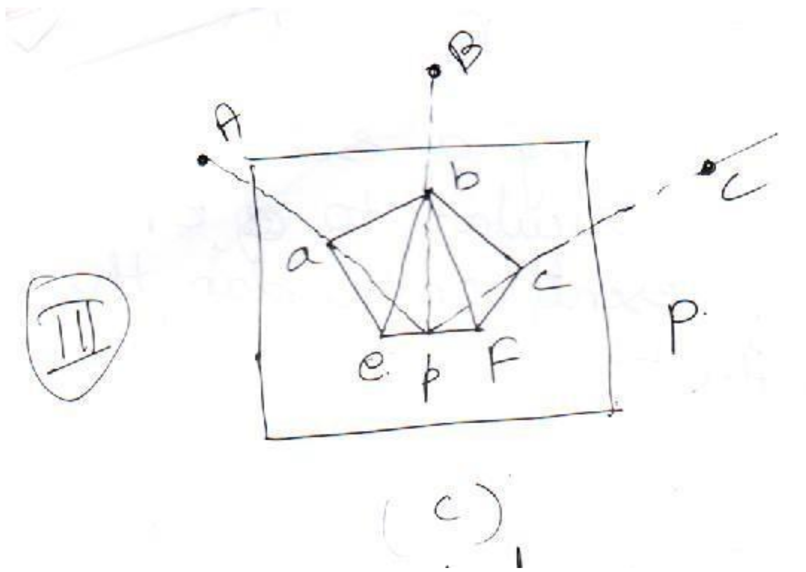


Fig. 28.1

Graphical Method :-

There are several graphical methods available, but the method given by Bessel is more suitable and is described first.

Bessel's Graphical Solution :-

After having set the table at station „P‟, keep the alidade on „ba‟ and rotate the table so that „A‟ is bisected. Clamp the table.

Pivoting the alidade about „b‟, sight to „C‟ and draw the ray „xy‟ along the edge of the alidade. [Fig28.2(a)]
Keep the alidade along „ab‟ and rotate the table till „B‟ is bisected clamp the table.
Pivoting the alidade about „a‟, sight to „C‟. Draw the ray along the edge of the alidade to interest the ray „xy‟ in „cf‟. [Fig 28.2 (b)] Join cc‟.
Keep the alidade along c‟c and rotate the table till „C‟ is bisected. Clamp the table.The table is correctly oriented [Fig 28.2(c)].
Pivoting the alidade about „b‟, sight to „B‟. Draw the ray to intersect cc‟ in „p‟. Similarly, if alidade is pivoted about „a‟ and „A‟ is sighted, the ray will pass through „p‟ if the work inaccurate.

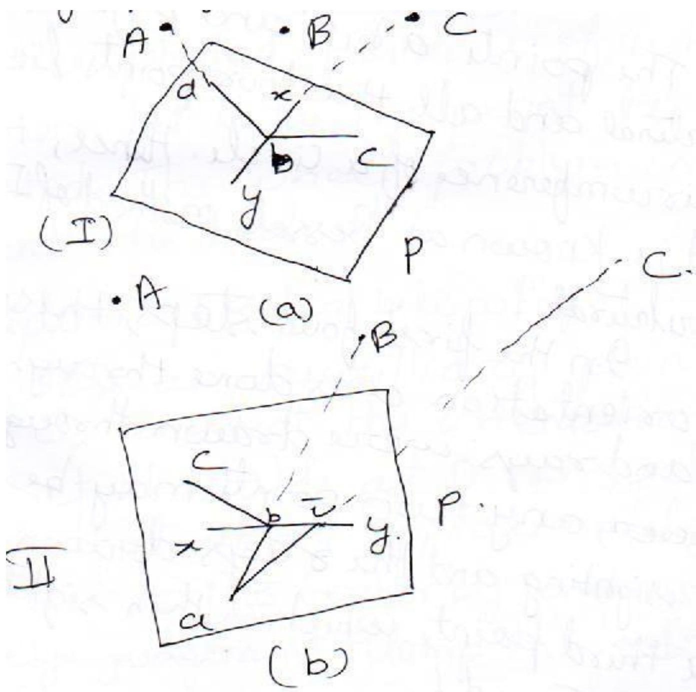


Fig 28.2

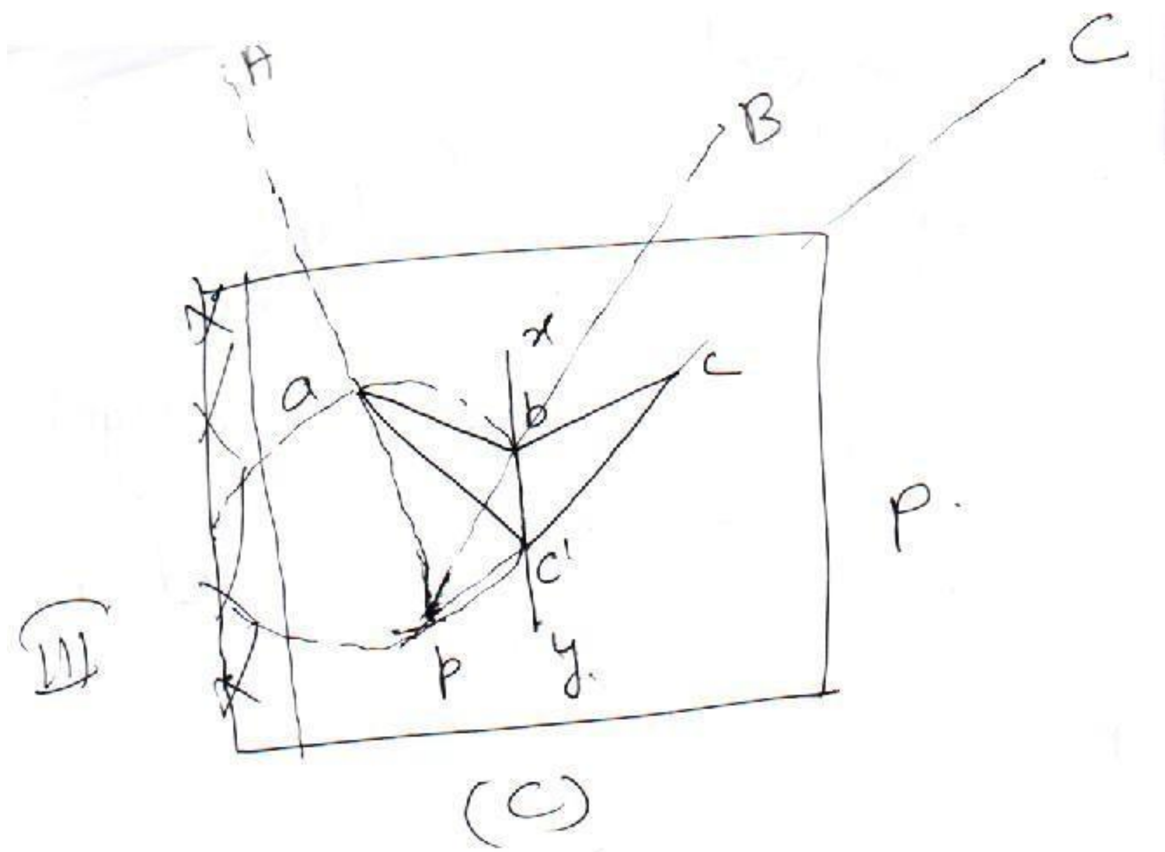


Fig 28.2

The points a, b, c‟ and „p‟ form a quadrilateral and all the four points lie along the circumference of a circle. Hence, this method is known as “Bessel‟s method of InscribedQuadrilateral”.

In the first four steps, the sightings for orientation was done through „a‟ and „b‟ and rays were drawn, through „c‟. However, any two points may be used for sighting and the rays drawn towards the third point, which is then sighted in steps 5 and 6.

Two Point Problem: -Statement :-

“Location of the position on the plan of the station occupied by the plane table by means of observation to two well defined points whose positions have been previously plotted on the plan.”

Let us take two points „A‟ and „B‟, the plotted positions of which are known.
Let „C‟ be the point to be plotted. The whole problem is to orient the table at „C‟.

Procedure : (Refer below Fig 29.)

Choose an auxiliary point „D‟ near „C‟, to assist the orientation at „C‟. set the tableat „D‟ in such a way that „ab‟ is approximately parallel to „AB‟ (either by compassor by eye judgment) clamp the table. Keep the alidade at „a‟ and sight „A‟. Draw the resectors. Similarly draw a resectorsfrom „b‟ and „B‟ to intersect the previous one in „d‟. The position of „d‟ is thus got,the degree of accuracy of which depends upon the approximation that has been made in keeping „ab‟ parallel to „AB‟. Transfer the point„d‟ to the ground and drive apeg.

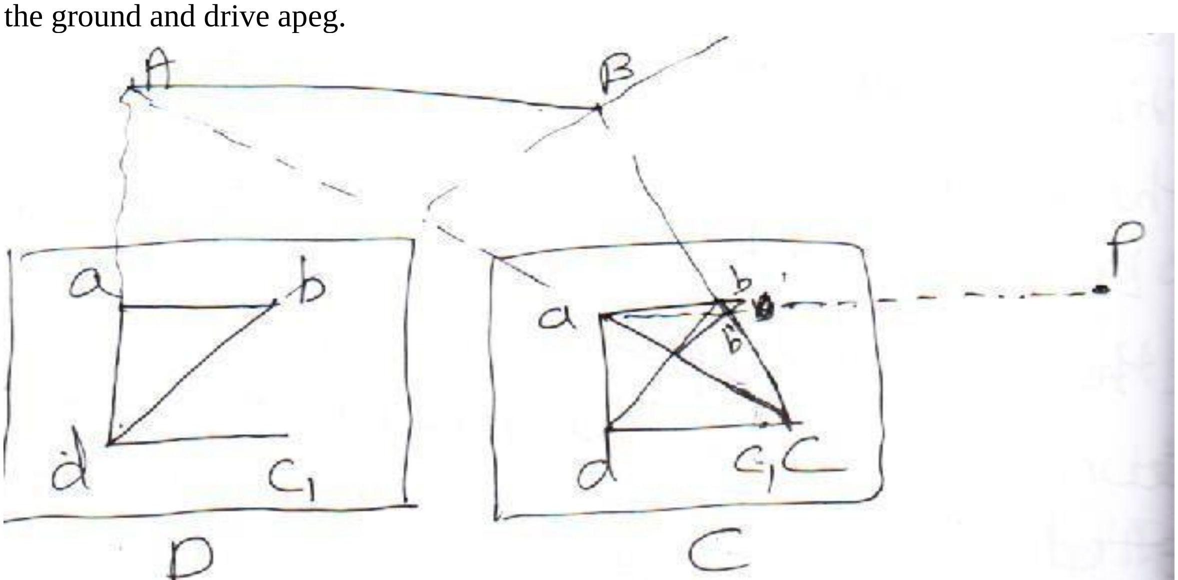


Fig 29 Two point problem

Keep the alidade at „d‟ and sight „C‟. Draw the ray. Mark a point c_1 on the ray by estimation to represent the distance „DC‟.
Shift the table to C, orient it (tentatively) by taking backside to „D‟ and centre it with reference to c_1. The orientation is, thus the same as it was at „D‟.
Keep the alidade pivoted at „a‟ and sight it to „A‟. Draw the ray to interest with thepreviously drawn ray from „D‟ in „c‟. thus, „c‟ is the point representing the station C_1 with reference to the approximate orientation made at „D‟.
Pivoting the alidade about „c‟, sight „B‟. Draw the ray to intersect with the raydrawn from „D‟ to „B‟ in b‟. Thus b‟ is the approximate representation of „B‟ with respect to the orientation made at „D‟.
The angle between ab and ab‟ is the error in orientation and must be corrected for. So that „ab‟ and ab‟ may coincide (or may become parallel) keep a pole „P‟ in linewith ab‟ and at a great distance. Keeping the alidade along „ab‟, rotate the table till
„P‟ is bisected. Clamp the table. The table is thus correctly oriented.
After having oriented the table as above, draw a resectors from „a‟ to „A‟ and another from „b‟ to „B‟, the intersection of which will give the position „C‟ occupied by the table.

It is to be noted here that unless the point „P‟ is chosen infinitely distant, „ab‟and ab‟ cannot be made parallel since the distance of „p‟ from „C‟ is limited due to otherconsiderations two-point problem does not give much accurate results. At the same time, more labour is involved because the table is also to be set on one more station to assist the orientation.
PLANE TABLE SURVEYING

Principle:-

The principle of plane tabling is parallelism, meaning that the rays drawn from stations to objects on the paper are parallel to the lines from the stations to the objects on the ground. The relative positions of the objects on the ground are representedby their plotted positions on the paper and lie on the respective rays. The table is always placed at each of the successive stations parallel to the position it occupied at the startingstation. Plane tabling is a graphical method of surveying there the field work and plotting are done simultaneously and such survey does not involve the use of a field book.

Plane table survey is mainly suitable for filling interior details when traversing is done by Theodelite sometimes traversing by plane table may also be done. But this survey is recommended for the work where great accuracy is not required. As the fitting and fixing arrangement of this instrument is not perfect, most accurate work cannot be expected.

Accessories of Plane Table:-

The Plane Table:-

The plane table is a drawing board of size 750 mm x 600 mm made of well seasoned wood like teak, pine etc. The top surface of the table is well leveled. The bottom surface consists of a threaded circular plate for fixing the table on the tripod stand by a wing nut.

The plane table is meant for fixing a drawing sheet over it. The positions of the objects are located on this sheet by drawing rays and plotting to any suitable scale.

The Alidade:-

There are two types of alidade.

- Plain
- Telescopic.

Plain Alidade:-

The plain alidade consists of a metal or wooden ruler of length about 50 cm. One of its edge is beveled and is known as the fiducially edge. It consists of two vanes at both ends which are hinged with the ruler. One is known as the „object vane" and carries a horse hair, the other is called the „sight vane" and is provided with a narrow slit.

Telescopic Alidade:-

The telescopic alidade consists of a telescope meant for inclined sight or sighting distant objects clearly. This alidade has no vanes at the ends, but is provided with fiducially edge. The function of the alidade is to sight objects. The rays should be drawn along the fiducially ends.

The Spirit Level:-

The spirit level is a small metal tube containing a small bubble of spirit. The bubble is visible on the top along a graduated glass tube. The spirit level is meant for leveling the plane table.

The Compass:-

There are two kinds of compass.

Trough compass and Circular box compass.

The Trough Compass:-

The trough compass is a rectangular box made of non-magnetic metal containing a magnetic needle pivoted at the centre. This compass consists of a „D" mark at both ends to locate the N-S direction

The Circular Box Compass:-

It carries a pivoted magnetic needle at the centre. The circular box is fitted on a square base plate sometimes two bubble tubes are fixed at right angles to each other on the base plate. The compass is meant for marking the north direction of themap.

U-fork or plumbing fork with plumb bob:-

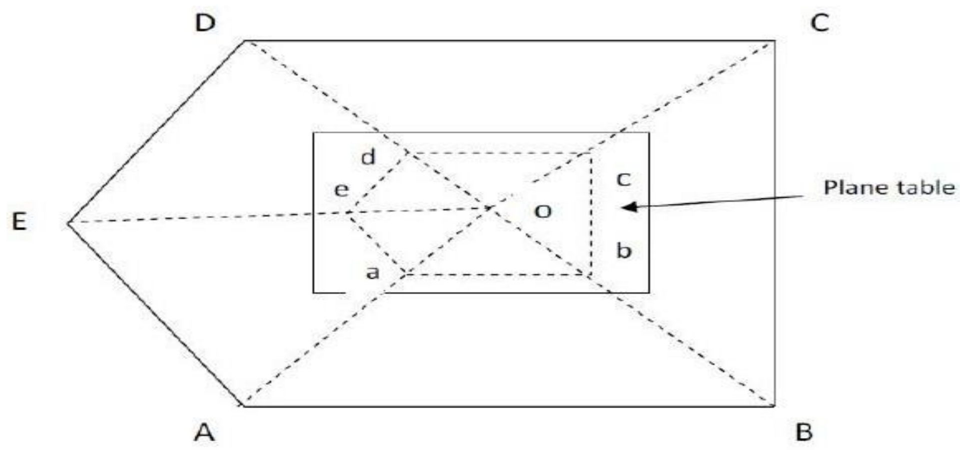
The U-fork is a metal strip bent in the shape of a „U" (hair pin) having equal arm lengths, the top arm is pointed and the bottom arm carried a hook for suspending a plumb bob. This is meant for centering the table over a station.

Methods of Plane Table Surveying

Four classes of plane tabling surveys arerecognized:

- Radiation method;
- Intersection method
- Traversing method
- ,Resection method
- Radiation Method

Here, the plane table is set up at one station which allows the other station to be accessed. The points to be plotted are then located by radiating rays from the plane table station to the points. After reducing the individual ground distances on the appropriate scale, the survey is then plotted. This method is suitable for small area surveys. It is rarely used to survey a complete project but is used in combination with other methods for filing in details within a chain length.



Plane Tabling using Radiation Method

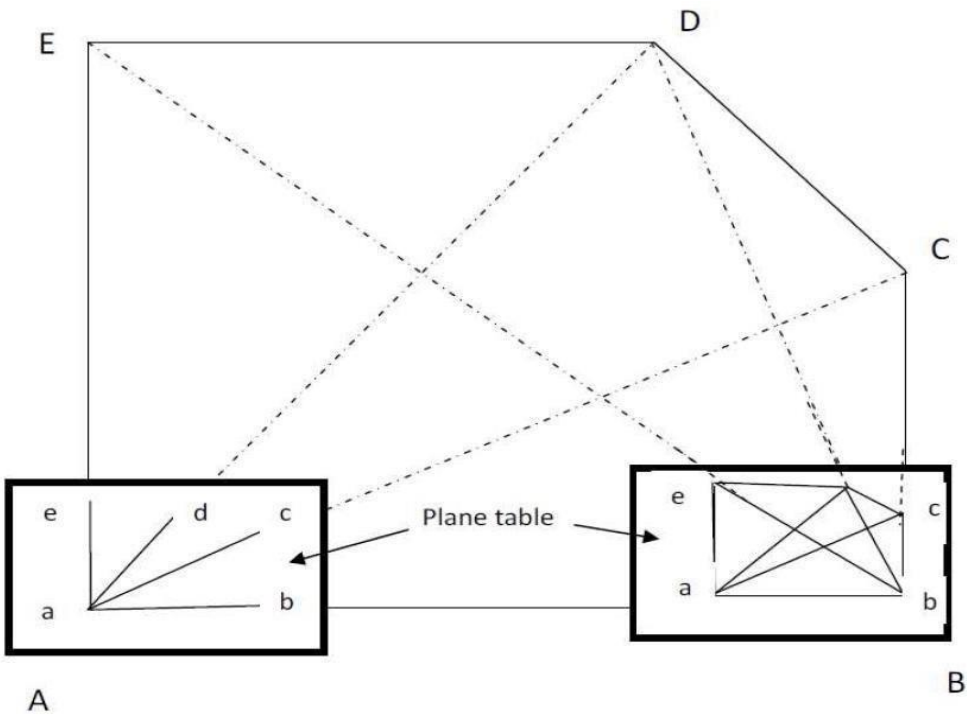
The following steps are taken:

- Select a point O such that all the points are visible Set up and level the instrument at O
- From O align the Alidade and draw radial lines towards. The stations A, B, C, D andE.
- Measure the distances OA, OB, OC, OD and OE: scale and draw Oa, Ob, Oc, Od andOe on the paper.
- Join the point a, b, c, d, and e to give the outline of the survey.

Intersection Method

In this method, two instrument stations are used with the distance between them called based line serving as the base to measure and plot the other locations:

- 2 points A and B are selected from which the rest of the stations can be seen.
- Set up and level the plane table at A and mark it as a in the paper to coincide with Aon the ground.
- Sight B, C, D and E with the Alidade from a and draw rays which forwards them.
- Measure AB, AC, AD and AE and using appropriate scale draw the correspondingpaper distance.
- Remove the equipment from A to B and repeat the procedure using B as the measuring station.



Plane Tabling using Intersection Method

Unit-4
CURVES

Curves are regular bends provided in the lines of communication like roads, railways and canals etc. to bring about gradual change of direction.

Curves are defined as arcs, with some finite radius, provided between intersecting straights to gradually negotiate a change in direction. This change in direction of the straights may be in a horizontal or vertical plane, resulting in the provision of a horizontal or vertical curve respectively. Curves are generally used on highways and railways where it is necessary to change the direction of motion. A curve may be circular, parabolic or spiral and is always tangential to the two straights

CLASSIFICATION

1. Horizontal curves – intersecting straights are in horizontal plane
2. Vertical curves - intersecting straights are in vertical plane. These curves are of two types i.e., summit curves and sag / valley curves

Horizontal curves:

Horizontal curves are further classified as:

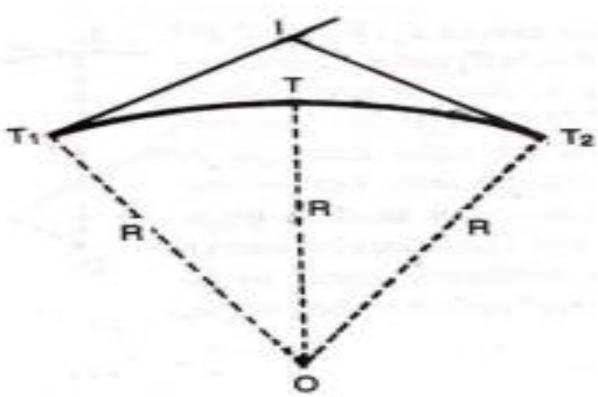
a) Circular curves
b) Non-circular curves – transition curves

Types of Circular Curves:

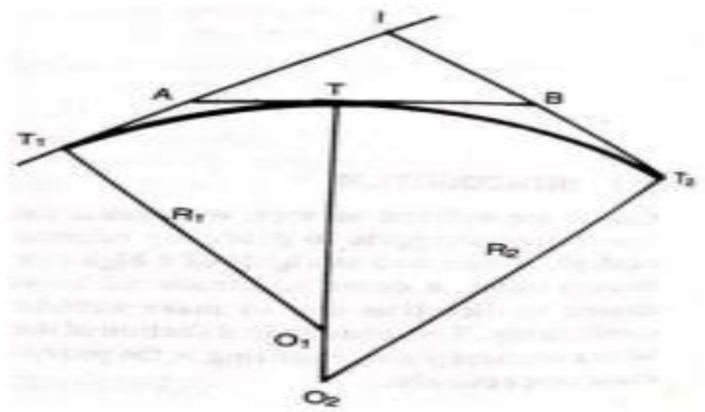
Circular curves are divided into three types:

I. Simple Circular Curve
II. Compound Curve
III. Reverse Curve

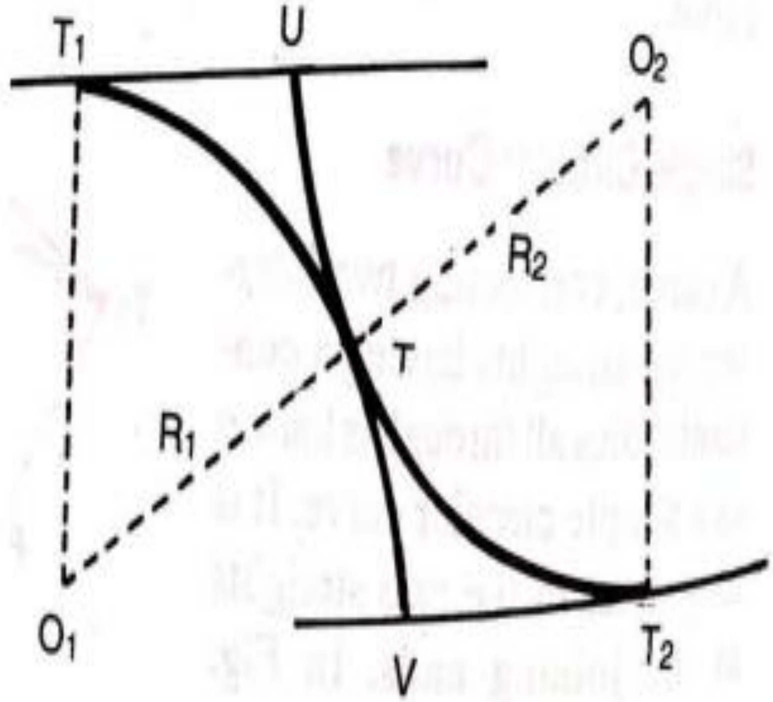
Simple Circular Curve: A curve which consists of a single arc of a circle connecting two straights is called simple circular curve.



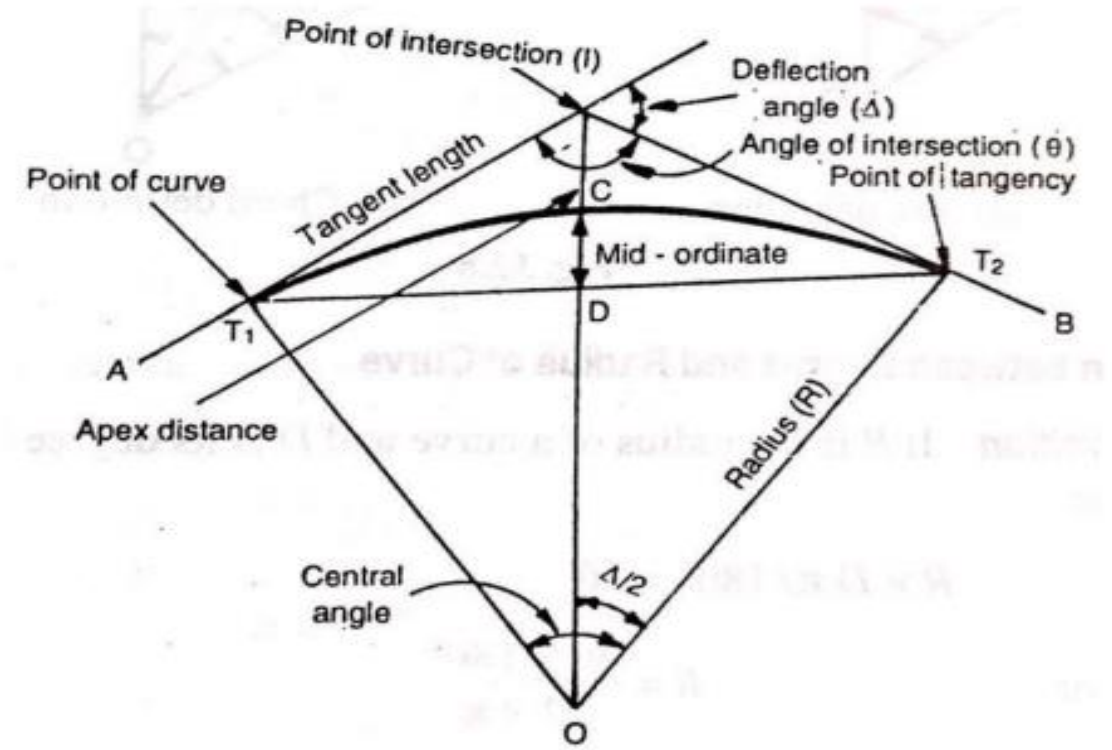
Compound Curve: A curve which consists of two or more arcs of different radii deflecting in the same direction and lying on the same side of common tangent is known as compound curve



Reverse Curve: A curve which consists of two circular arcs of same or different radii, having their centres on the opposite sides of common tangent is known as reverse curve These curves are quite common in railway yards, but are unsuitable for modern highways. These are also known as serpentine curve or S-curve because of their shape



Elements/ Component Parts of a Simple Circular Curve:



1. **Back Tangent:** The tangent previous to the curve is known as back tangent or first tangent.

2. **Forward Tangent:** The tangent following the curve is known as forward tangent or second tangent.

3. **Point of Intersection (P.I):** The point at which the two tangents intersect is called the point of intersection.

4. **Point of Curve (P.C):** The point at which the curve changes its alignment from straight to a curve is called as point of curve. It is the beginning of the curve.

5. **Point of Tangency (P.T):** The point at which the curve changes its alignment from curve to a straight is called as point of tangency. It is the end of the curve

6. . **Intersection Angle (ϕ):** The interior angle between the two tangents is called intersection angle.

7. **Deflection Angle (Δ):** The exterior angle between the two tangents is called deflection angle.

8. **Tangent Length/Distance (T):** The distance between point of curve/point of tangency and the point of intersection is called tangent distance/length.

9. **External Distance (E):** The distance between mid-point of the curve and point of intersection is called external distance.

10. **Length of the Curve (l):** The curved distance between point of curve and point of tangency is called length of curve.

11. **Long Chord (L):** The straight distance between point of curve and point of tangency is called long chord

12. **Mid-Ordinate (M):** The vertical distance between mid-point of curve and mid-point of long chord is known as mid-ordinate.

13. **Normal Chord (c):** The horizontal distance between two successive regular stations on the curve is called normal chord.

14. **Sub-Chord (c'):** Any chord shorter than the normal chord is called sub-chord.

15. **Right Handed Curve:** If the curve deflects to the right hand side of the progress of the survey work, then it is called a right handed curve.

16. **Left Handed Curve:** If the curve deflects to the left hand side of the progress of the survey work, then it is called a left handed curve.
    .

Tachometric Surveying

It is a method of angular surveying in which the horizontal distance from the instrument to the staff stations and the elevations of the staff stations concerning the line of collimation of the instrument are determined from instrumental observations only

Thus the chaining operations are eliminated. Field Work can be completed very rapidly Tachometry is mainly used for preparing the contour plans of areas

Methods of Tachometric Survey

Various methods of tachometry survey are based on the principle that the horizontal distance between an instrument Station "A" and a staff station "B" and the elevation of point "B" with reference to the line of sight of the instrument at point "A" depend on the angle subtended at point "A" by a known distance at point "B" and the vertical angle from point "B" to point "A" respectively.

This principle is used in different methods in different ways. Mainly there are two methods of tachometry survey

- Stadia system, and
- Tangential system
- Stadia System of Tachometry;

In the stadia system, the horizontal distance to the staff Station from the instrument station and the elevation of the staff station concerning the line of sightof the instrument is obtained with only one observation from the instrument Station

In the stadia method, there are mainly two systems of surveying.

(1) fixed hair method and,

(2) Movable hair method.

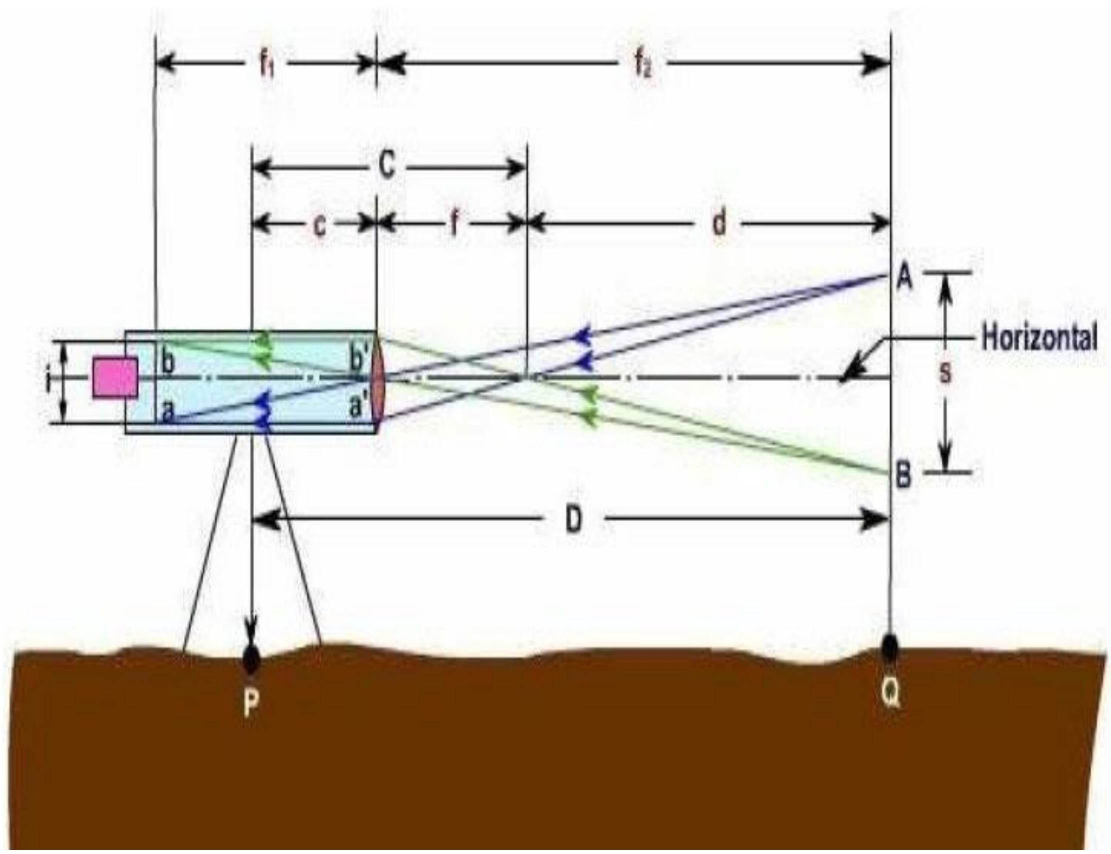
(i) Fixed Hair Method:

In the fixed hair method of tachometric surveying, the instrument employed for taking observations consist of a telescope fitted with two additional horizontal cross hairs one above and the other below the central hair. These are placed equidistant from the central hair and are called stadia hairs

When a staff is viewed through the telescope, the stadia hairs are seen to intercept a certain length of the staff and this varies directly with the distance between the instrument and the stations.

As the distance between the stadia hair is fixed, this method is called the “fixed hair method

Problems on Tachometric leveling and curves

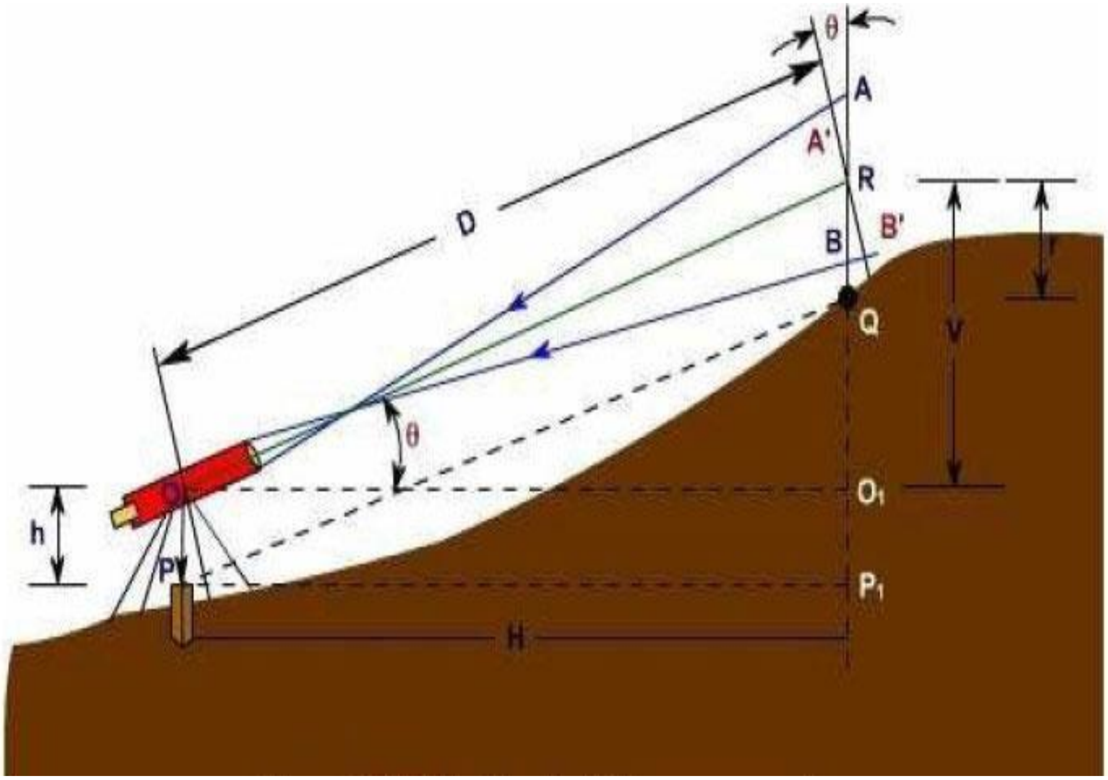


ii) **Movable Hair Method**

In the movable Hair method of tachometric surveying, the instrument used for taking observations consist of a telescope fitted with stadia hairs which can be moved and fixed at any distance from the central hair (within the limits of the diaphragm).

The staff used with this instrument consists of two targets (marks) at a fixed distance apart (say 3.4 mm).

The Stadia interval which is variable for the different positions of the staff is measured, and the horizontal distance from the instrument station to the staff station is computed



UNIT-5
MODERN SURVEYING

ADVANCED SURVEYING

By the 1970's, relatively small, lightweight and easy-to-use electronic distance measuring devices, called EDM's were in use.

The advance of technology and miniaturization of electronic components enabled the building of theodolites that measure angles electronically, called Electronic Theodolite
Combination of an electronic theodolite and electronic distance meter, and software running on an external laptop computer known as a data collector, called Total Station

The Global Positioning System (GPS) was designed for military applications. Its primary purpose was to allow soldiers to keep track of their position and to assist in guiding weapons to their targets
a computerized data base management system for capture, storage, retrieval, analysis, and display of spatial data, called GIS.

MODERN SURVEYING EQUIPMENTS

- Electronic Theodolite
- EDM – Electronic distance measurement eqp.
- Auto Level.
- Digital Level.
- Laser Level.
- Laser Distance meter
- Total station.
- GPS – global positioning system.

ELECTRONIC THEODOLITE

- For precise surveys the vernier theodolites are replaced by modern theodolites such as optical and electronic theodolites.
- The electronic theodolites have optical system to scan both horizontal and vertical circles and display them digitally on a screen
- Electronic Distance meter
- EDM is Electronic Distance meter
- Measurement of distance is done by a modulated microwave or infrared carrier signal
- The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency

DIGITAL LEVEL

- They are not popular instead auto levels are more extensively used.
- The Trimble DiNi Digital Level : Determine accurate height information 60% faster than with automatic leveling
- Eliminate errors and reduce rework with
- digital readings
- Transfer data to the office easily
- Measure to a field of just 30 cm

LASER LEVEL

- The word ***laser*** is an acronym for Light Amplification by Stimulated Emission of Radiation and is the name applied to an intense beam of highly monochromatic, coherent light.
- Laser rangefinders use these relationships to calculate Distance

Distance = speed of light * (time/2)

The time refers to time of pulse to go from the instrument to the tree and back again

EDM+ THEODOLITE

- EDM is used to measure the horizontal distances.
- Some EDM are attached with electronics theodolite which has the adapter system.
- Some are advanced models which itself reads the distance without theodolite

TOTAL STATION

A **Total station** integrates the functions of a **Electronic theodolite** for measuring angles, an **EDM** for measuring distances, digital data and a data recorder

Angles and distances, coordinates and height differences and many other items can be computed, displayed and stored into internal memory.

Functions of total station

- **Angle measurement**

Most total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc-second. Inexpensive "construction grade" total stations can generally measure angles to 5 or 10 arc-seconds.

- **Distance measurement**

Main article: Distance measurement

Measurement of distance is accomplished with a modulated infrared carrier signal, generated by a small solid-state emitter within the instrument's optical path, and reflected by a prism reflector or the object under survey. The modulation pattern in the returning signal is read and interpreted by the computer in the total station. The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency. Most total stations use purpose-built glass prism (surveying) reflectors for the EDM signal. A typical total station can measure distances up to 1,500 meters (4,900 ft) with an accuracy of about 1.5 millimeters (0.059 in) ± 2 parts per million.[2]

Reflectorless total stations can measure distances to any object that is reasonably light in color, up to a few hundred meters.

- **Coordinate measurement**

The coordinates of an unknown point relative to a known coordinate can be determined using the total station as long as a direct line of sight can be established between the two points. Angles and distances are measured from the total station to points under survey, and the coordinates (X, Y, and Z; or easting, northing, and elevation) of surveyed points relative to the total station position are calculated using trigonometry and triangulation.

To determine an absolute location, a total station requires line of sight observations and can be set up over a known point or with line of sight to 2 or more points with known location, called free stationing.[3][4]

For this reason, some total stations also have a Global Navigation Satellite System receiver and do not require a direct line of sight to determine coordinates. However, GNSS measurements may require longer occupation periods and offer relatively poor accuracy in the vertical axis.[3]

- **Data processing**

Some models include internal electronic data storage to record distance, horizontal angle, and vertical angle measured, while other models are equipped to write these measurements to an external data collector, such as a hand-held computer.

When data is downloaded from a total station onto a computer, application software can be used to compute results and generate a map of the surveyed area. The newest generation of total stations can also show the map on the touch-screen of the instrument immediately after measuring the points.

Applications of to Total Station

Total stations are mainly used by land surveyors and civil engineers, either to record features as in topographic surveying or to set out features (such as roads, houses or boundaries). They are also used by archaeologists to record excavations and by police, crime scene investigators, private accident reconstructionists and insurance companies to take measurements of scenes.

- **Mining**

Total stations are the primary survey instrument used in mining surveying.

A total station is used to record the absolute location of the tunnel walls, ceilings (backs), and floors as the drifts of an underground mine are driven. The recorded data are then downloaded into a CAD program, and compared to the designed layout of the tunnel.

The survey party installs control stations at regular intervals. These are small steel plugs installed in pairs in holes drilled into walls or the back. For wall stations, two plugs are installed in opposite walls, forming a line perpendicular to the drift. For back stations, two plugs are installed in the back, forming a line parallel to the drift.

A set of plugs can be used to locate the total station set up in a drift or tunnel by processing measurements to the plugs by intersection and resection.

- **Mechanical and electrical construction**

Total stations have become the highest standard for most forms of construction layout.

They are most often used in the X and Y axis to lay out the locations of penetrations out of the underground utilities into the foundation, between floors of a structure, as well as roofing penetrations.

Because more commercial and industrial construction jobs have become centered around building information modeling (BIM), the coordinates for almost every pipe, conduit, duct and hanger support are available with digital precision. The application of communicating a virtual model to a tangible construction potentially eliminates labor costs related to moving poorly measured systems, as well as time spent laying out these systems in the midst of a full blown construction job in progress

- **Meteorology**

Meteorologists also use total stations to track weather balloons for determining upper-level winds. With the average ascent rate of the weather balloon known or assumed, the change in azimuth and elevation readings provided by the total station as it tracks the weather balloon over time are used to compute the wind speed and direction at different altitudes. Additionally, the total station is used to track ceiling balloons to determine the height of cloud layers. Such upper-level wind data is often used for aviation weather forecasting and rocket launches.

Photogrammetry

Photogrammetry or photographic surveying is a method of surveying in which plans or maps are prepared from photographs taken from suitable camera stations

Two Types

1. Terrestrial or ground photogrammetry
2. Aerial photogrammetry

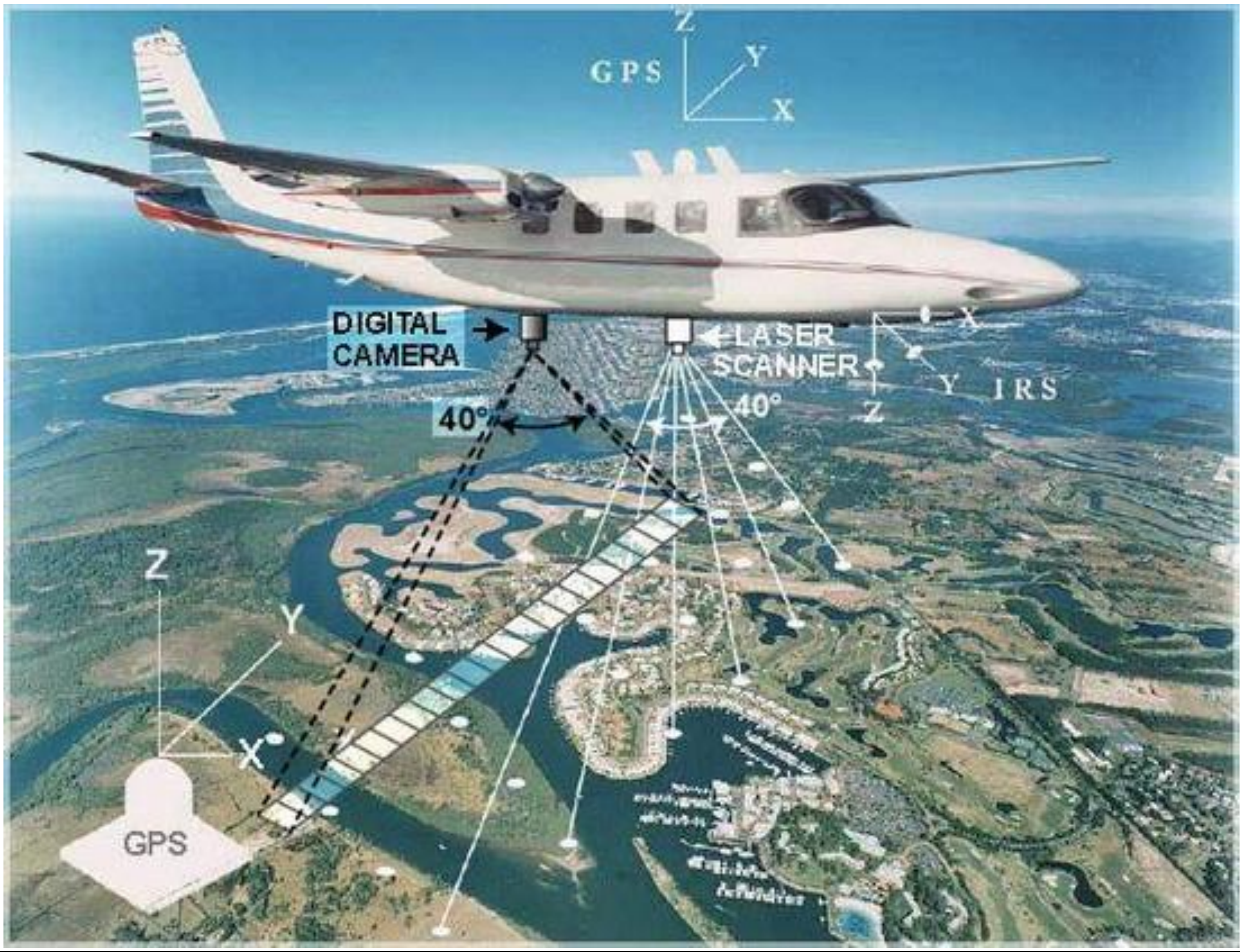
Terrestrial Photogrammetry:

Maps are prepared from photographs taken from some fixed positions on or near the ground with camera axis horizontal

Used for-

- Small scale mapping of open hilly or mountainous countries
- Reproduction of plan and elevation views of buildings and structures
- Motion picture photography
- For furnishing supplementary ground control for aerial photography

Aerial Photogrammetry



Maps are prepared from photographs taken by a precision camera mounted in an aircraft flying over the area with camera axis vertical.

Used for-

- country's reconnaissance and preliminary surveys
- Survey of rivers, roads and railways
- Survey of inaccessible regions like deserts and wooded countries
- Survey of power schemes and transmission lines
- Acquisition of land
- Town and village planning
- Flood control, irrigation, drainage and soil conservation
- Harbors, navigation channels and coastal defense
- Mining prospects
- Study of geology
- Soil and agricultural studies

Military installations, camping and forbidden zones

DEFINATIONS

Static Photographs: photographs of still or static objects; such as building

Quasi- Static Photographs: A series of photographs taken in fairly rapid sequence in order to picture the positions of a slow moving object at various circumstances;
such as movement of ships near a port or traffic flow after a regular interval of time

Dynamic Photographs: Photographs of an object which changes its size, shape and position or orientation from one instant to another
Taken by motion picture camera

Eccentric camera station: when it is not possible to get a greater photo coverage from the main camera station the photo theodolite is placed over a position eccentric to the main camera station

Side camera station: neither the main nor the eccentric camera station is found suitable to obtain a greater photo coverage, the photographs are taken with the photo theodolite centered over a point remote from the primary or eccentric camera station

Vertical Photograph: It is an aerial photograph taken with the camera or optical axis coinciding with the direction of gravity

Tilted photograph: It is an aerial photograph taken with the camera or optical axis unintentionally tilted from the vertical by a small amount, usually less than 3 degree

Oblique Photograph: It is an aerial photograph taken with the camera or optical axis intentionally tilted by about 30 degree to the forward direction

Exposure station: It is a point in space, in the air, occupied by the camera lens at the instant of exposure

Flying height or flight altitude: It is the elevation of the exposure station above the mean sea level or any other selected datum

Stereoscopy : If two overlapping aerial photographs containing the same objects, taken from different positions, are viewed through a stereoscope, the corresponding objects will fuse and the terrain will appear in three dimensions.