LECTURE NOTES

ON

SURVEYING AND GEOMATICS

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SYLLABUS

MODULE – I

INTRODUCTION TO SURVEYING

Principles, Linear, angular and graphical methods, Survey stations, Survey lines ranging, bearing of survey lines, levelling: Plane table surveying, Principles of levelling booking and reducing levels; differential, reciprocal levelling, profile levelling and cross sectioning. Digital and Auto Level, Errors in levelling; contouring: Characteristics, methods, uses; areas and volumes. Triangulation and Trilateration Theodolite survey: Instruments, Measurement of horizontal and vertical angle; Horizontal and vertical control methods, triangulation network signals. Baseline choices instruments and accessories extension of base lines corrections Satellite station reduction to centre, Inter visibility of height and distances, Trigonometric levelling, Axis single corrections.

MODULE- II

CURVES

Elements of simple and compound curves, Method of setting out, Elements of Reverse curve, Transition curve, length of curve, Elements of transition curve, Vertical curves.

MODULE- III

MODERN FIELD SURVEY SYSTEMS

Principle of Electronic Distance Measurement, Modulation, Types of EDM instruments, Distomat, Total Station, Parts of a Total Station, Accessories, Advantages and Applications, Field Procedure for total station survey, Errors in Total Station Survey.

Global Positioning Systems (GPS), Segments, GPS measurements, errors and biases, Surveying with GPS, Co-ordinate transformation, accuracy considerations.

MODULE- IV

PHOTOGRAMMETRIC SURVEYING

Introduction, Basic concepts, perspective geometry of aerial photograph, relief and tilt displacements, terrestrial photogrammetry, flight planning; Stereoscopy, ground control extension for photographic mapping aerial triangulation, radial triangulation, methods; photographic mapping, mapping using paper prints, mapping using stereo plotting instruments, mosaics, map substitutes

MODULE– V

REMOTE SENSING

Introduction, Electromagnetic Spectrum, interaction of electromagnetic radiation with the atmosphere and earth surface, remote sensing data acquisition: platforms and sensors; visual image interpretation; digital image processing.

Text Books:

1. Madhu, N, Sathikumar, R and Satheesh Gobi, "Advanced Surveying: Total Station, GIS and Remote Sensing", Pearson India, 2nd Edition, 2006.
2. Manoj, K. Arora and Badjatia, "Geomatics Engineering", Nem Chand & Bros, 2011.
3. Bhavikatti, S.S., "Surveying and Levelling", I.K. International, Vol. I and II, 2010.

Reference Books:

1. Chandra, A.M., "Higher Surveying", New Age International (P) Limited, 3rd Edition, 2002.
2. Anji Reddy, M., "Remote sensing and Geographical information system", B. S. Publications, 2001
3. Arora, K.R., "Surveying", Standard Book House, Vol-I, II and III, 2015.

MODULE-1
INTRODUCTION TO SURVEYING

General:
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:
The type of surveying where the mean surface of the earth is considered as a planeAll angles are considered to be plane angles. For small areas less than 250 km2 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 196km2

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

Introduction
For easy understanding of surveying and the various components of the subject, we need a deep understanding of the various ways of classifying it.

Objective
To enable the students have understanding of the various ways of classifying surveying

Classification of Surveying
Surveying is classified based on various criteria including the instruments used, purpose, the area surveyed and the method used.
Classification on the Basis of Instruments Used.
Based on the instrument used; surveys can be classified into;
- i) Chain tape surveys
- ii) Compass surveys
- iii) Plane table surveys
- iv) Theodolite surveys

Classification based on the surface and the area surveyed
Land surveying
Land surveys are done for objects on the surface of the earth. It can be subdivided into:
(a) Topographic survey:
This is for depicting the (hills, valleys, mountains, rivers, etc) and manmade features(roads, houses, settlements…) on the surface of the earth.
(b) Cadastral survey
It is used to determining property boundaries including those of fields, houses, plots land,etc.
(c) 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.

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.

Marine or Hydrographic Survey:
Those are surveys of large water bodies for navigation, tidal monitoring, the construction of harbored.

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
i) Engineering survey
ii) Control Survey:
Control survey uses geodetic methods to establish widely spaced vertical and horizontal control points.
iii) Geological Survey

Geological survey is used to determine the structure and arrangement of rock strata. Generally, it enables to know the composition of the earth.

iv) Military or Defense Survey

It is carried out to map places of military and strategic importance

v) Archeological survey is carried out to discover and map ancient/relies of antiquity.

Classification Based On Instrument Used

i. Chain/Tape Survey:

This is the simple method of taking the linear measurement using a chain or tape with angularmeasurements made.

ii. Compass Survey:

Here horizontal angular measurements are made using magnetic compass with thelinear measurements made using the chain or tape.

iii. Plane table survey:

This is a quick survey carried out in the field with the measurements and drawings made at the same time using a plane table.

iv. 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 conventionalsymbols.

v. Theodolite Survey:

Theodolite survey takes vertical and horizontal angles in order to establish controls

CLASSIFICATION BASED ON THE METHOD USED

i. Triangulation Survey:

In order to make the survey, manageable, the area to be surveyed is first covered with series of triangles. Lines arefirst run round the perimeter of the plot, then the detailsfixed 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 shaped area with minimum space left.

ii. 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 traverseA 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.

1. 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.

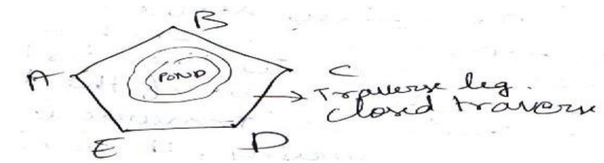


Fig 1: Closed traverse is suitable for the survey of boundaries of ponds,forests etc.

2. **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.

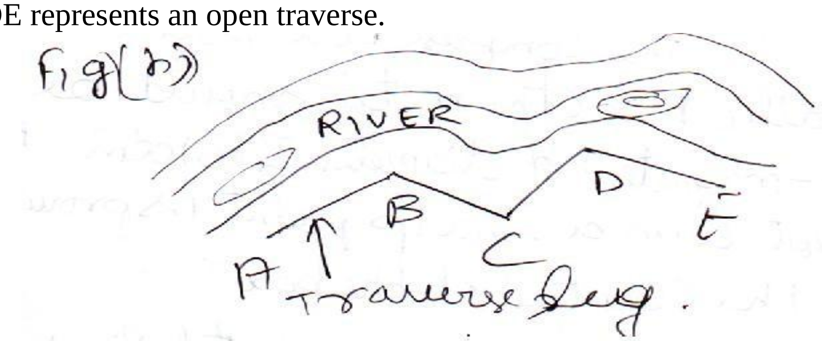


Fig 2: Open traverse is suitable for the survey of boundaries of ponds,forests etc.

CLASSIFICATION OF SURVEYORS

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

1. **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.

2. **Planning and Development Surveyors**
   - They are concerned with preparing planning applications and negotiating with local authorities' planners to obtain planning permission.

3. **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's discipline.
   - The Quantity SurveyorsThey evaluates project cost and advice on alternative proposals. They also measure that each element of a project agrees with the cost plan allowance and that the overall project remains within budget

Fig 3:Building Surveyors

4. **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.

5. **Mineral Surveyors**
   - They plan the development and future of mineral workings. They work with local authorities and the land owners on planning applications and appeals, mining laws and working rights, mining subsidence and damage, the environmental effects of land and deep underground mines.

6. **Land surveyors:**

Fig 4:Land Surveying Instrument

   - 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.

BRANCHES OF SURVEYING

1. **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.

Fig 5:AerialSurveyors

2. 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**.**

Fig 6: Hydrographic survey

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.

Fig 7: Hydrographic surveys

3. 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.

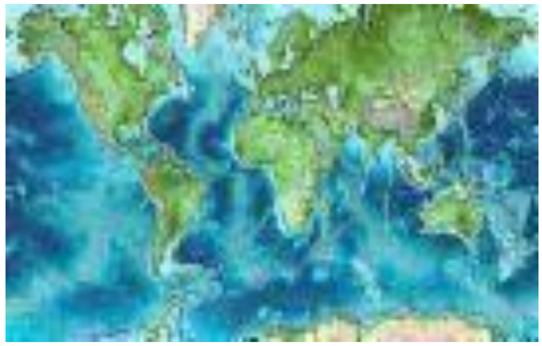


Fig 8: Geodetic survey

4. 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

5. 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 take topographical features.

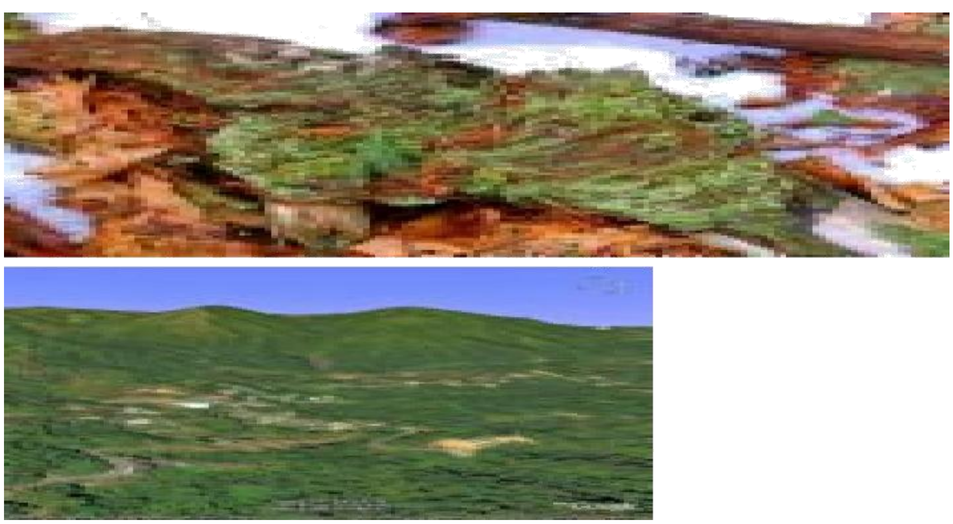


Fig 9 Cadastral Surveying

6. 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.

7. Engineering Survey

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

Fig 10: Engineering Survey

8. Reconnaissance:

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

- Reconnaissance is made on arrival to site during which an overall picture or view of 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

1. To ascertain the possibility of building or constructing route or track through the area.
2. To choose the best one or more routes and record on amp
3. To estimate probable cost and draft airport.

Introduction

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.

(a) 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.

(b) 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.

i) Using points A and B as the centers ascribe arcs and fix (where they intersect).
ii) Draw a perpendicular from D along AB to a point C.
iii) To locate C, measure distance AB and use your protractor to equally

measure angle ABC.

iv) 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.

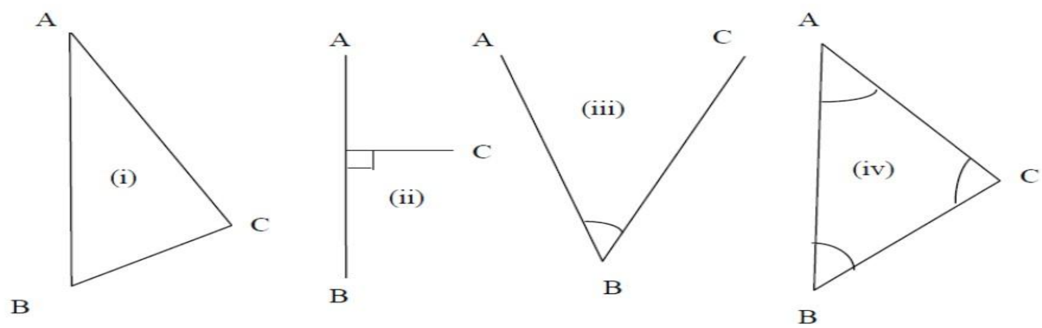


Fig. 11: Fixing the third points using two points

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

(a) Reconnaissance survey
This is a pre-field work and measurement phase. It requires taking an overall inspectionof 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.

(b) 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.

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

IMPORTANCE OF SCIENTIFIC HONESTY

- Honesty is essential in booking notes in the field and when plotting and computations in the office. There is nothing to be gained from cooking the survey or altering dimensions so that points will tie-in on the drawing. It is utterly unprofessional to betray such trust at each stage of the survey.
- This applies to the assistants equally as it does to the surveyor in charge. Assistants must also listen carefully to all instructions and carry them out to the later without questions.

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.

ACCURACY AND PRECISION

These terms are used frequently in engineering surveying both by manufacturers when quoting specifications for their equipment's and on site by surveyors to describe results obtained from field work.

- Accuracy allows a certain amount of tolerance (either plus or minus) in a measurement, while;
- Precision demands exact measurement. Since there is no such things as an absolutely exact measurement, a set of observations that are closely grouped together having small deviations from the sample mean will have a small standard error and are said to be precise.

Economy of accuracy and its influence on choice of equipment's

- Survey work is usually described as being to a certain standard of accuracy which in turn is suited to the work in hand. Bearing in mind the purpose for which the survey is being made, it is better to achieve a high degree of accuracy than to aim for precision (exactness) which if it were to be altered would depend not only on the instrument used but also on the care taken by the operator to ensure that his work was free from mistake.
- Always remember that, the greater the effort and time needed both in the field and in the office, the more expensive survey will be for the client. The standard accuracy attained in the field must be in keeping with the size of the ultimate drawings.
- The equipment selected should be appropriate to the test in hand. An important factor when selecting equipment is that the various instruments should produce roughly the same order of precision. A steel chain best at an accuracy of 1/500 to 1/1000 would be of little use for work requiring an accuracy of 1/1000. Similarly, the Theodolite reading to one second would be pointless where a reading to one minute insufficient.
- Having selected the equipment necessary, the work should be thoroughly checked and if found wanting should be adjusted, repaired or replaced or have allowance calculated for its deficiencies. This task will be less tedious if field equipment is regularly maintained.

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 themeasurement 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): -
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

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

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.

Fig 12: Measuring chain

Chains are made up of links which measure 200mmfrom 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 measurement namely:

(i) Engineers chain
(ii) 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;

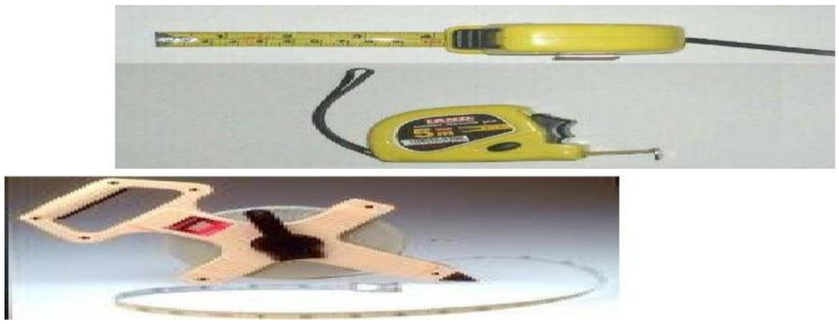


Fig 13: Measuring tapses

i. **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.

ii. **Fibre Glass Tapes:**
   These are much stronger than lines and will not stretch inuse.

iii. **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:

Fig 14: Arrow

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 lineswith the tape, and for marking any points which need to be 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 andthe 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 the main 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 AbneyLevel.

AbneyLevel

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 surveying instruments

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

General procedure in making a chain survey

1. Reconnaissance: Walk over the area to be surveyed and note the general layout, the position of features and the shape of the area.
2. Choice of Stations: Decide upon the framework to be used and drive in the station pegs to mark the stations selected.
3. 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 roads or hard surfaces.
4. 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 by others after a long interval.
5. Offsetting:-Offsets are usually taken perpendicular to chain lines in order to dodge obstacles on the chain line.
6. 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 mind as the criteria to provide the best arrangement of survey lines,

a. **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.
b. **Long base line:** A long line should be positioned right across the site to form a base on which to build the triangles.
c. **Well conditioned triangle with angles greater than 30^{o} and not exceeding 150^{o}:** It is preferable that the arcs used for plotting should intersect as close as 90^{o} in order to provide sharp definition of the stations point.
d. **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.
e. Obstacles such as steep slopes and rough ground should be avoided as far as possible.
f. **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.
g. Stations should be positioned on the extension of a check line or triangle. Such points 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

1. **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 areusing.
- 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 with a chain or a tape where such accuracy is required.

(i) Pull correction,
(ii) Temperature correction
(iii) Standard length correction
(iv) Sag correction
(v) Slope correction
(vi) Mean sea level correction.

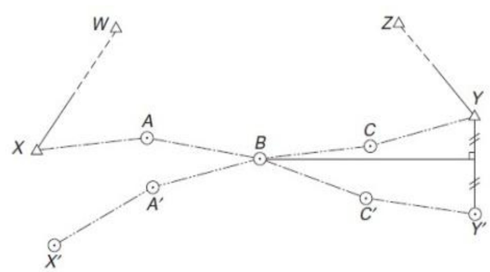
Pull Correction:-

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 is employed to measure a length at a pull P_F

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.

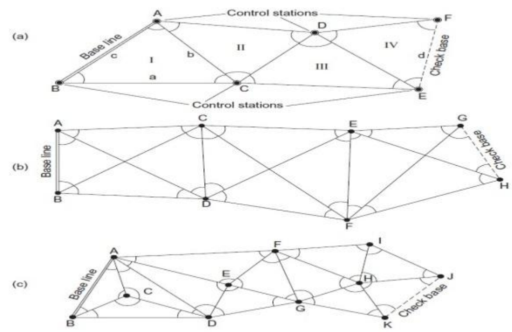
Many countries used triangulation as the basis of their national mapping system. The procedure was generally to establish primary triangulation networks, with triangles having sides ranging from 30 to 50 km in length. The primary trig points were fixed at the corners of these triangles and the sum of 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 measurementof the base line will result in scale error throughout the network. Thus, in ordertocontrolthiserror, checkbaseline should be measured at intervals thescale

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:

(1) Reconnaissance of the area, to ensure the best possible positions for stations and base lines.

(2) Construction of the stations.

(3) Consideration of the type of target and instrument to be used and also the method of observation.All of these depend on the precision required and the length of sights are involved.

(4) Observation of angles and base-line measurements.

(5) Computation: base line reduction, station and figural adjustment, coordinates of stationsby 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 purpose of the survey stations should not be forgotten and their position located accordingly.

(1) 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.

(2) 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.

(3) 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.

Overcoming obstacles during chaining:

Agor (1993) classified the various types of obstacles encountered in the course of chaining into three

- Obstacles which obstruct ranging but not chaining
- Obstacles which obstruct chaining but not ranging
- Obstacle which obstruct both ranging and chaining

Obstacles that obstruct ranging but not chaining

Such a problem arises when a rising ground or a jungle area interrupts the chain line. Here the end stations are not interred visible.

There may be two cases:-

Case I :

The end stations may be visible from some intermediate points on the rising ground. In this case, reciprocal ranging is resorted to and the chaining is done by the stepping method.

Case II:

The end stations are not visible from intermediate points when a jungle area comes across the chain line. In this case the obstacle may be crossed over using a random line as explained below:

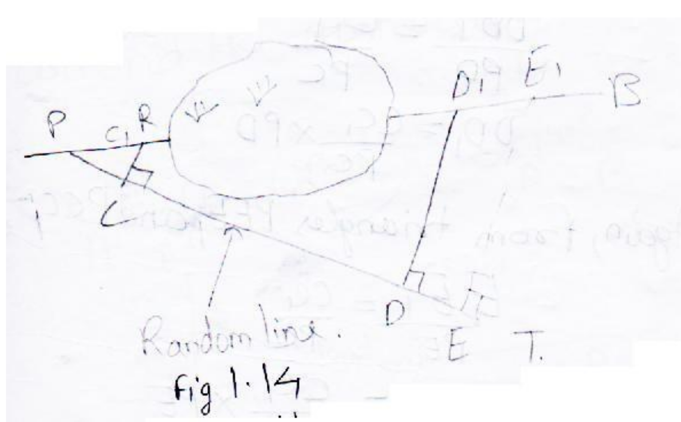


Fig 1.14

Let ‘AB’ be the actual chain line which can be ranged and extended because of interruption by a jungle. Let the chain line be extended up to ‘R’. A point ‘P’ is selected on the chain line and a random line ‘PT’ is taken in a suitable direction. Points C , D and E are selected on the random line and perpendicular are projected from them. The perpendicular at ‘C’ meets the chain line atC_1.

Theoretically, the perpendiculars at ‘D’ and ‘E’ will meet the chain line at D_1 and E_1. Now the distances PC, PD, PE and CC_1 are measured (Fig 14.1(1.14)) from triangles PDD_1 and PCC_1.

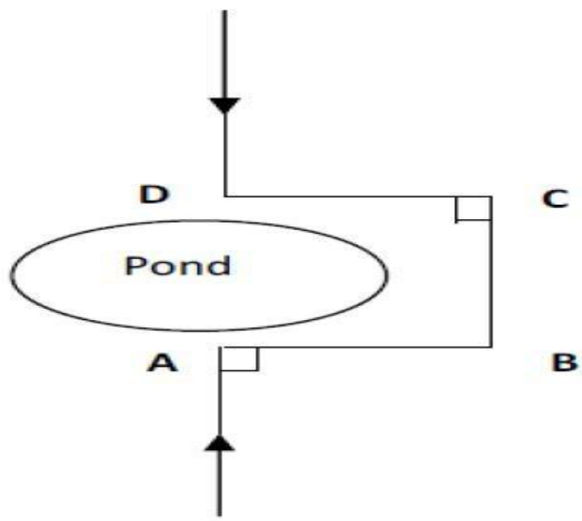
Obstacles which obstruct chaining but not ranging:

Water bodies like lakes, ponds and rivers are typical examples of obstacles in this category. It is possible to chain around these obstacles by using the following methods.

i. By constructing rectangles: Chaining had reached A and encountered an obstacle. Toget to B, mark A and B with an arrow. Set of perpendiculars AC and BD high enough to clear the obstacles. Join and measure DC which now equals AB. This allows chaining to continue from B.

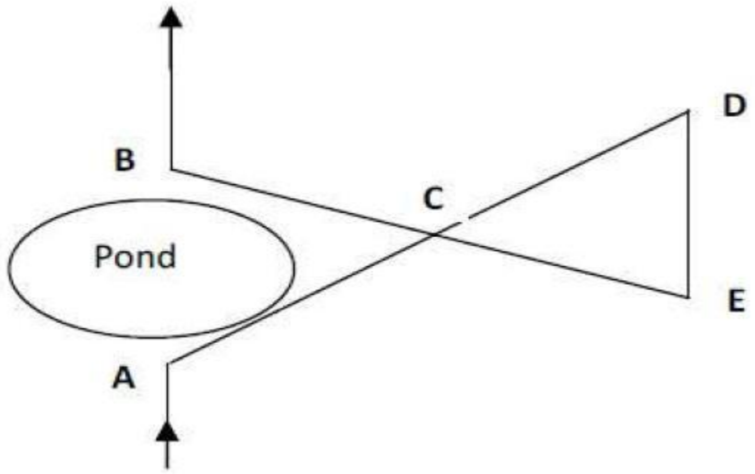
ii.By constructing similar triangles:

To continue chaining from B, fix a point C away from the obstacle. Range a pole at D

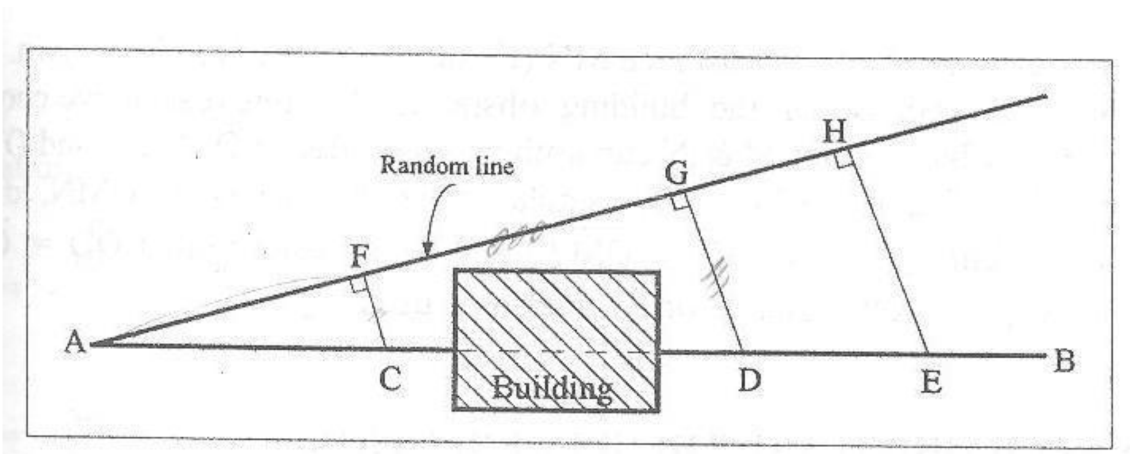


Toalign with AC hence AC = CD. In line with BC range another point E in line with BC. Hence BC= CE.

Measure ED which equals AB hence chaining can continue from B



Obstacle which obstruct both ranging and chaining



GD = (FC x GA) / FA HE = (FC x HA) / FA

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 of bearing

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.

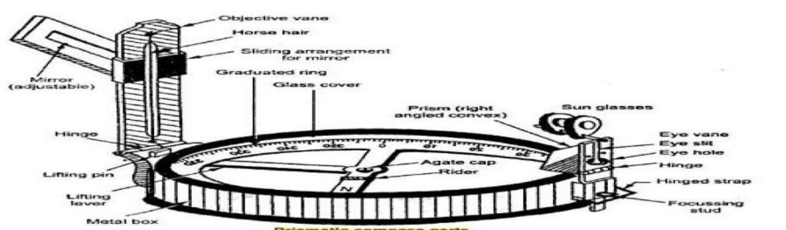
The prismatic attachment consists of a 45º reflecting prism with the eye and reading faces made slightly convex so as to magnify the image of the graduations. The prism is carried on a mounting which can be moved up and down between slides fixed on the outside of thecase.

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 ontop 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 and contain 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, rainetc.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 blacEye vane is a fine slit provided with the eye hole at bottom to bisect the object from slit.
- **Glass cover:**
  It covers the instrument box from the top such that needle and graduated 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 brake pin

Temporary adjustment of prismatic compass

- The following procedure should be adopted after fixing the prismatic compass on the tripod for measuring the bearing of aline.
- **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 tends to 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 lunar month, year, eleven years, etc.

Irregular Variation: These are caused by magnetic storms which can produce 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:

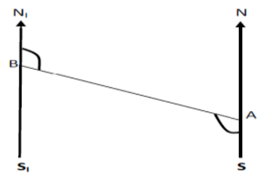
It is defined as the angle between the direction of the magnetic meridian and the true meridian at any point.

Surveyor's Compass:
Similar to the prismatic compass but with few modifications, the surveyors compass is an 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:
Introduction:
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 N1S1 are the magnetic NS lines, then Forward bearing (FB) = < N A S + < S A B

Back bearing BA = < N1 B ABack 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.
Choosing a suitable scale, the traverse is then plotted taking into consideration the general shape of the area.
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 onring.

Designation of bearing

- The bearing are designated in the following two system:-
    - Whole Circle Bearing System.(W.C.B)
    - QuadrantBearing 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, and up 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.

Reduced bearing (R.B)

- When the whole circle bearing is converted into Quadrantal bearing, it is termed as "REDUCEDBEARING".
- Thus , the reduced bearing is similar to the Quadrantalbearing.

- Its values lies between 0^{O} to 90^{O}, but the quadrant should be mentioned for proper designation.

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

W.C.B OF ANY LINE	QUADRANT IN WHICH IT LIES	RULES FOR CONVERSI ON	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 magnetic north pole

Unavoidable substances that affect are

- Magnetic ore
- Underground iron pipes
- High voltage transmission line
- Electric poleetc.

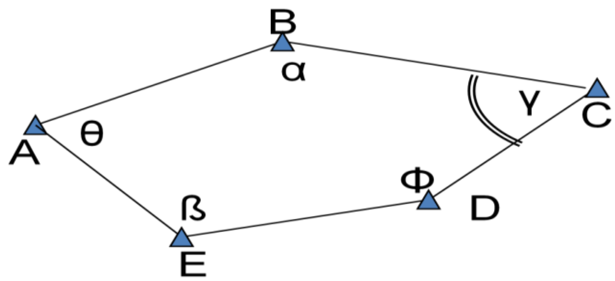
Influence caused by avoidable magnetic substance doesn't come under local attraction such as instrument, watch wrist, keyetc

Detection of Localattraction

- 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 ofR.B.)
- We confirm the local attraction only if the difference is not due to observational errors.

If detected, that has tobeeliminatedtwo methods ofelimination

- First method
- Second method



First method

- Difference of B.B. & F.B. of each lines of traverse is checked to note if they 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

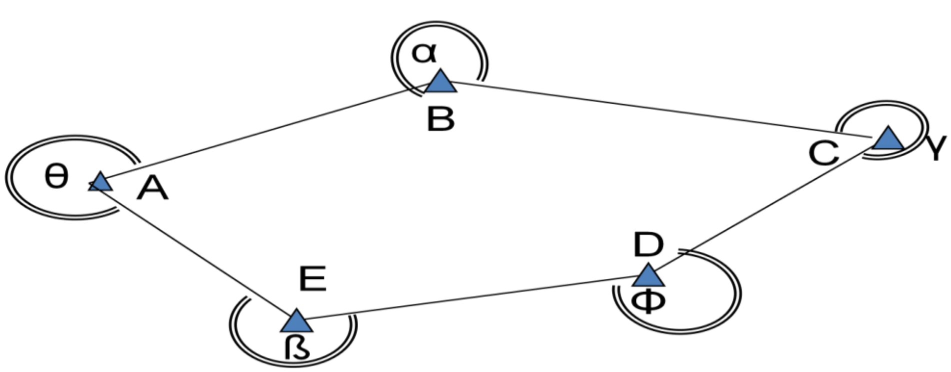
- Based on the fact that the interior angle measured on the affected station is right.
- All the interior angles are measured
- Check of interior angle – sum of interior angles = (2n-4) x right angle, where n is number of traverse side
- Errors are distributed and bearing of lines are calculated with the corrected angles from the lines with unaffected station.

Checks in closed Traverse

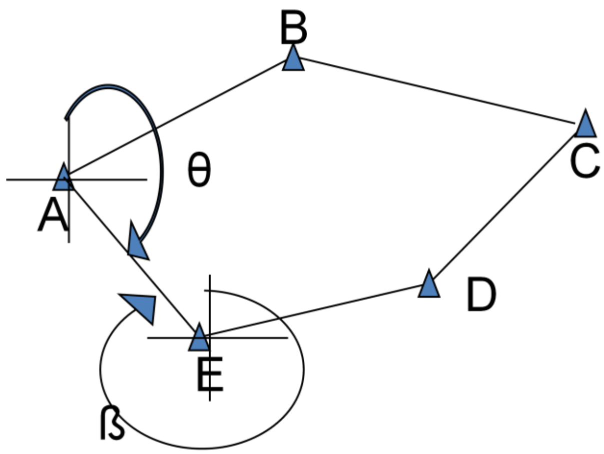
- Errors in traverse is contributed by both angle and distance measurement
- Checks are available for angle measurement but
- There is no check for distance measurement
- For precise survey, distance is measured twice, reverse direction second time

Checks for angular error are available

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

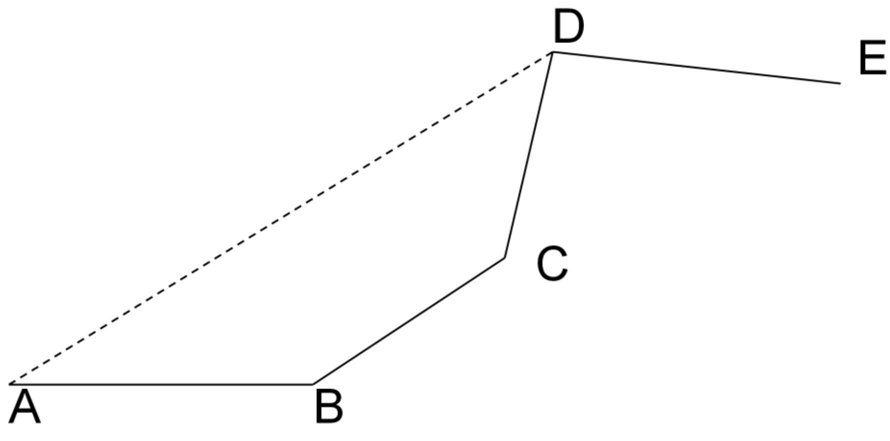


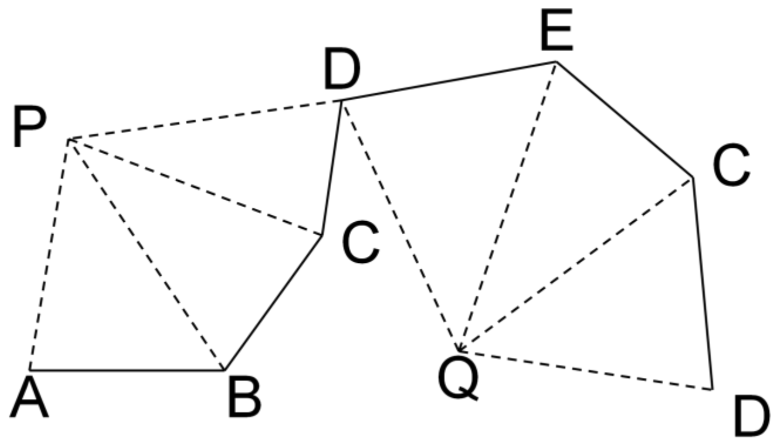
- Deflection angle – algebraic sum of the deflection angle should be 0^0 or 360^0.
- Bearing – The fore bearing of the last line should be equal to its back bearing ± 180^0 measured at the initial station.



Checks in open traverse

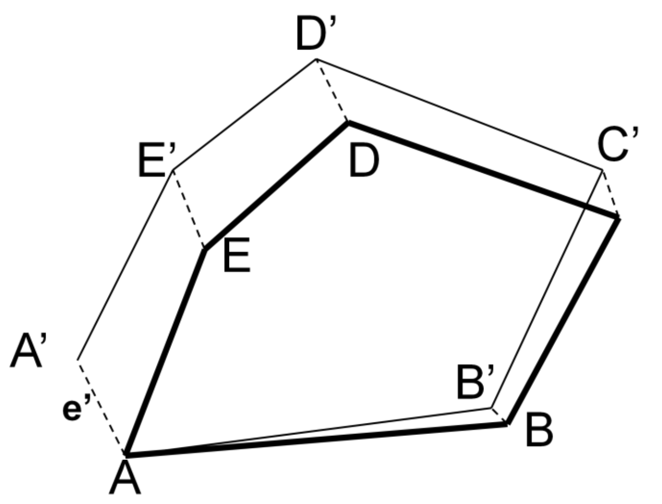
- No direct check of angular measurement is available
- Indirect checks
- Measure the bearing of line AD from A and bearing of DA from D
- Take the bearing to prominent points P & Q from consecutive station and check in plotting.

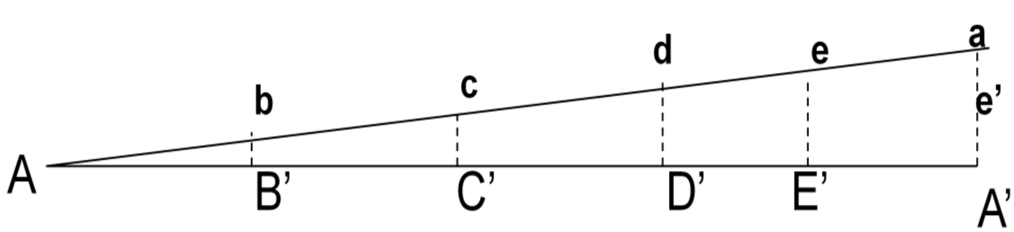




Methods
Compass rule(Bowditch)
When both angle and distance are measured with same precision
Transit rule
When angle are measured precisely than the length
Graphical method Rule

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





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 represented by 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 starting station. 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:-

1. **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.

2. **The Alidade:-**

   There are two types of alidade.

   (i) Plain
   (ii) Telescopic.

(a) 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.

(b) Telescopic Alidade:-

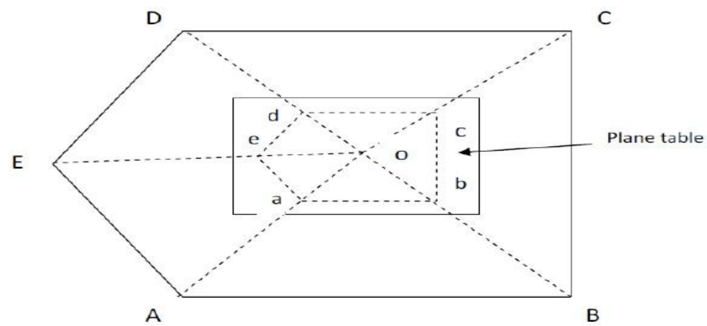
The telescopic alidade consists of a telescope meant for inclined sight or sighting distant objects clearly. This alidade has no vanes at the ends, but is provided with fiducially edge. The function of the alidade is to sight objects. The rays should be drawn along the fiducially ends.

3. **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.

4. The Compass:-

There are two kinds of compass.



(a) Trough compass and
(b) Circularbox compass.

(a) 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

(b) 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.

5. 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 are recognized:

- 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

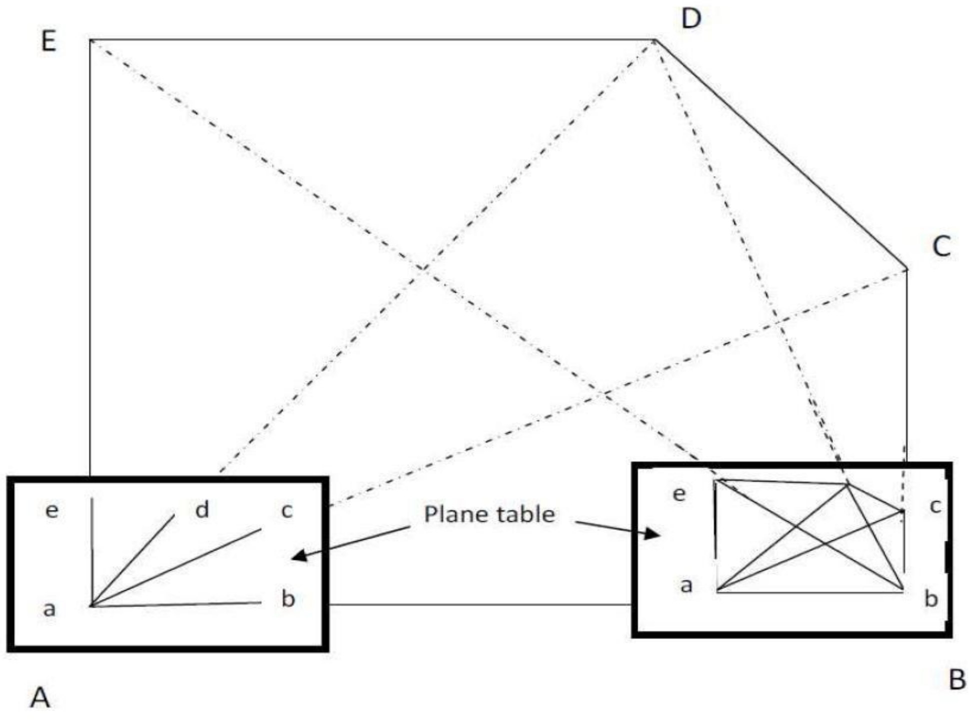
The following steps are taken:

1. Select a point O such that all the points are visible
2. Set up and level the instrument atO
3. From O align the Alidade and draw radial lines towards. The stations A, B, C, D and E.
4. Measure the distances OA, OB, OC, OD and OE: scale and draw Oa, Ob, Oc, Od and Oe on thepaper.
5. Join the point a, b, c, d, and e to give the outline of thesurvey.

Intersection Method

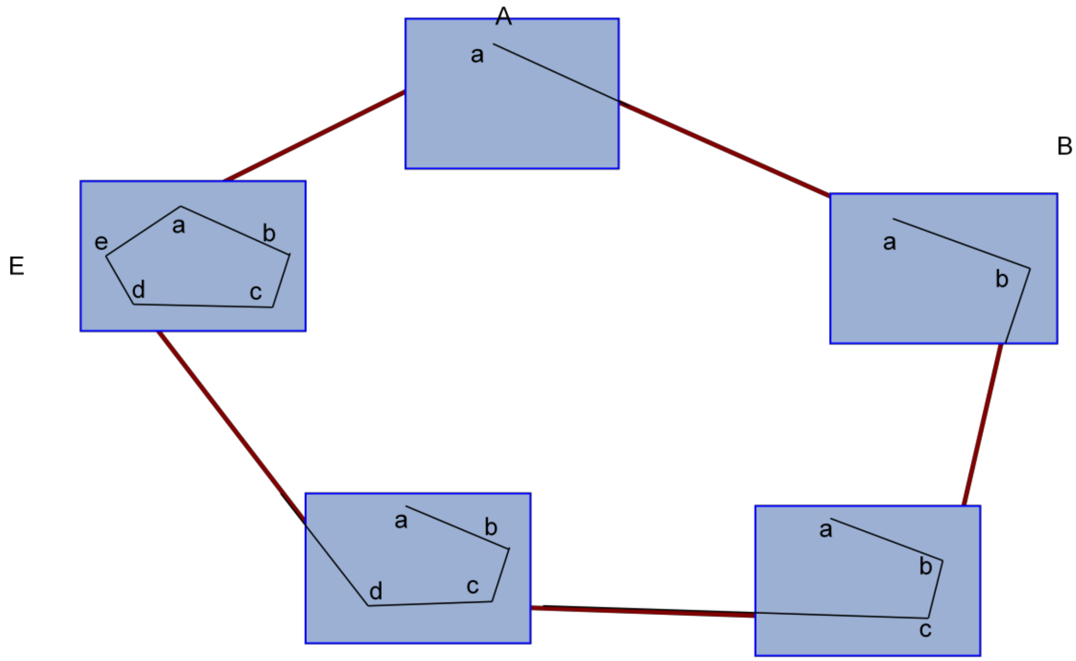
In this method, two instrument stations are used with the distance between them called based line serving as the base to measure and plot the other locations:

1. 2 points A and B are selected from which the rest of the stations can beseen.
2. Set up and level the plane table at A and mark it as a in the paper to coincide with A on the ground.
3. Sight B, C, D and E with the Alidade from a and draw rays which forwards them.
4. Measure AB, AC, AD and AE and using appropriate scale draw the corresponding paper distance.
5. Remove the equipment from A to B and repeat the procedure using B as the measuring station.



Plane Tabling using Intersection Method

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 :-

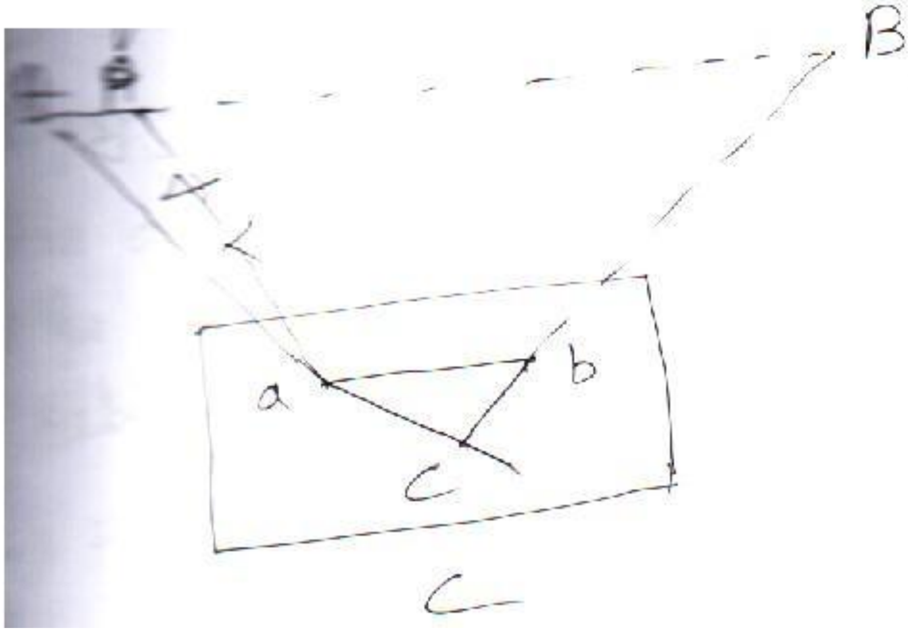
Resection is the process of determining the plotted position of the station occupied by the plane table, by means of sights taken towards known points, locations of which have been plotted.

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 resistors 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.

(i) Resection after orientation by compass.
(ii) Resection after orientation by back sighting.
(iii) Resection after orientation by three point problem.
(iv) Resection after orientation by two-point problem.

(i) Resection after orientation by compass:-

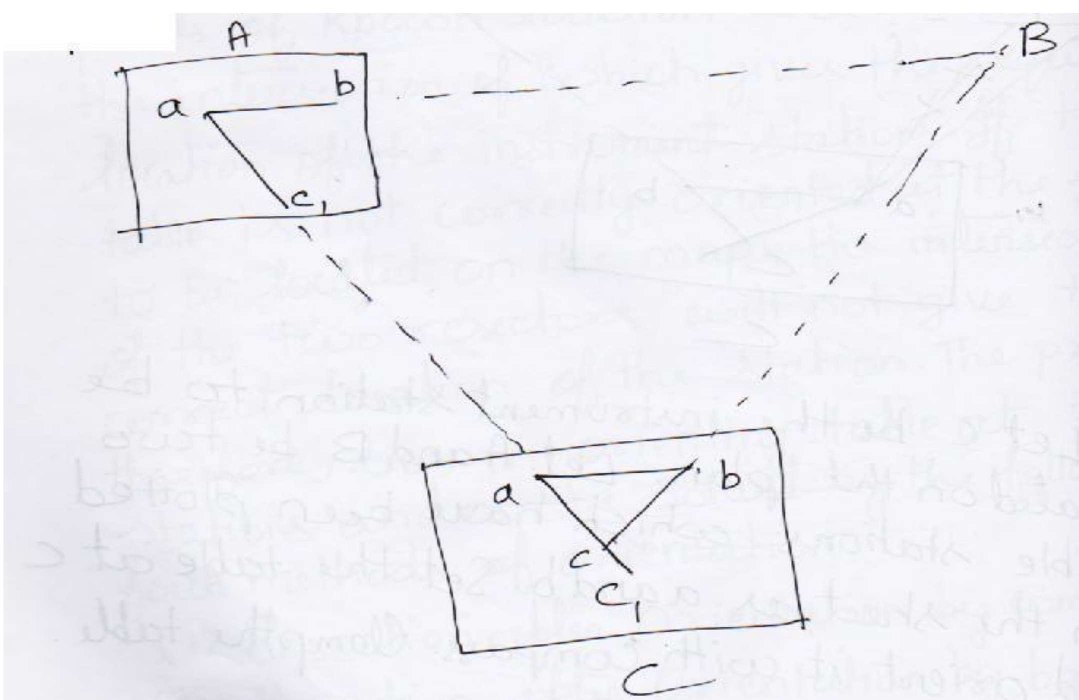
The method is utilized only for small scale or rough mapping for which the relatively large errors due to orienting with the compass needle would not impair the usefulness of the map. The method is as follows:



1. 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.
2. 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’, the required point.

(ii) 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:



1. 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'.
2. Pivoting the alidade at 'a'. sight 'C' and draw a ray. Estimate roughly the position of 'C' on this ray asC_1.
3. 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.
4. 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 :-

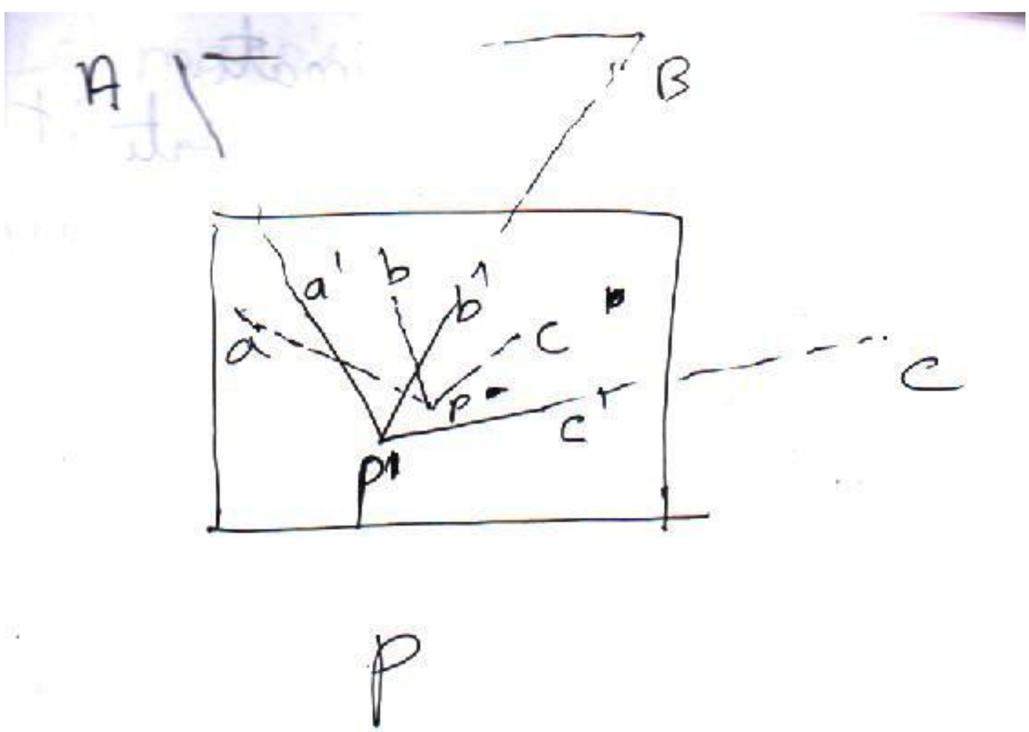
Location of the position, on the plan of the station occupied by the plane table by means of observations to three well-defined points whose positions have been previously plotted on the plan.

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

(a) Mechanical Method (Tracing Paper Method)
(b) Graphical Method
(c) Lehmann's Method (Trial and Error Method)

(a) 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.

(1) Set thetableonP. Orient the table approximately with eye so that‘ab’isparalleltoAB.
(2) Fix a tracing paper on the sheet and mark on it P’ as the approximately location of ‘P’ with the help of plumbingfork.
(3) 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.
(4) 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, pbandpc.
(5) 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 thusoriented.
(6) 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 onpc.

Lehmann’s Method:-

This is the easiest and quickest solution. The principles of the method areasfollows:

(a) 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 uniquepoint.
(b) When rays are drawn from control signals, the angles of their intersections are true angles whether or not the board is properlyoriented.

Procedure :-

1. Set the table over new station p and approximately orient it.
2. 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.
3. To reduce the triangle of error to zero, another point ‘p’ is chosen as per Lehmann’s rule.
4. 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). Then sight ‘B’ with alidade at b and ‘C’ with alidade at c. The rays will again form a triangle of error but much smaller.
5. The method has to be repeated till the triangle of error reduces tozero.

Lehmann’s Rules:-

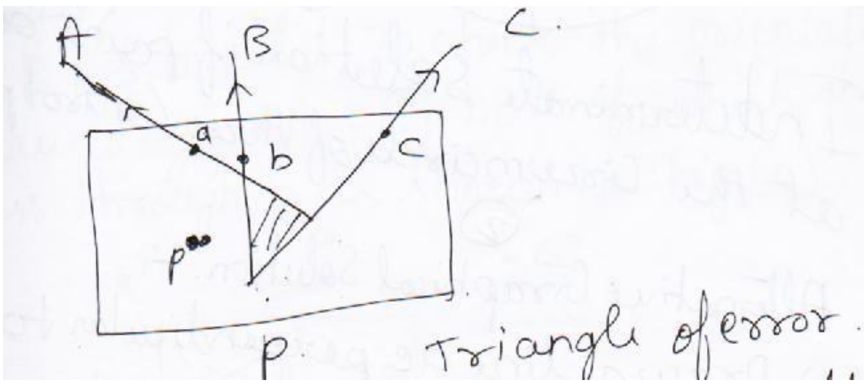
There are three rules to help in proper choice of the point p’.

1. If the plane table is set up in the triangle formed by the three points (i.e. p lies

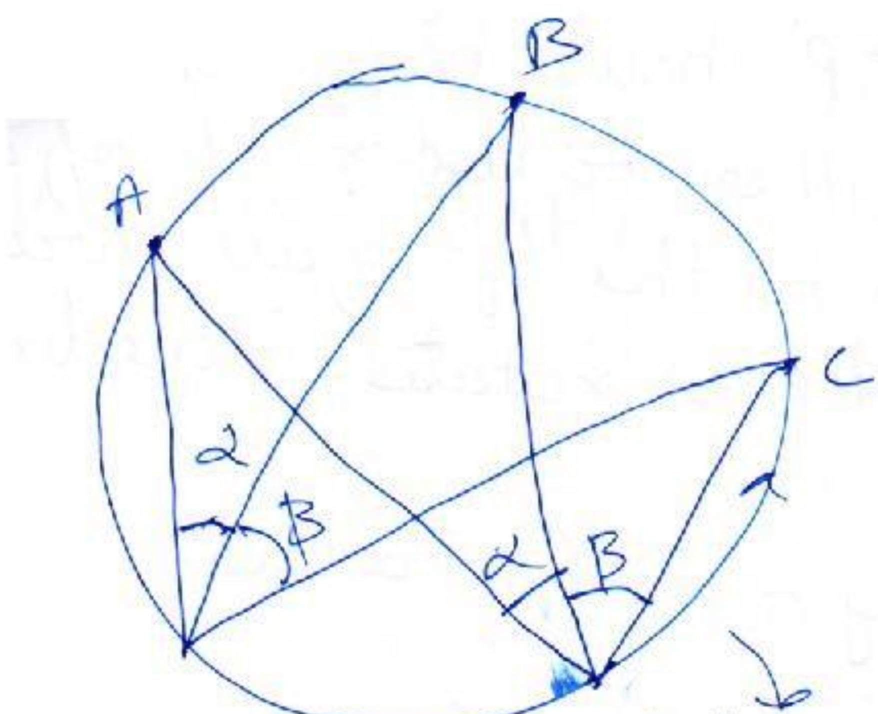
within the triangle ABC) then the position of the instrument on the plan will be inside the triangle of error, if not it will be outside.

2. 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.
3. 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 locateP.

Referring to the figure below:



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 the distances 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 three control points :-

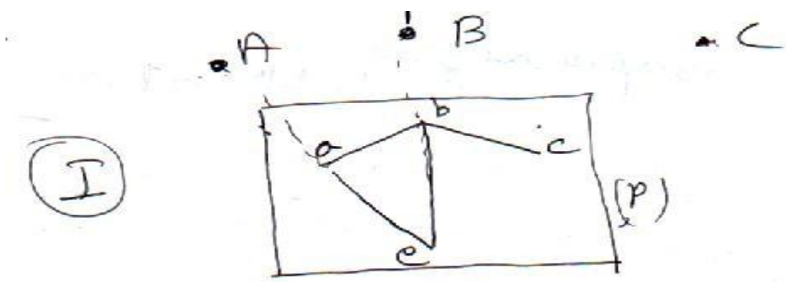
Alternative Graphical Solution:-

(1) 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, direct the alidade to sight B and draw the ray be to cut ‘ae’ in ‘e’ Fig 28.1(a)

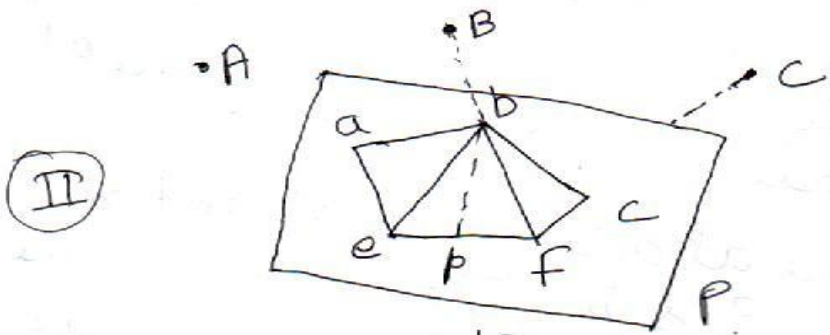
(2) Similarly, draw ‘cf’ perpendicular to ‘bc’ at ‘c’. Keep the alidade along ‘FC’ and rotate the plane table till ‘c’ is bisected clamp the table. With ‘b’ as centre, direct the alidade to sight ‘B’ and draw the ray ‘bf’ to cut ‘cf’ in F Fig 28.1(b)

(3) 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.

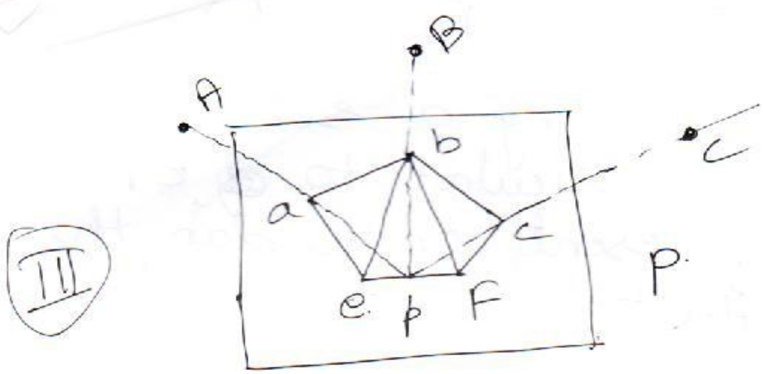
(4) To orient the table, keep the alidade along ‘pb’ rotate the plane table till ‘B’ is bisected. To check the orientation draw rays aA, cC both of which should pass through ‘p’ as shown in Fig. 28.1(c).



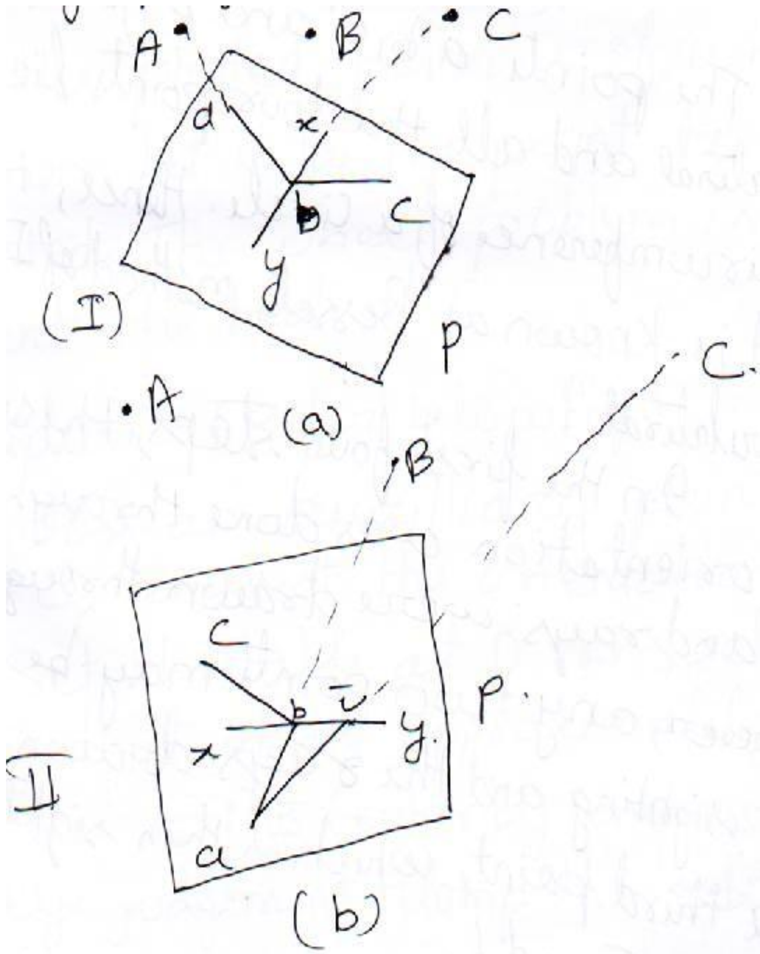
(a)



(b)



c)



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:-

(1) 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.

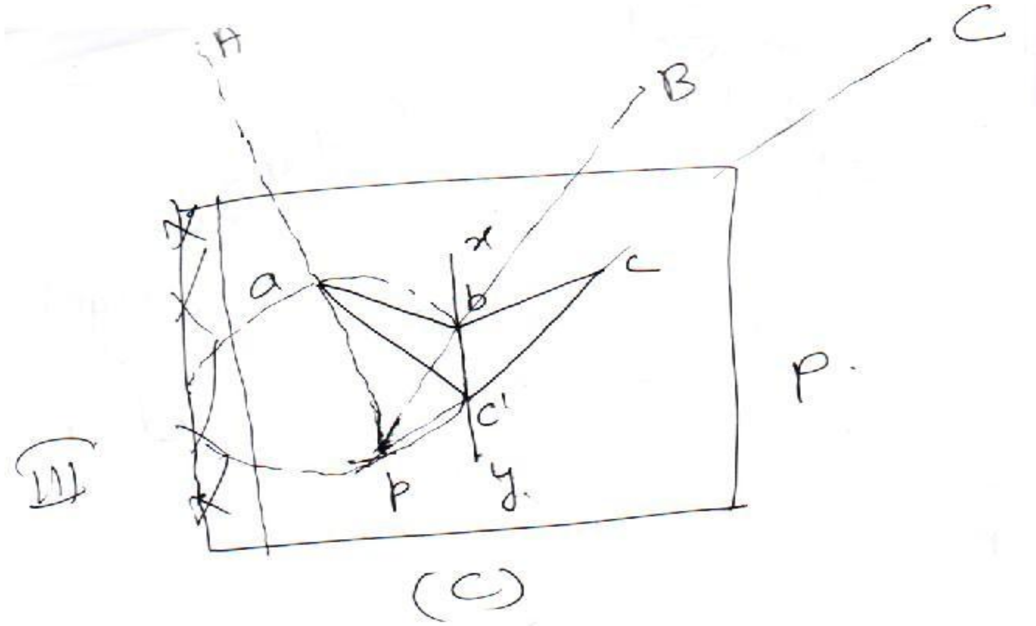
(2) Pivoting the alidade about 'b', sight to 'C' and draw the ray 'xy' along the edge of the alidade. [Fig28.2(a)]

(3) Keep the alidade along 'ab' and rotate the table till 'B' is bisected clamp the table.

(4) 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)] Joincc'.

(5) 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)].

(6) 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.



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 Inscribed Quadrilateral”.

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:-

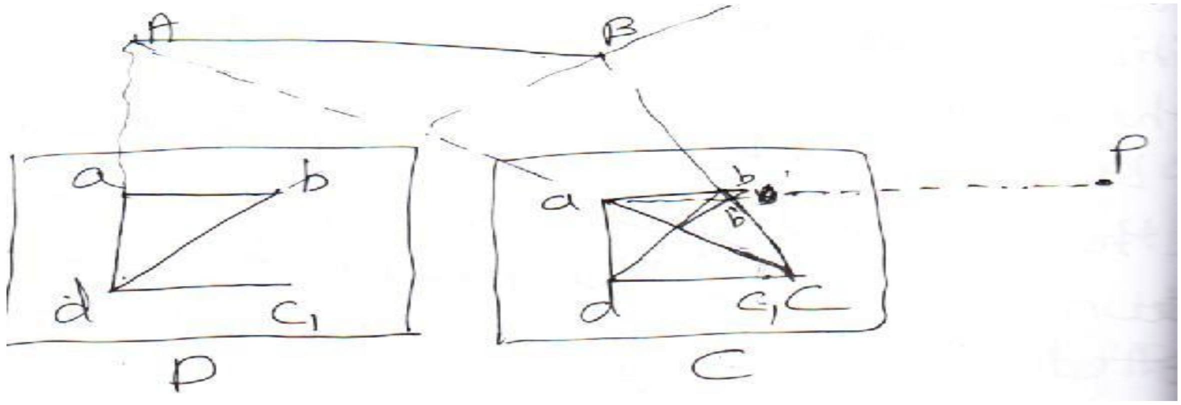
“Location of the position on the plan of the station occupied by the plane table by means of observation to two well defined points whose positions have been previously plotted on the plan.”Let us take two points ‘A’ and ‘B’, the plotted positions of which are known.

Let ‘C’ be the point to be plotted. The whole problem is to orient the table at ‘C’.

Procedure :

Choose an auxiliary point ‘D’ near ‘C’, to assist the orientation at ‘C’. set the table at ‘D’ in such a way that ‘ab’ is approximately parallel to ‘AB’ (either by compass or by eye judgment) clamp the table.

(1) Keep the alidade at ‘a’ and sight ‘A’. Draw the resectors. Similarly draw a resectors from ‘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.



Two point problem

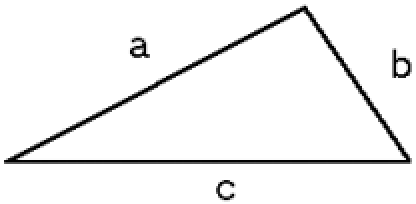
(2) Keep the alidade at ‘d’ and sight ‘C’. Draw the ray. Mark a point c_1 on the ray by estimation to represent the distance‘DC’.
(3) Shift the table to C, orient it (tentatively) by taking backside to ‘D’ and centre it with reference to c_1. The orientation is, thus the same as it was at‘D’.
(4) Keep the alidade pivoted at ‘a’ and sight it to ‘A’. Draw the ray to interest with the previously 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’.
(5) Pivoting the alidade about ‘c’, sight ‘B’. Draw the ray to intersect with the ray drawn from ‘D’ to ‘B’ in b’. Thus b’ is the approximate representation of ‘B’ with respect to the orientation made at ‘D’.
(6) 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 line with 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.
(7) 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 other considerations 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 asistheorientation.

COMPUTATION OF AREAS AND VOLUMES

Introduction

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 and irregular 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)

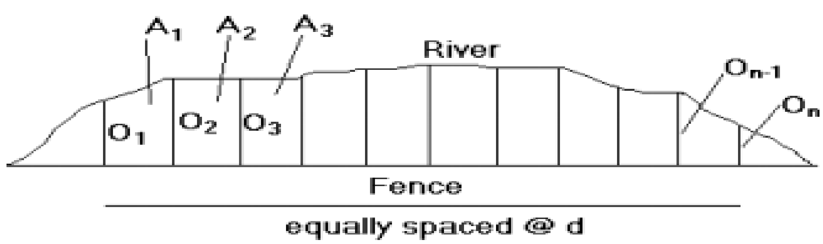
Calculating area of a polygon from Coordinates: If the coordinate points are numbered clockwise: area = 1 2 ∑ i=1 n (Ni . Ei+1 - Ei . Ni+1) This formula is not easy to remember, so let's look at a practical application

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)



$A_1 = d \cdot (O_1 + O_2) / 2$

$A_2 = d \cdot (O_2 + O_3) / 2$

$A_3 = d \cdot (O_3 + O_4) / 2$

Hence, the total area is:

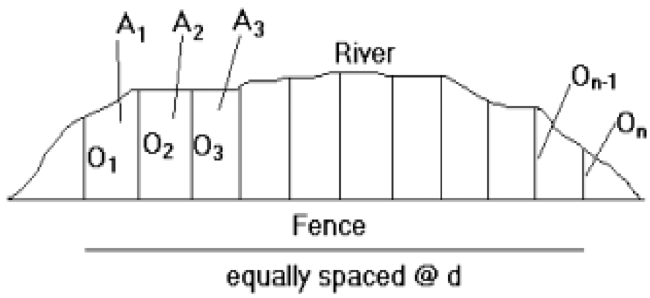
$$A = (d/2) \cdot [O_1 + 2.O_2 + 2.O_3 + ... + 2.O_{n-1} + O_n]$$

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.

Simpson's Rule

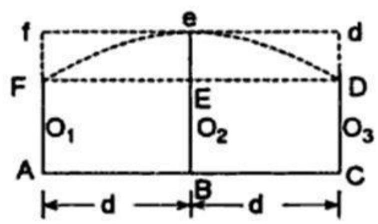


Fig. 7.13

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

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

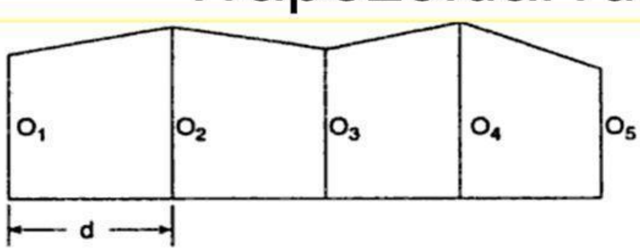


Fig. 7.12

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

d = common distance

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

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

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

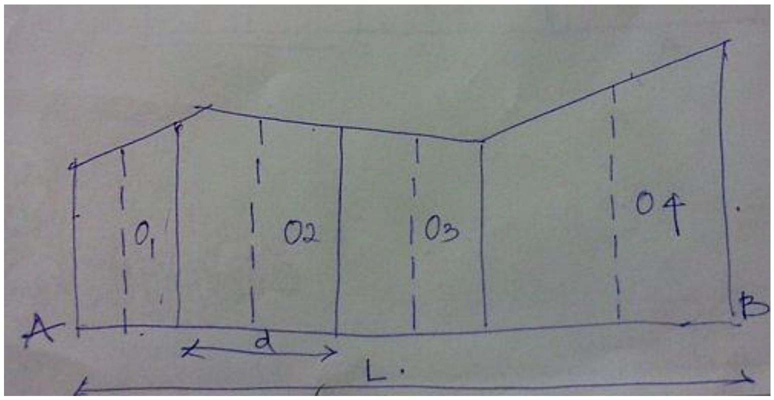
$$\text{Last area} = \frac{O_{n-1} + O_n}{2} \times d$$

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

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

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).



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

Ordinates

O1 = 10

O2 = 13

O3 = 17

O4 = 16

O5 = 19

O6 = 21

O7 = 20

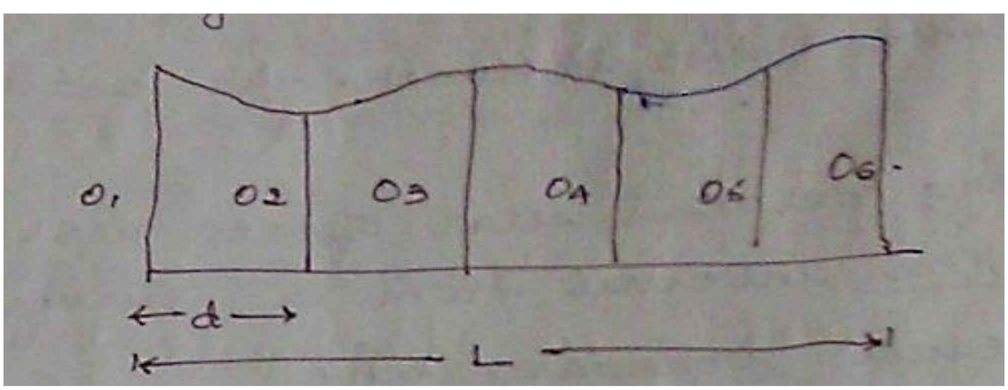
O8 = 18

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



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 $1/3^{rd}$ 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

COMPUTATION OF VOLUMES

INTRODUCTION

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
Problem
Compute the cost of earth work involved in cutting open a trench of following size. Length 200 m, side slope 2: 1, depth of trench 4 m, bottom, width of trench 1.5 m. Cost of earth work Rs. 50 per m3 . Cross sectional area of trench, A = (b + sh)*h
A = (1.5 + 2*4)*4 A = 9.5 * 4 = 38 m2
∴ Volume of earth work, V = A*L = 38 * 200 = 7600 m3
∴ Cost of earth work = 7600 * 50 = Rs. 3,80,000.00
Compute the volume of earth work involved in constructing a farm pond of the following size: size, at bottom 6 x 4 m. Side slope 2: 1, depth of pond 4 m work out the cost of earth work also if it costs Rs. 50 per cubic metre.

Size of pond at bottom = 6 x 4 m

Area at bottom = 24 m^2 (a_1)

Size of pond at ground level:

Length of pond = 6 + 8 + 8 = 22 m

Breadth of pond = 4 + 8 + 8 = 20 m

Cross sectional area of pond at ground level = 20 * 22 = 440 m^2 (a_3)

Area of pond at mid height = $\frac{(22+6)}{2} * \frac{(20+4)}{2} = 14*12 = 168\, m^2$ (a_2)

Using prismoidal rule, $V = \frac{D}{2}[a_2 + a_3 + 2(a_2)]$

$$V = \frac{D}{2}[24 + 440 + 2(168)]$$

$$V = \frac{2}{2}[464 + 336] = 800\ m^3$$

∴ Cost of earth work = 50 * 800 = **Rs. 40, 000**

An embankment of width 10 m and side slopes 1 ½:1 is required to be made on a ground which is level in a direction transverseto the centre line. The central heights at 40 m intervals are as follows:

0.90,1.25,2.15,2.50,1.85,1.35, and 0.85
Calculate the volume of earth work according to
i) Trapezoidal formula
ii) Prismoidal formula

Solution: the c/s areas are calculated by

$\Delta = (b+sh)*h$

$\Delta_1 = (10+1.5*0.90)*0.90 = 10.22\ m^2$

$\Delta_2 = (10+1.5*1.25)*0.90 = 14.84\ m^2$

$\Delta_3 = (10+1.5*1.25)*2.15 = 28.43\ m^2$

$\Delta_4 = (10+1.5*2.50)*2.50 = 34.38\ m^2$

$\Delta_5 = (10+1.5*1.85)*1.85 = 23.63\ m^2$

$\Delta_6 = (10+1.5*1.35)*1.35 = 16.23\ m^2$

$\Delta_7 = (10+1.5*0.85)*0.85 = 9.58\ m^2$

(a) Volume according to trapezoidal formula

$V = 40/2\{10.22 + 9.58 + 2(14.84+28.43+34.38+23.63+16.23)\}$

$= 20\{19.80+235.02\} = 5096.4\ m^2$

(b) Volume calculated in prismoidal formula:

$V = 40/3\ \{10.22+9.58+4(14.84+34.38+16.23)+2(28.43+23.63)\}$

$= 40/3\ (19.80+261.80+104.12) = 5142.9\ m^2$

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 of slop 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 is the 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 be computed:

1. Level section.
2. Two-level section.
3. Side-hill two-level section.
4. Three-level section.
5. Multi-level section

1. Level-Section (Fig. 12.2):

In this case the ground is level transversely.

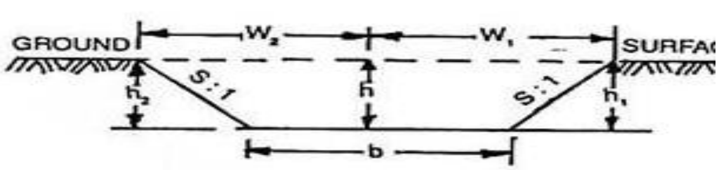


Fig. 12.2

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

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.

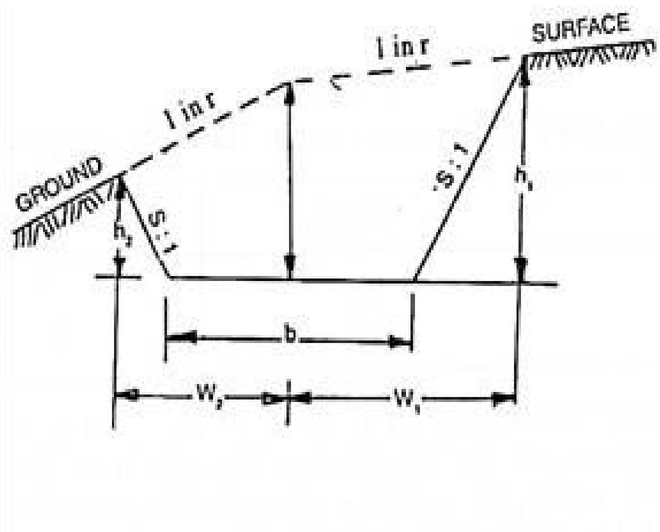


Fig. 12.4

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

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

[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.

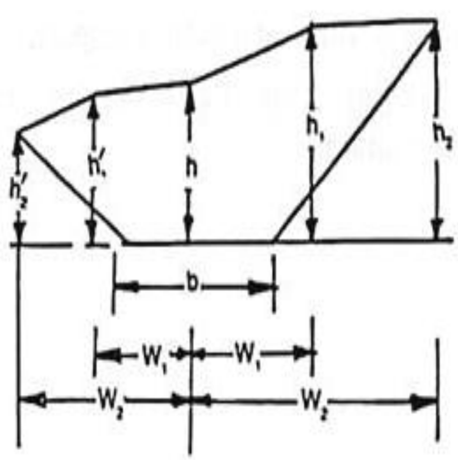
$$h_1 = \left(h + \frac{w_1}{r_1}\right)$$

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

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

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

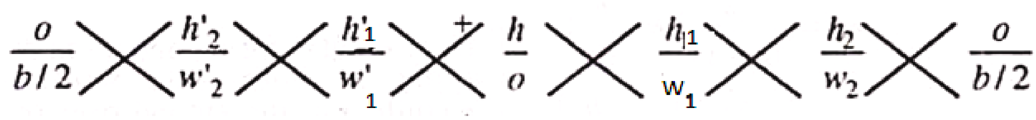
In this case, the transverse slope of the ground is not uniform but-has multiple cross-slopes as is clear from the figure.



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.



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 upto 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

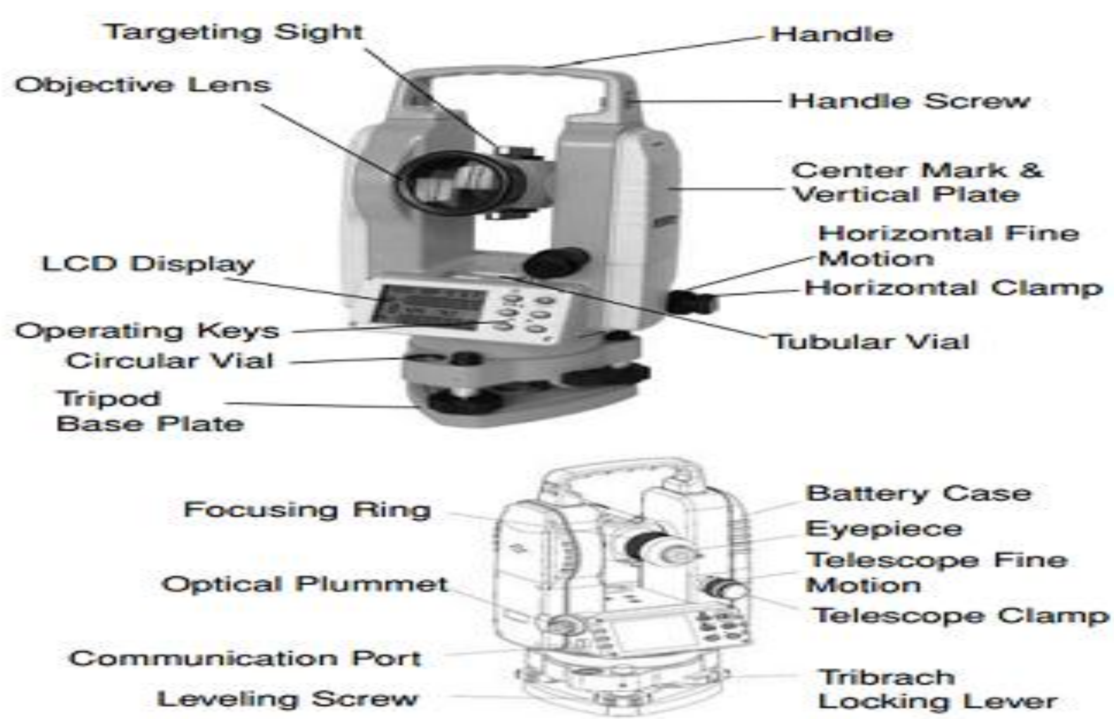
Converting Lift into lead:
The lift is converted into lead by the following rules:

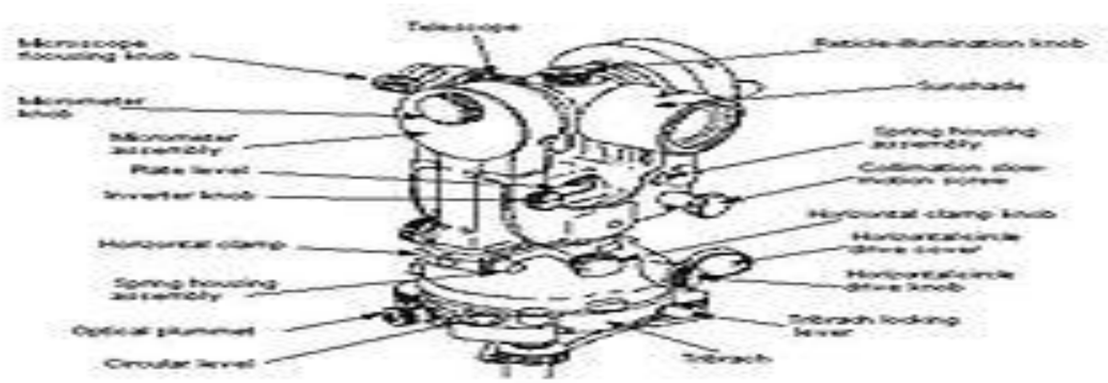
1. The lift up to 3 .6m is multiplied by 10
2. Lift more than 3.6m and less than 6m is squared and multiplied by 3.3.
   Lift more than 6m is multiplied by 20

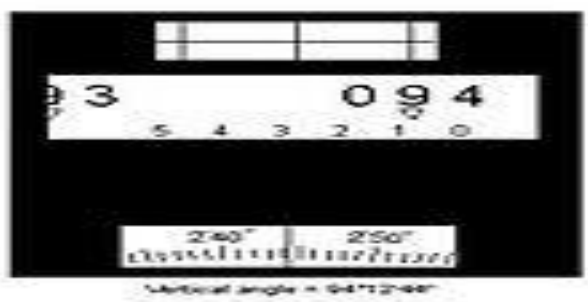
THEODOLITE AND TRAVERSE SURVEYING

Types of Theodolite

There are two different kinds of Theodolite: digital and non digital. Non digital Theodoliteare rarely used anymore. Digital Theodoliteconsists 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 Theodoliteare convenient because the digital readouts take the place of traditional graduated circles and this creates more accurate readings.







How Does a TheodoliteWork

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 are mainly used for surveying, but they are also useful in these applications:
- 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. This axis 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 of the 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 itscentre

Tachometric and advanced 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

(1)Stadia system, and
(2) 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 sight of the instrument is obtained with only one observation from the instrument Station
In the stadia method, there are mainly two systems of surveying.

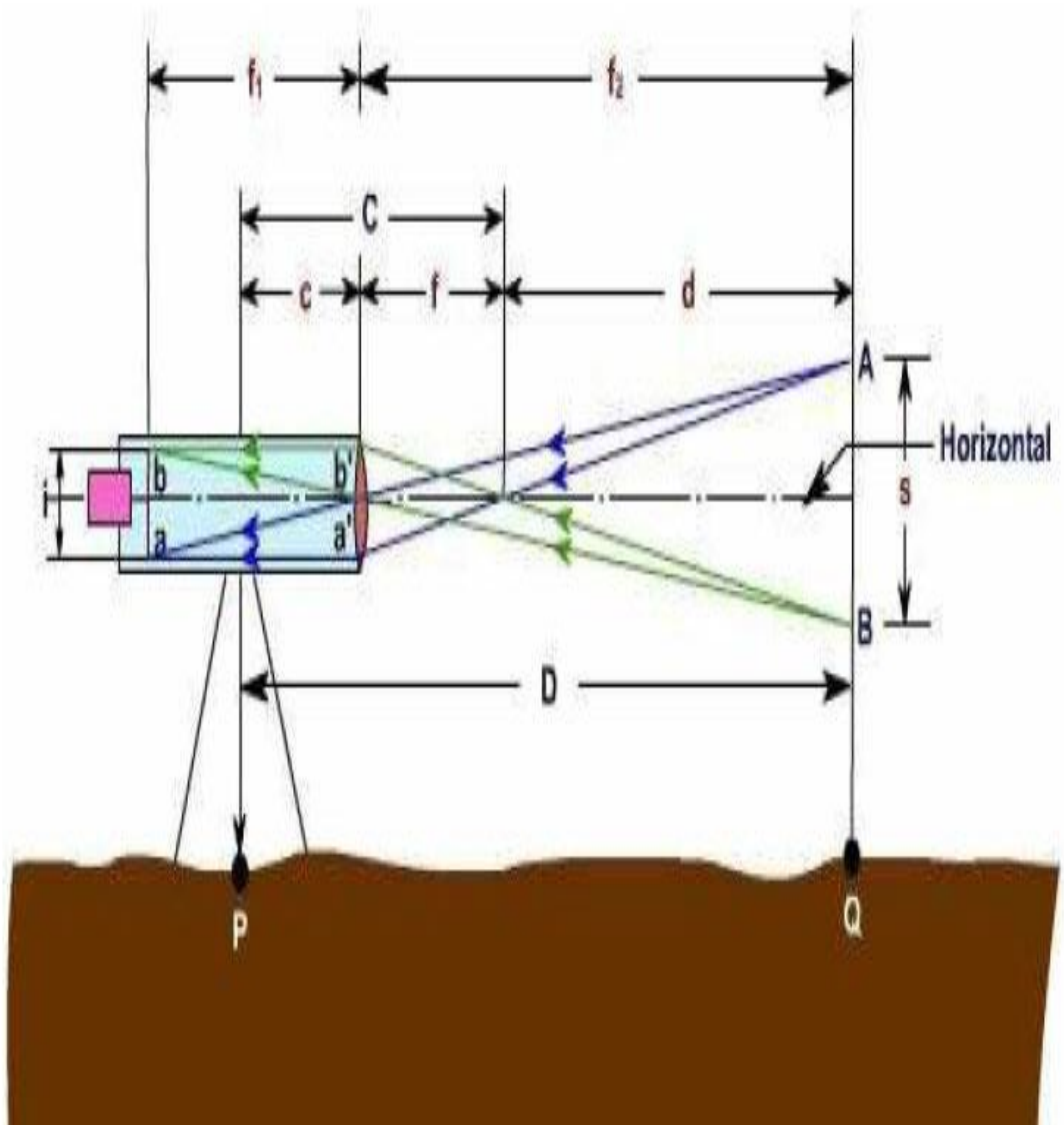
(1) fixed hair method and,
(2) Movable hair method.

(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.

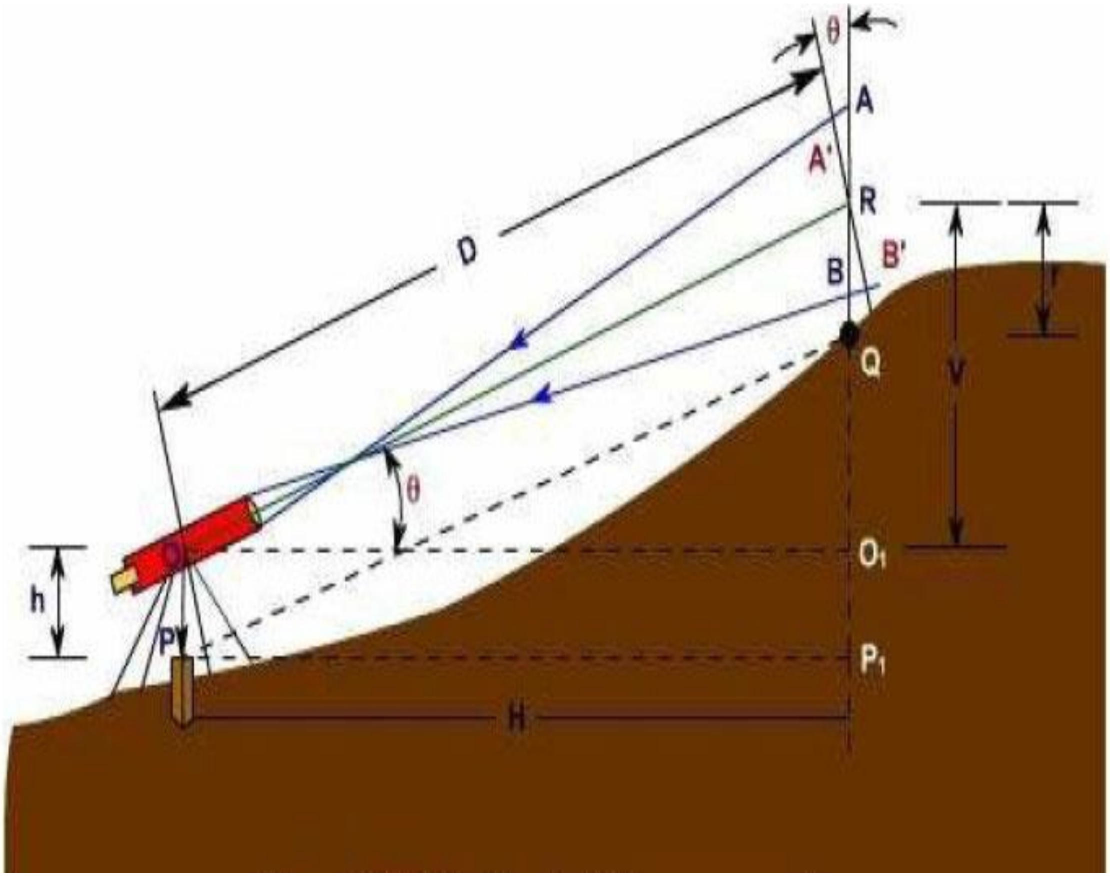
As the distance between the stadia hair is fixed, this method is called the "fixed hair method



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



Tangential System of Tacheometric Surveying:

In this system of tachometric surveying, two observations will be necessary from the instrument station to the staff station to determine the horizontal distance and the difference in the elevation between the line of collimation and the staff station

MODULE-II
CURVES

Definition of Curves:

Curves are regular bends provided in the lines of communication like roads, railways etc. and also in canals to bring about the gradual change of direction. They are also used in the vertical plane at all changes of grade to avoid the abrupt change of grade at the apex.

Curves provided in the horizontal plane to have the gradual change in direction are known as Horizontal curves, whereas those provided in the vertical plane to obtain the gradual change in grade are known as vertical curves. Curves are laid out on the ground along the centre line of the work. They may be circular or parabolic.

Classification of Curves:

(i) Simple,
(ii) Compound
(iii) Reverse

(i) Simple Curve:

A simple curve consists of a single arc of a circle connecting two straights. It has radius of the same magnitude throughout.

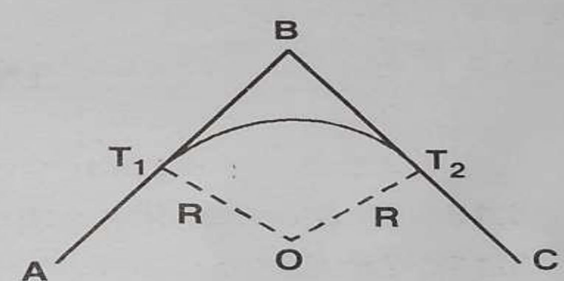


Fig. 3.1 Simple Curve

(ii) Compound Curve:

A compound curve consists of two or more simple curves having different radii bending in the same direction and lying on the same side of the common tangent. Their centres lie on the same side of the curve.

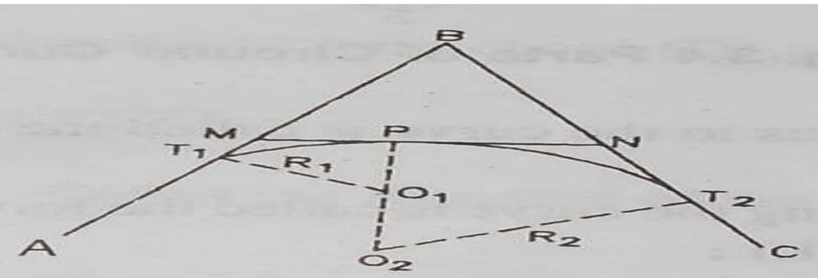


Fig. 3.2 Compound curve

(iii) Reverse (or Serpentine) Curve:

A reverse or serpentine curve is made up of two arcs having equal or different radii bending in opposite directions with a common tangent at their junction. Their centres lie of opposite sides of the curve.

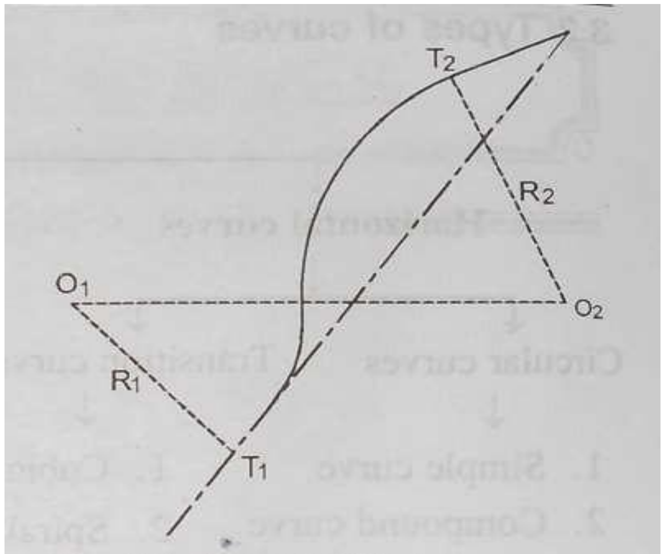


Fig. 3.3 Reverse Curve

(iv) Deviation Curve:

A deviation curve is simply a combination of two reverse curves. It is used when it becomes necessary to deviate from a given straight path in order to avoid intervening obstructions such as a bend of river, a building, etc.

Definition and Notation of Simple Curve

1) Back tangent or First Tangent - AT_1 – Pervious to the curve

2) Forward Tangent or Second tangent- B T_2 - Following the curve.

3) Point of Intersection (P.I.) or Vertex. (v) If the tangents AT_1 and BT_2 .are produced they will meet in a point called the point of intersection

4)Point of curve (P .C.) –Beginning Point T_1 of a curve. Alignment changes from a tangent to curve.

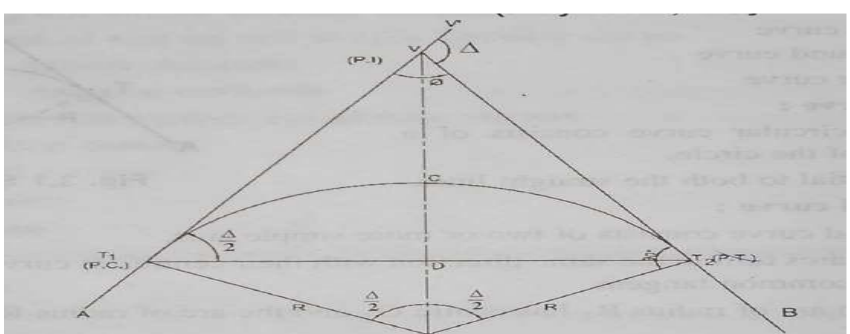
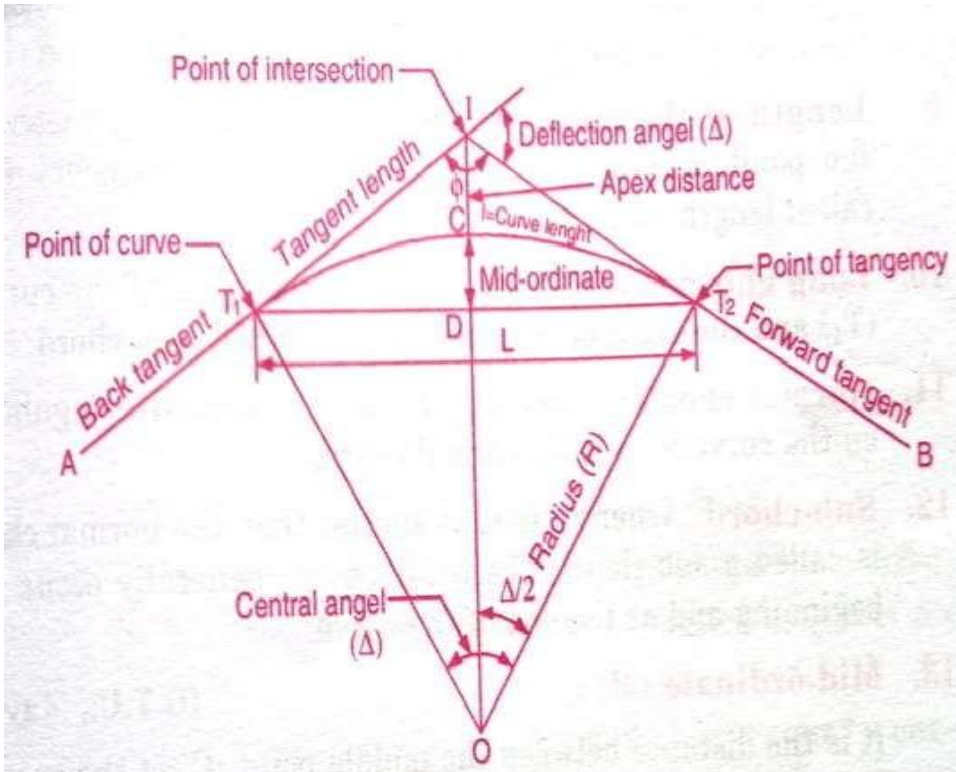


Fig. 3.4 Parts of Circular Curve



Designation of Curves:
A curve may be designated either by the radius or by the angle subtended at the centre by a chord of particular length In India, a curve is designated by the angle (in degrees) subtended at the centre by a chord of 30 metres (100 ft.) length. This angle is called the degree of the curve (D).

Methods of Curve Ranging:

A curve may be set out:

1. By linear methods, where chain and tape are used.
2. By angular or instrumental methods, where a theodolite with or without a chain is used.

   Before starting setting out a curve by any method, the exact positions of the tangent points between which the curve lies, must be determined. Measure the tangent length (BT_1) backward along the rear tangent BA from the intersection point B, thus locating the position of T_1.Similarly, locate the position of T_2 by measuring the same distance forward along the forward tangent BC from B,

Having located the positions of the tangent points T_1 and T_2; their changes may be determined. The change of T_1 is obtained by subtracting the tangent length from the known change of the intersection point B. And the change of T_2 is found by adding the length of the curve to the change to T_1.
Then the pegs are fixed at equal intervals on the curve. The interval between the pegs is usually 30 m or one chain length. This distance should actually be measured along the arc, but in practice it is measured along the chord, as the difference between the chord and the corresponding arc is small and hence negligible. In order that this difference is always

small and negligible, the length of the chord should not be more than 1/20th of the radius of the curve. The curve is then obtained by joining all these pegs.
The distances along the centre line of the curve are continuously measured from the point of beginning of the line upto the end, i.e., the pegs along the centre line of the work should be at equal interval from the beginning of the line to the end. There should be no break in the regularity of their spacing in passing from a tangent to a curve or from a curve to a tangent.

For this reason, the first peg on the curve is fixed at such a distance from the first tangent point (T_1) that its change becomes the whole number of chains i.e. the whole number of peg interval. The length of the first chord is thus less than the peg interval and is called as a sub- chord. Similarly there will be a sub chord at the end of the curve. Thus a curve usually consists of two-chords and a number of full chords. This is made clear from the following example.

Transition Curves:
A non-circular curve of varying radius introduced between a straight and a circular curve for the purpose of giving easy changes of direction of a route is called a transition or easement curve. It is also inserted between two branches of a compound or reverse curve.

Advantages of providing a transition curve at each end of a circular curve:
(i) The transition from the tangent to the circular curve and from the circular curve to the tangent is made gradual.
(ii) It provides satisfactory means of obtaining a gradual increase of super-elevation from zero on the tangent to the required full amount on the main circular curve.
(iii) Danger of derailment, side skidding or overturning of vehicles is eliminated.
(iv) Discomfort to passengers is eliminated.

Conditions to be fulfilled by the transition curve:
- It should meet the tangent line as well as the circular curve tangentially.
- The rate of increase of curvature along the transition curve should be the same as that of increase of super-elevation.
- The length of the transition curve should be such that the full super-elevation is attained at the junction with the circular curve.
- Its radius at the junction with the circular curve should be equal to that of circular curve.

There are three types of transition curves in common use:
(1) A cubic parabola,
(2) A cubical spiral, and
(3) A lemniscate, the first two are used on railways and highways both, while the third on highways only.
When the transition curves are introduced at each end of the main circular curve, the combination thus obtained is known as combined or Composite Curve.

Super-Elevation or Cant:

When a vehicle passes from a straight to a curve, it is acted upon by a centrifugal force in addition to its own weight, both acting through the centre of gravity of the vehicle. The centrifugal force acts horizontally and tends to push the vehicle off the track.

In order to counteract this effect the outer edge of the track is super elevated or raised above the inner one. This raising of the outer edge above the inner one is called super elevation or cant. The amount of super-elevation depends upon the speed of the vehicle and radius of the curve.

Vertical Curves

Vertical curves are provided to change the slope in the road and may or may not. be symmetrical. They are parabolic and not circular like horizontal curves. Identifying the proper grade and the safe passing sight distance is the main design criterion of the vertical curve, iln crest vertical curve the length should be enough to provide safe stopping sight distance and in sag vertical curve the length is important as it influences the factors such as headlight sight distance, rider comfort and drainage requirements.

Types of Vertical Curve:

Sag Curve

Sag Curves are those which change the alignment of the road from uphill to downhill,

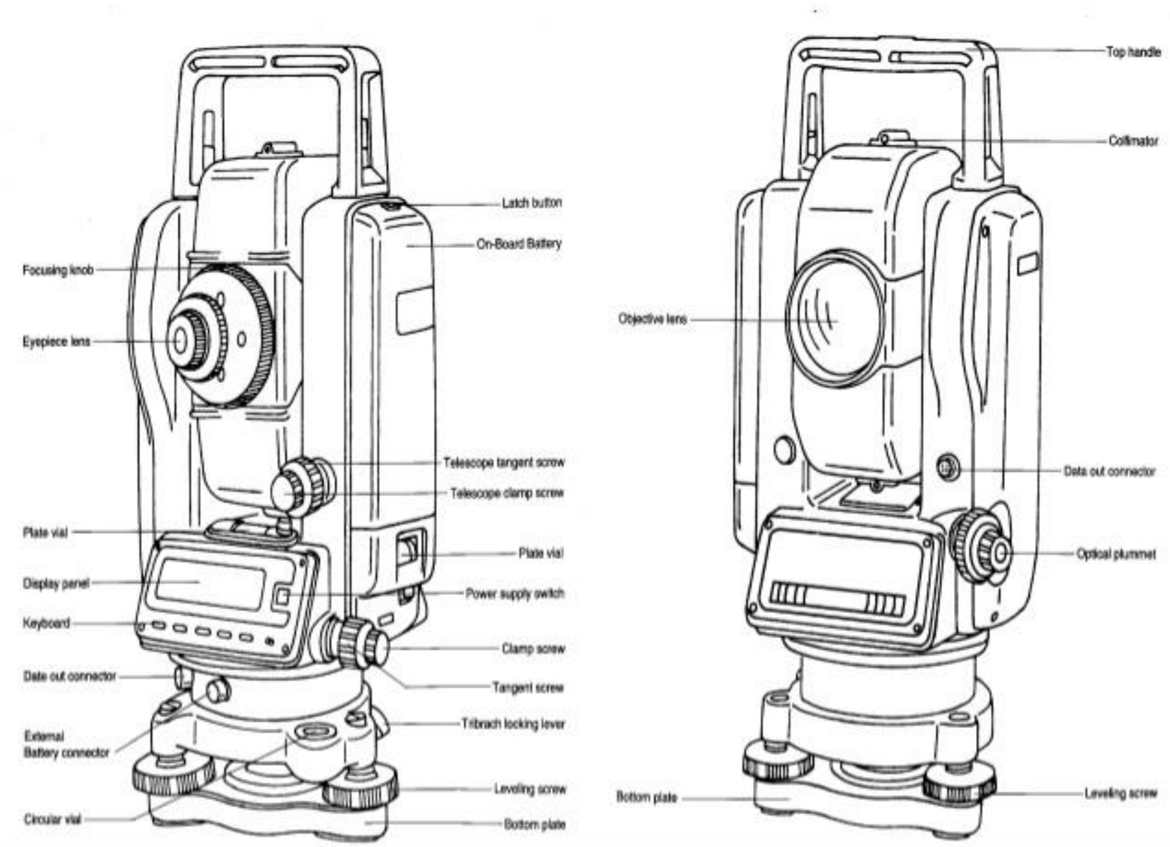
Crest Curve/Summit Curve

Crest Curves are those which change the alignment of the road from downhill to uphill. In designing crest vertical curves it is important that the grades be not] too high which makes it difficult for the motorists to travel upon it.

MODULE-III
MODERN FIELD SURVEY SYSTEMS

Total station is a surveying equipment combination of Electromagnetic Distance Measuring Instrument and electronic theodolite. It is also integrated with microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument.

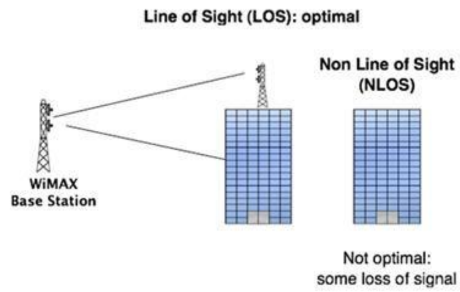
ADVANCED SURVEYING



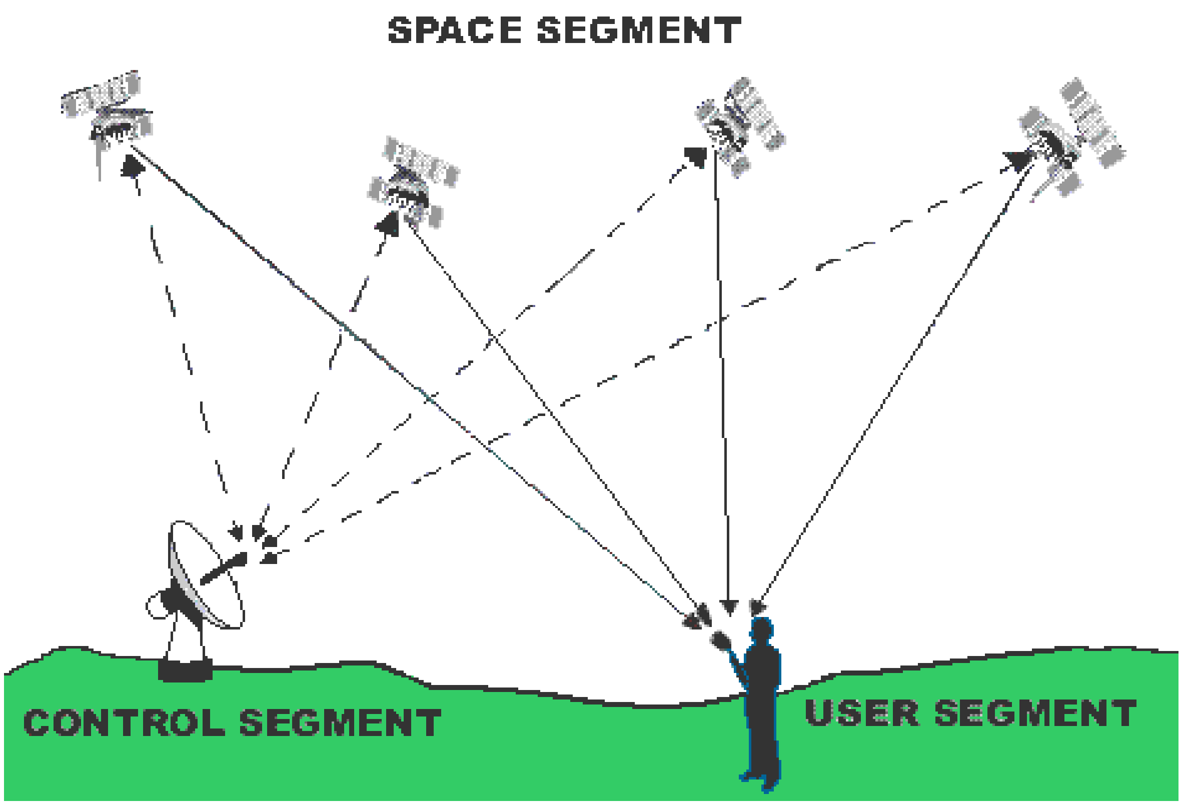
ADVANTAGES OF TOTAL STATION SURVEYING

- Accurately gathers enormous amount of survey measurements quickly
- Receiving and transmitting measured or layout data increases processing efficiency
- Read and write errors are eliminated
- Data is saved and managed on a PC
- Designs can be implemented from planning stage
- Overall reduction in man hours spend on the job

Disadvantages



- Line-of-sight (*LOS*) is required for long distance (5-30 mile) connections.
- Heavy rains can disrupt the service.
- Other wireless electronics in the vicinity can interfere with the WiMAX connection and cause a reduction in data throughput or even a total disconnect.



GPS Surveying

The Global Positioning System (GPS) is a satellite-based navigation and surveying system for determination of precise position and time, using radio signals from the satellites, in realtime or in post-processing mode. GPS is being used all over the world for numerous navigational and positioning applications, including navigation on land, in air and on sea, determining the precise coordinates of important geographical features as an essential input to mapping and Geographical Information System (GIS), along with its use for precise cadastral surveys, vehicle guidance in cities and on highways using GPS-GIS integrated systems, earthquake and landslide monitoring, etc. In India also, GPS is being used for numerous applications in diverse fields like aircraft and ship navigation, surveying, geodetic control networks, crustal deformation studies, cadastral surveys, creation of GIS databases, time service, etc., by various organisations.

GPS is primarily a navigation system for real-time positioning. However, with the transformation from the ground-to-ground survey measurements to ground-to-space measurements made possibly by GPS, this technique overcomes the numerous limitations of terrestrial surveying methods, like the requirement of intervisibility of survey stations, dependability on weather, difficulties in night observations, etc.. These advantages over the conventional techniques, and the economy of operations make GPS the most promising surveying technique of the future. With the well-established high accuracy achievable with GPS in positioning of points separated by few hundreds of meters to hundreds of km, this unique surveying technique has found important applications in diverse fields.

Errors and uncertainty

Positions are the products of measurements. All measurements contain some degree of error. Errors are introduced in the original act of measuring locations on the Earth surface. Errors are also introduced when second- and third-generation data is produced, say, by scanning or digitizing a paper map.
In general, there are three sources of error in measurement: human beings, the environment in which they work, and the measurement instruments they use.

- Human errors include mistakes, such as reading an instrument incorrectly, and judgments. Judgment becomes a factor when the phenomenon that is being measured is not directly observable (like an aquifer), or has ambiguous boundaries (like a soil unit).
- Environmental characteristics, such as variations in temperature, gravity, and magnetic declination, also result in measurement errors.
- Instrument errors follow from the fact that space is continuous. There is no limit to how precisely a position can be specified. Measurements, however, can be only so precise. No matter what instrument, there is always a limit to how small a difference is detectable. That limit is called resolution.

SURVEYING WITH GPS

Within the span of few years of its operation, GPS has truly revolutionized the field of surveying, with its potential to replace many conventional surveying techniques in use today. The different methods of surveying with GPS will be briefly described here, along with a review of GPS instrumentation and method of computation of geodetic and map coordinates from the GPS observations. 3.1 Methods of Observations The different methods of observations with GPS include, absolute positioning, relative positioning in translocation mode, relative positioning using differential GPS technique, and kinematic GPS surveying technique. 3.1.1 Absolute Positioning In the absolute positioning mode, the absolute coordinates of the antenna position (centred over the survey station) are determined using single GPS receiver, by a method similar to the resection method used in plane tabling. The pseudo ranges (the satellite-antenna range, contaminated by the receiver clock bias) from minimum four satellites are observed at the given epoch, from which the four unknown parameters - the 3-D position of the antenna (x, y, z) and the receiver clock error can be determined. The accuracy of the position obtained from this method depends upon the accuracy of the time and position messages received from the satellites. With the selective availability operational, the accuracy of absolute positioning in real-time was limited to about 100 metres, which has now improved to a about 10 to 20 metres, since the SA is switched-off. This can be further improved to few centimetres level by using post-processed satellite orbit information in the post-processing mode. The accuracy of absolute positioning with GPS is limited mainly due to the high orbit of the satellites. However, very few applications require absolute position in real time.

Relative Positioning

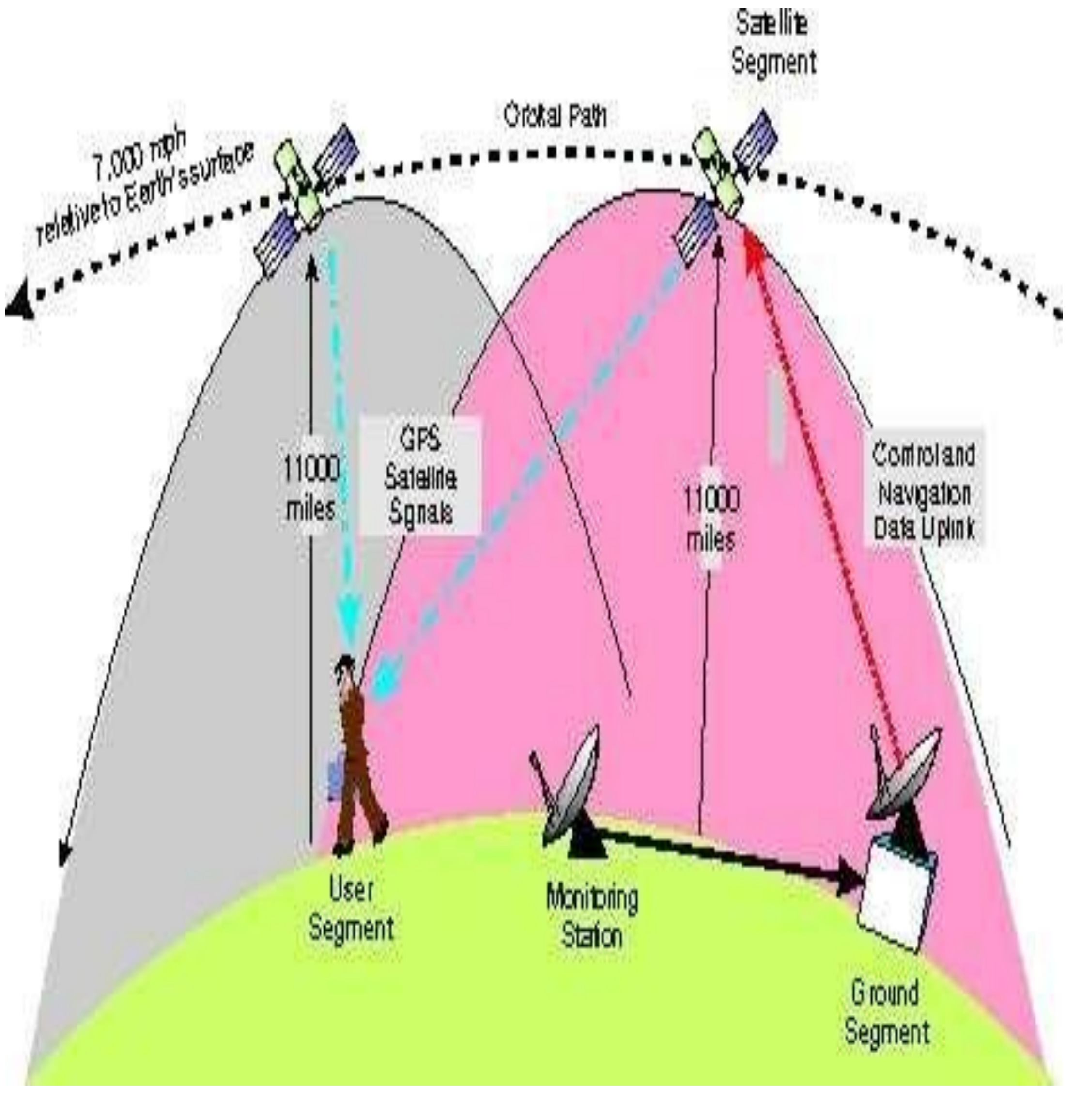
In the translocation mode, with two or more GPS receivers observing the same satellites simultaneously, many common errors, including the major effect of SA get cancelled out, yielding the relative positions of the two or more observing stations to a very high level of accuracy. The length of the baseline between two stations, and also the absolute position of one of the stations, if accurate position of the other station is known, can be obtained to cmlevel accuracy, using carrier phase observations. In differencing mode of observations, using single difference (difference of carrier phase observations from two receivers to the same satellite), double difference (between observations from two receivers to two satellites) and triple difference (difference of double differences over two time epochs), effect of many errors such as receiver and satellite clock errors etc., can be minimised. Use of dual frequency observations (both L1 and L2 frequencies) eliminates the major part of ionosphere effect on the signal, thus improving the accuracy of positioning. With accurate satellite orbit information, and use of such refined data-processing and modelling techniques, few mm to cmlevel accuracy is possible even in regional or global scale surveys.

Differential GPS

A modification of the relative positioning method is the differential GPS (DGPS) technique, where one of the two receivers observing simultaneously is equipped with a transmitter and other receiver(s) can receive the messages given by this transmitter. The transmitting receiver is kept fixed on a point whose location is known to high degree of accuracy. Based upon this position, the receiver computes corrections to the range/phase observations from a GPS satellite, and transmits them to the other receiver, which can apply these corrections to improve the accuracy of its own position computed from GPS observations. Such a system is suited for applications such as vehicle guidance system, locating fishing boats close to the seashore, etc. The limited range of the transmitter restricts the use of such system to few km.

Kinematic GPS

In the Kinematic GPS technique, one of the receivers is in relative motion with respect to the other receiver, having been mounted either on a vehicle, ship or aircraft. Even with the difficulties encountered in obtaining the constantly changing position of the moving receiver, the method also offers some advantages over static surveying, including the ease with which the ambiguity resolution (estimating the whole number of wavelengths in the phase observable) can be done. This technique has a number of important applications, including ship and aircraftnavigation, photogrammetric survey control, etc.



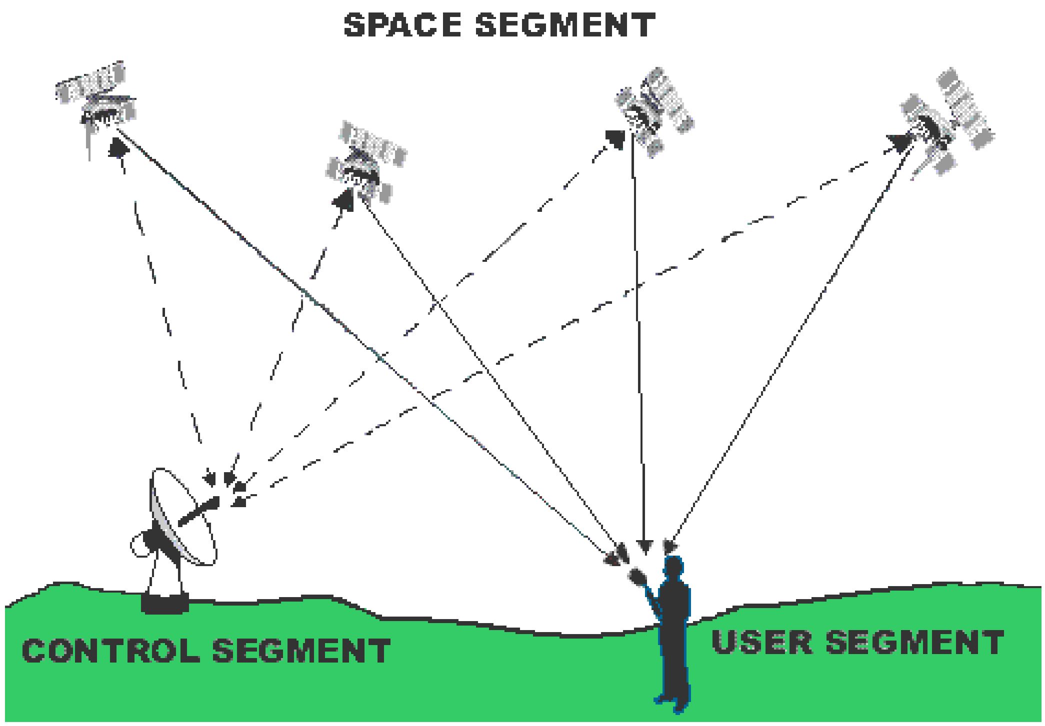
GPS Segments

The Global Positioning System basically consists of three segments:

- Space Segment
- Control Segment
- User Segment.

Space Segment

The Space Segment contains 24 satellites, in 12-hour near-circular orbits at altitude of about 20000 km, with inclination of orbit 55°. The constellation ensures at least 4 satellites in view from any point on the earth at any time for 3-D positioning and navigation on world-wide basis. The three axis controlled, earth-pointing satellites continuously transmit navigation and system data comprising predicted satellite ephemeris, clock error etc., on dual frequency L1 and L2 bands.



Control segment

This has a Master Control Station (MCS), few Monitor Stations (MSs) and an Up Load Station (ULS). The MSs are transportable shelters with receivers and computers; all located in U.S.A., which passively track satellites, accumulating ranging data from navigation signals. This is transferred to MCS for processing by computer, to provide best estimates of satellite position, velocity and clock drift relative to system time. The data thus processed generates refined information of gravity field influencing the satellite motion, solar pressure parameters, position, clock bias and electronic delay characteristics of ground stations and other observable system influences. Future navigation messages are generated from this and loaded into satellite memory once a day via ULS which has a parabolic antenna, a transmitter and a computer. Thus, role of Control Segment is:

- To estimate satellite [space vehicle (SV)] ephemerides and atomic clock behaviour.
- To predict SV positions and clock drifts.
- To upload this data to SVs.

User Segment

The user equipment consists of an antenna, a receiver, a data-processor with software and a control/display unit. The GPS receiver measures the pseudo range, phase and other data using navigation signals from minimum 4 satellites and computes the 3-D position, velocity and system time. The position is in geocentric coordinates in the basic reference coordinate system: World Geodetic reference System 1984 (WGS 84), which are converted and displayed as geographic, UTM, grid, or any other type of coordinates. Corrections like delay due to ionospheric and tropospheric refraction, clock errors, etc. are also computed and applied by the user equipment / processing software.

MODULE-IV
PHOTOGRAMMETRIC SURVEYING

Photogram metric surveying or photogrammetry is the science and art of obtaining accurate measurements by use of photographs, for various purposes such as the construction of plan metric and topographic maps, classification of soils, interpretation of geology, acquisition of military intelligence and the preparation of composite pictures of the ground. The photographs are taken either from the air or from station on the ground. Terrestrial photogrammetry is that Brach of photogrammetry wherein photographs are taken from a fixed position on or near the ground. Aerial photogrammetry is that branch of photogrammetry wherein the photographs are taken by a camera mounted in an aircraft flying over the area. Mapping from aerial photography is the best mapping procedures yet developed for large projects, and are invaluable for military intelligence. The major users of aerial mapping methods are the civilian and military mapping agencies of the Government.

Principles behind terrestrial photogrammetry

The principle of terrestrial photogrammetry was improved upon and perfected by Capt. Deville, then Surveyor General of Canada in 1888. In terrestrial photogrammetry, photographs are taken with the camera supported on the ground. The photographs are taken by means of a photo theodolite which is a combination of a camera and a theodolite. Maps are then compiled from the photographs. The principle underlying the method of terrestrial photogrammetry is exactly similar to that of plane table surveying, i.e. if the directions of same objects photographed from two extremities of measured base are known, their position can be located by the intersection of two rays to the same object. However, the difference between this and plane tabling is that more details are at once obtained from the photographs and their subsequent plotting etc. is done by the office while in plane tabling all the detailing is done in the field itself. Thus in Fig , A and B are the two stations at the ends of base AB. The arrows indicate the directions of horizontal pointing (in plan) of the camera. For each pair of pictures taken from the two ends, the camera axis is kept parallel to each other. From economy and speed point of view, minimum number of photographs should be used to cover the whole area and to achieve this, it is essential to select the best positions of the camera stations. A thorough study of the area should be done from the existing maps, and a ground reconnaissance should be made. The selection of actual stations depends upon the size and ruggedness of the area to be surveyed. The camera should be directed downward rather than upward, and the stations should be at the higher points on the area. The terrestrial photogrammetry can be divided into two branches:

1. Plane-table photogrammetry.
2. Terrestrial stereo photogrammetry

The plane table photogrammetry consists essentially in taking a photograph of the area to be mapped from each of the two or three stations. The photograph perpendiculars may be oriented at any angle to the base, but usually from an acute angle with the latter. The main difficulty arises in the identifications of image points in a pair of photographs. In the case of homogeneous areas of sand or grass, identification becomes impossible. The principles of stereo photogrammetry, however, produced the remedy. In terrestrial stereo photogrammetry, due to considerable improvement of accuracy obtained by the stereoscopic measurement of pairs of photographs, the camera base and the angles of intersection of the datum rays to the points to be measured can be considerably reduced since the camera axes at the two stations exhibit great similarity to each other. The image points which are parallactically displaced relative to each other in the two photographs are fused to a single spatial image by the stereoscopic measurement.

Photogrammetry can be defined as the science of making reliable measurements using photographs or digital photo imagery to locate features on or above the surface of the earth. The end result produces the coordinate (X, Y, and Z) position of a particular point, planimetric feature, or 3-D graphic representation of the terrain.

Photogrammetry has evolved into a reliable substitution of ground surveying activities when large area mapping is necessary. It can relieve survey crews of the most tedious, time consuming tasks required to produce topographic maps and Digital Terrain Models (DTMs). Ground survey methods will always remain an indispensable part of Photogrammetry and are not replaceable by the photogrammetric process.

Photogrammetric Advantages

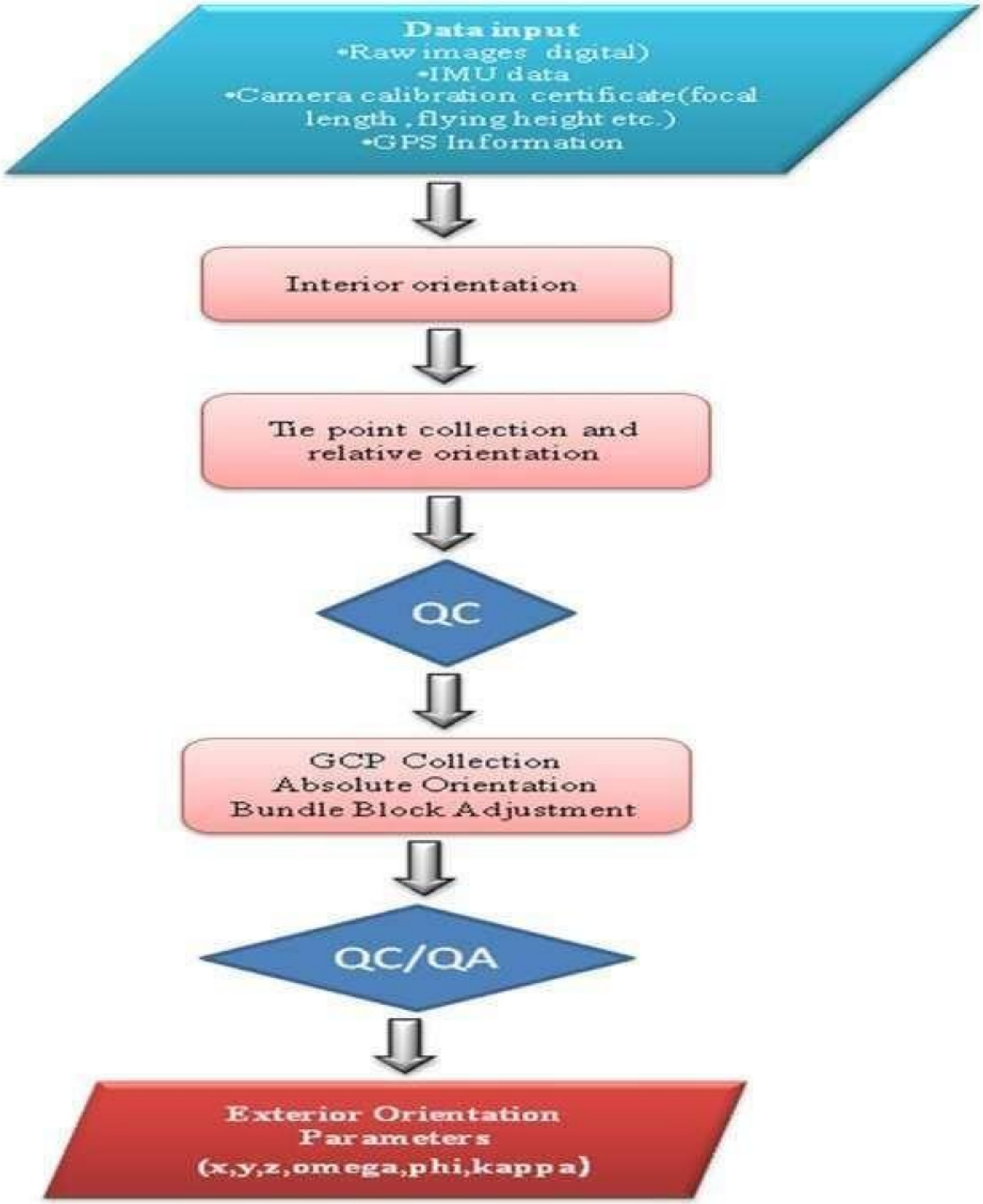
- Aerial imagery provides a permanent record of the conditions as they existed at the time the photograph was taken.
- The imagery can be used to convey information to the general public, local, state or federal agencies.
- Terrain data and mapping features can be extracted from stereo image models with little effort and at a low cost.
- Large area mapping and digital terrain models can be accomplished quicker and at a lower cost when compared to ground survey methods.
- Photogrammetry can be used in locations that are difficult or impossible to access from the ground.
- If information must be re-surveyed or re-evaluated, it is not necessary to perform expensive field work. The image stereo model can be re-loaded and measurements verified and/or additional information compiled in a timely manner.

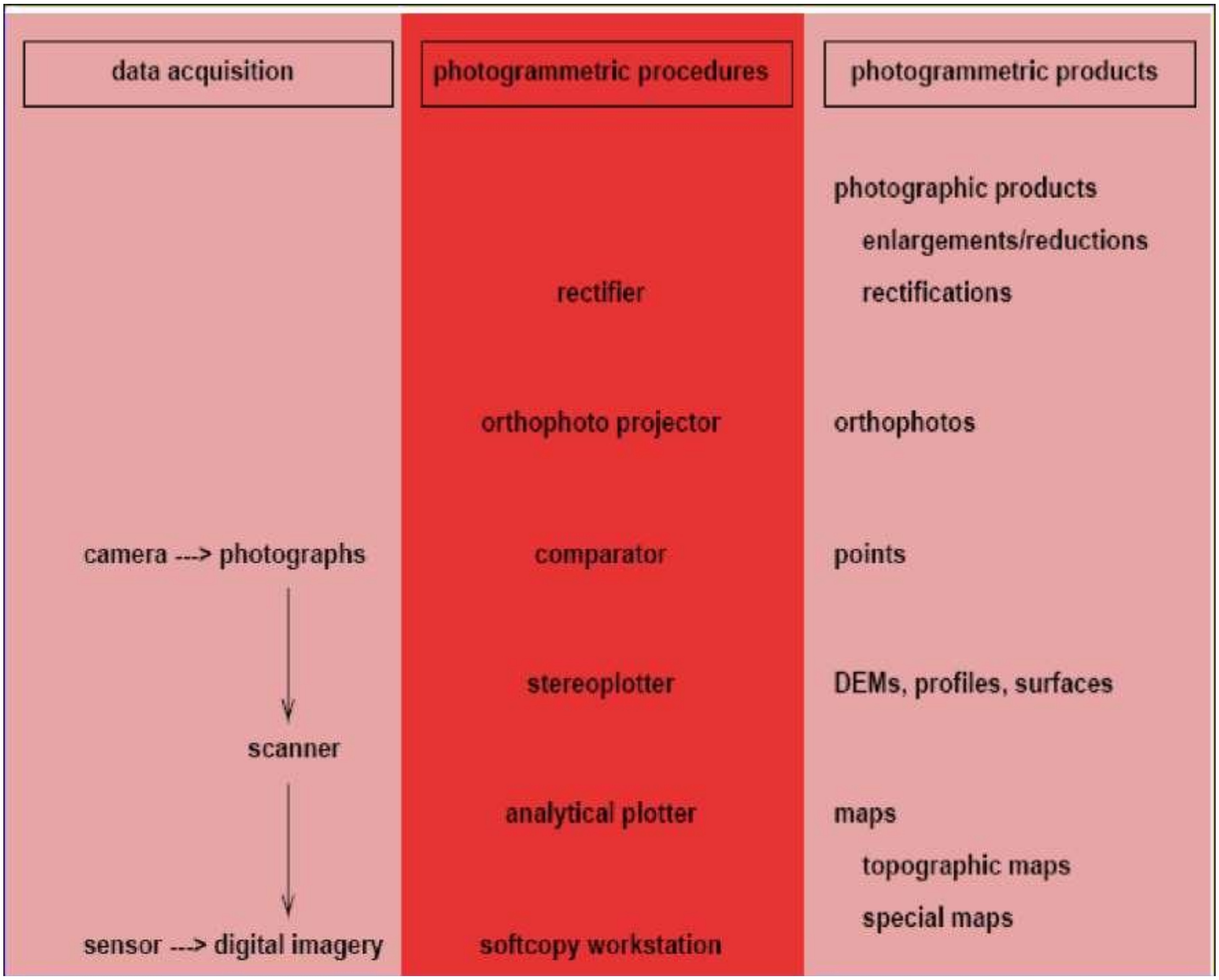
Photogrammetric Disadvantages

- Seasonal weather patterns that produce increased wind and cloud cover may hamper the ability to perform the mission.
- Solar conditions such as sun angles less than 30° above the horizon will cast long shadows. Sun angles greater than 45° will produce sun spots on the image.
- It may be difficult or impossible to collect measurements in areas with dark shadows, dense vegetation, snow, water, or overhanging features.

Process flow

- Raw data form client (scans)
- Aerial triangulation
- Data capturing
- Dem genaration
- Contour genaration
- Orthophoto generation


Data input
•Raw images digital)
•IMU data
•Camera calibration certificate(focal length , flying height etc.)
•GPS Information
Interior orientation
Tie point collection and relative orientation
QC
GCP Collection
Absolute Orientation
Bundle Block Adjustment
QC/QA
Exterior Orientation Parameters
(x,y,z,omega,phi,kappa)



The Data Preparation

- Buildings
- Transportation Features
- Hydro Features
- Utilities
- Vegetation
- Breaklines
- DTM points
- Bridges

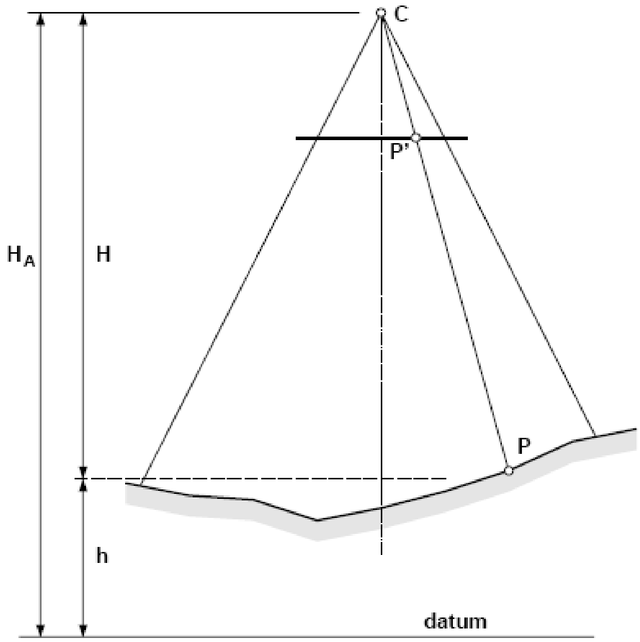


Figure 4.4: Flight height, flight altitude and scale of aerial photograph.

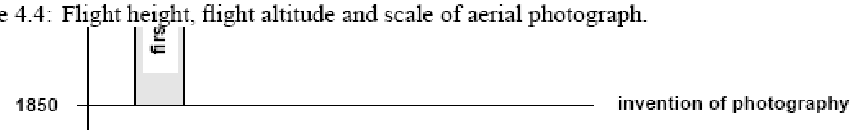


Figure 1.5: Major photogrammetric phases as a result of technological innovations.

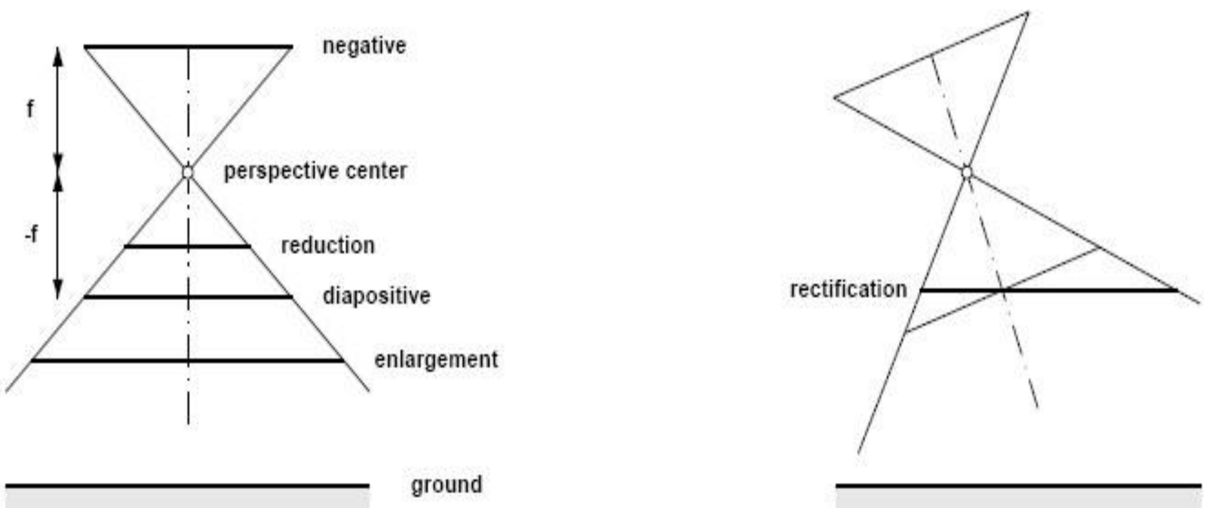
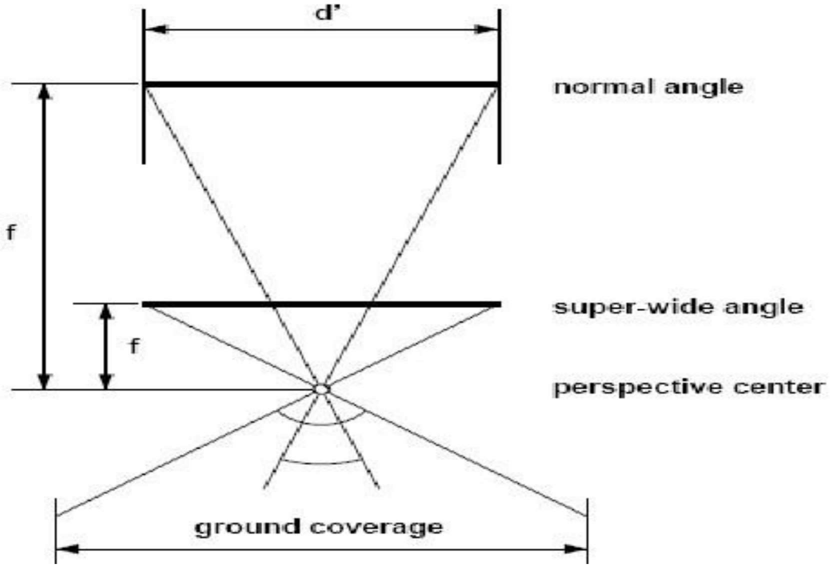


Figure 1.4: Negative, diapositive, enlargement reduction and plane rectification.

An airplane flying with velocity v advances by a distance $D = v\,t$ during the exposure time t. Since the object on the ground is stationary, its image moves by a



distance $d = D/m$ where m is the photo scale. We have

$$m_b = \frac{c}{H} \qquad d = \frac{v\,t}{m} = \frac{v\,t\,f}{H}$$

with f the focal length and H the flying height.
Example:

exposure time t	1/300 sec
velocity v	300 km/h
focal length f	150 mm
flying height H	1500 m
image motion d	28 μm

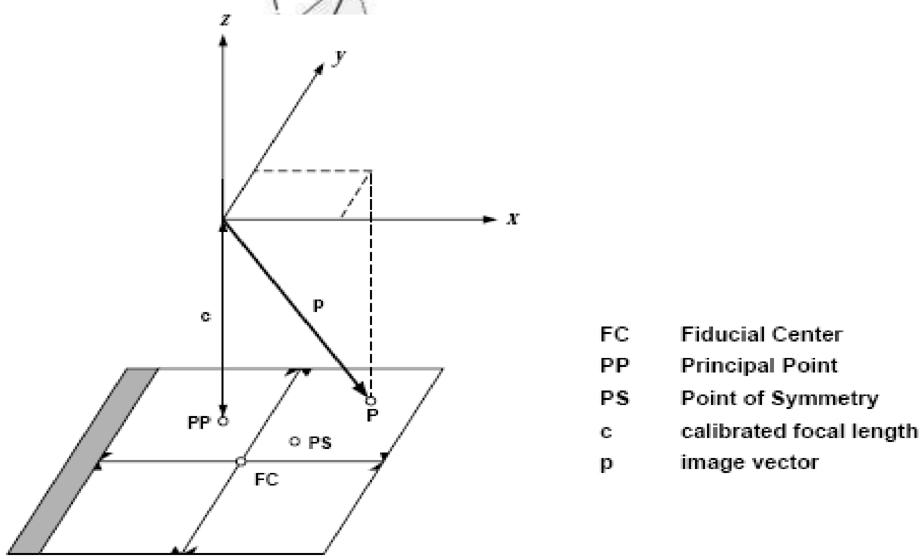


Figure 5.2: Definition of the photo-coordinate system.

4.3.3 Photo scale

We use the representative fraction for scale expressions, in form of a ratio, e.g. 1 : 5,000. As illustrated in Fig. 4.4 the scale of a near vertical photograph can be approximated by

$$m_b = \frac{c}{H} \tag{4.1}$$

where m_b is the *photograph scale number*, c the calibrated focal length, and H the *flight height* above mean ground elevation. Note that the flight height H refers to the average ground elevation. If it is with respect to the datum, then it is called *flight altitude* H_A, with $H_A = H + h$.

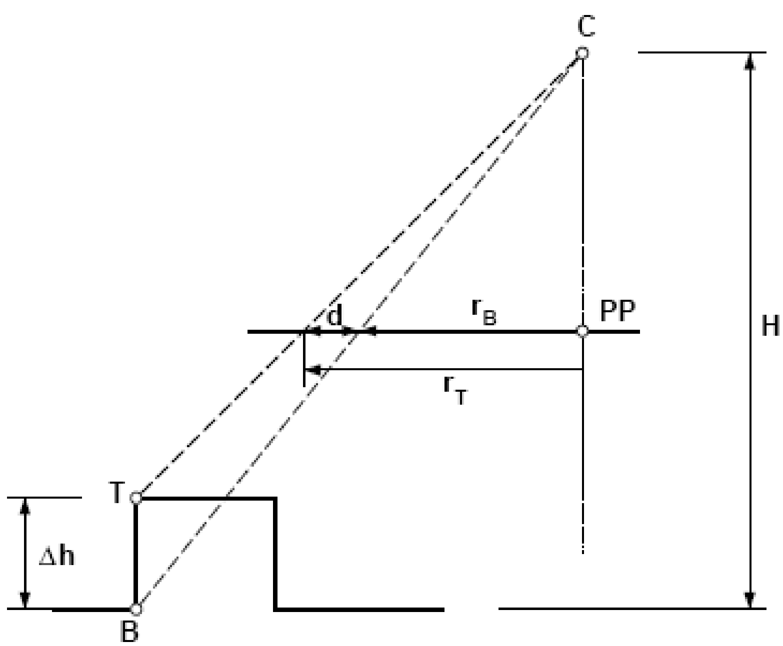
The photograph scale varies from point to point. For example, the scale for point P can easily be determined as the ratio of image distance CP' to object distance CP by

$$m_P = \frac{CP'}{CP} \tag{4.2}$$

$$CP\prime = \sqrt{x_P^2 + y_P^2 + c^2} \tag{4.3}$$

$$CP = \sqrt{(X_P - X_C)^2 + (Y_P - Y_C)^2 + (Z_P - Z_C)^2} \tag{4.4}$$

Relief Displacement

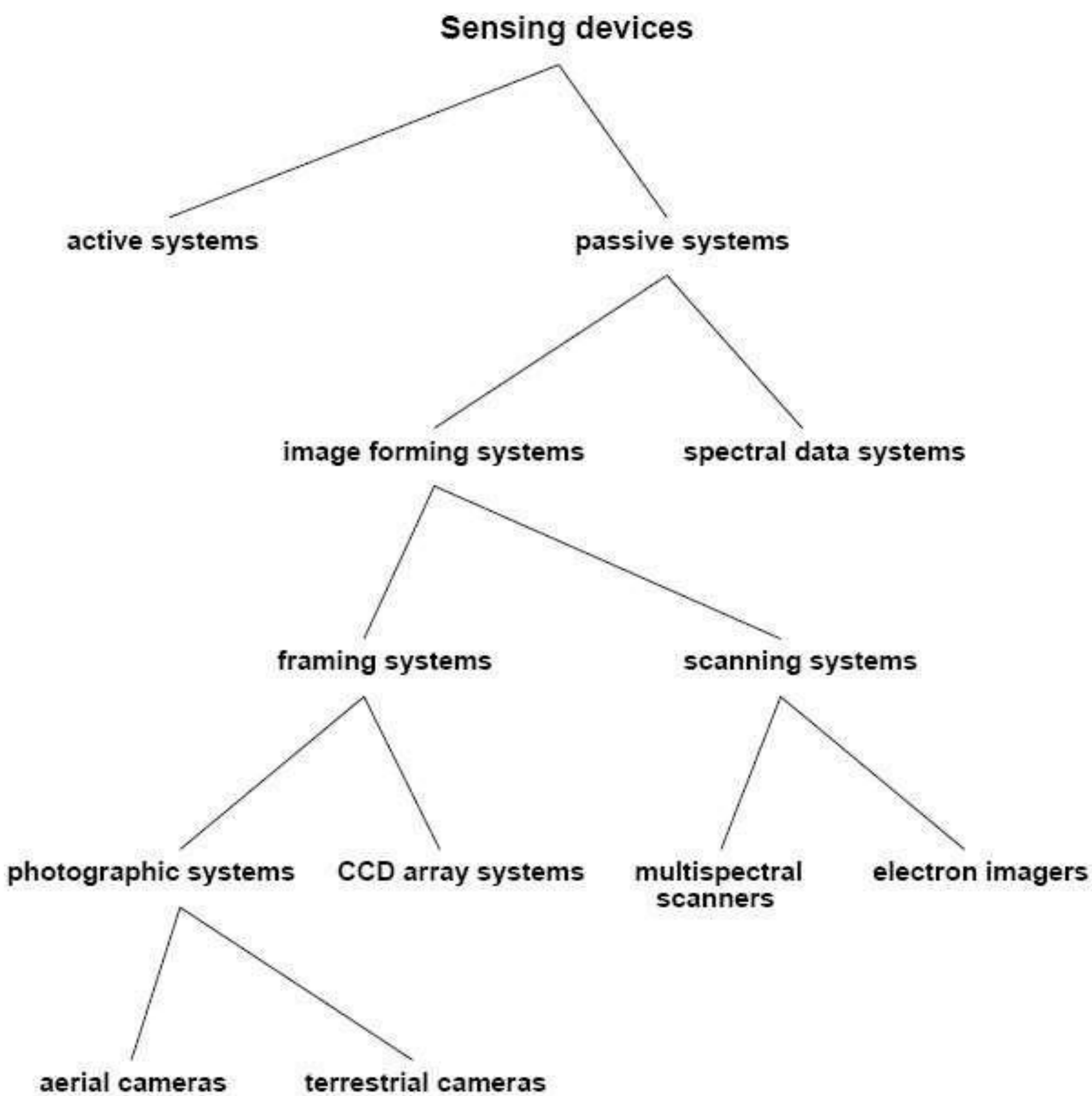


The magnitude of relief displacement for a true vertical photograph can be determined by the following equation

$$d = \frac{r\ \Delta h}{H} = \frac{r'\ \Delta h}{H - \Delta h} \tag{4.5}$$

where $r = \sqrt{x_T^2 + y_T^2}$, $r' = \sqrt{x_B^2 + y_B^2}$, and Δh the elevation difference of two points on a vertical. Eq. 4.5 can be used to determine the elevation Δh of a vertical object

$$h = \frac{d\ H}{r} \tag{4.6}$$



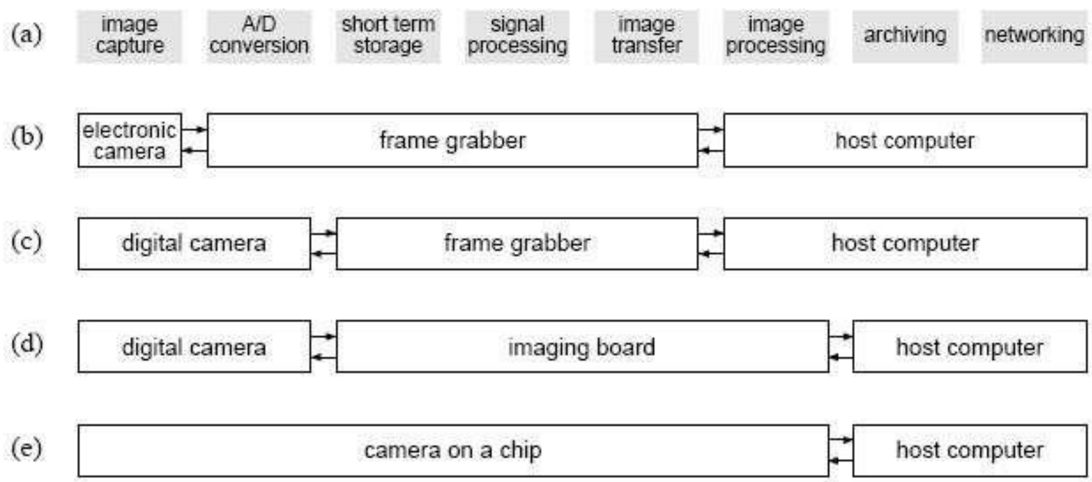
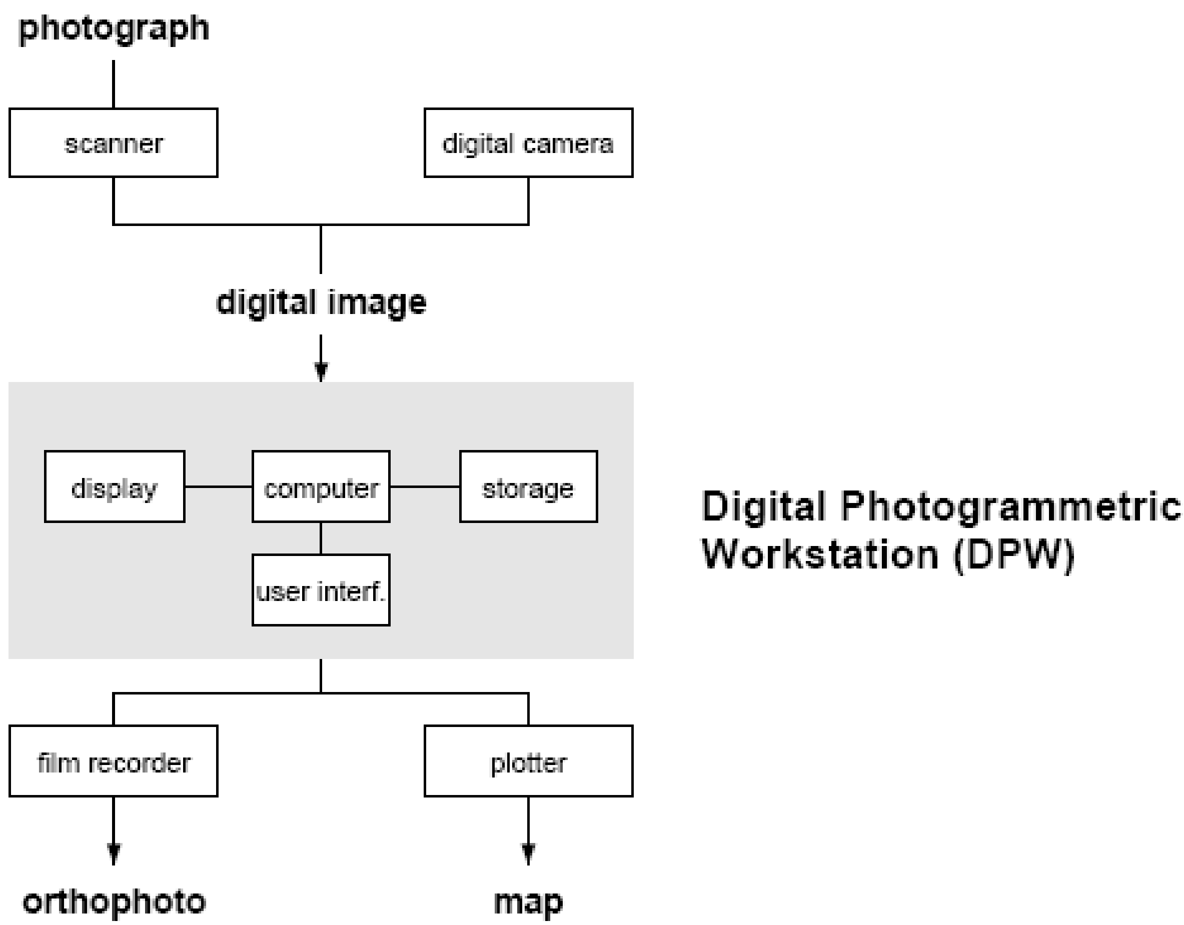


Figure 3.2: Functional block diagram of a solid-state camera. A real camera may not have all components. The diagram is simplified, e.g. external signals received by the camera are not shown.




Stereo-satellite imagery

MODULE-V
REMOTE SENSING

Remote sensing is an art and science of obtaining information about an object or feature without physically coming in contact with that object or feature. Humans apply remote sensing in their day-to-day business, through vision, hearing and sense of smell. The data collected can be of many forms: variations in acoustic wave distributions (e.g., sonar), variations in force distributions (e.g., gravity meter), variations in electromagnetic energy distributions (e.g., eye) etc. These remotely collected data through various sensors may be analyzed to obtain information about the objects or features under investigation. In this course we will deal with remote sensing through electromagnetic energy sensors only.
Thus, remote sensing is the process of inferring surface parameters from measurements of the electromagnetic radiation (EMR) from the Earth's surface. This EMR can either be reflected or emitted from the Earth's surface. In other words, remote sensing is detecting and measuring electromagnetic (EM) energy emanating or reflected from distant objects made of various materials, so that we can identify and categorize these objects by class or type, substance and spatial distribution [American Society of Photogrammetry, 1975].

Remote sensing provides a means of observing large areas at finer spatial and temporal frequencies. It finds extensive applications in civil engineering including watershed studies, hydrological states and fluxes simulation, hydrological modeling, disaster management services such as flood and drought warning and monitoring, damage assessment in case of natural calamities, environmental monitoring, urban planning etc.

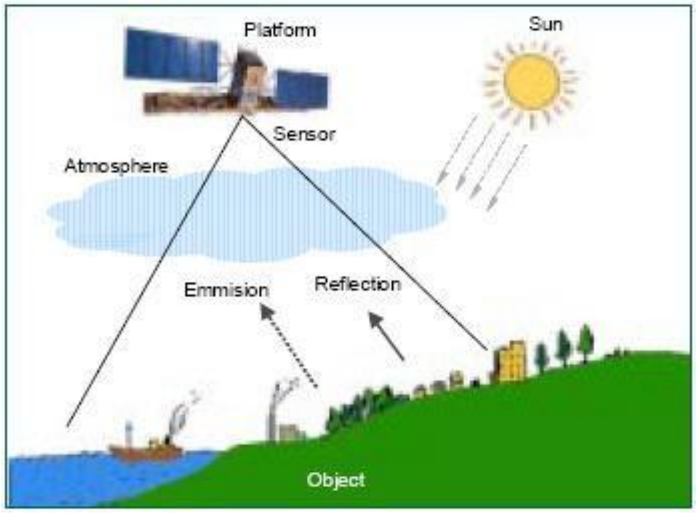
Electromagnetic Energy
Electromagnetic energy or electromagnetic radiation (EMR) is the energy propagated in the form of an advancing interaction between electric and magnetic fields (Sabbins, 1978). It travels with the velocity of light. Visible light, ultraviolet rays, infrared rays, heat, radio waves, X-rays all are different forms of electro-magnetic energy.
Electro-magnetic energy (E) can be expressed either in terms of frequency (f) or wave length (λ) of radiation as

$$E = h\,c\,f \quad \text{or} \quad h\,c / \lambda \qquad (1)$$

where h is Planck's constant (6.626 x 10-34 Joules-sec),
c is a constant that expresses the celerity or speed of light (3 x 108 m/sec),
f is frequency expressed in Hertz and
λ is the wavelength expressed in micro meters (1μm = 10-6 m).

As can be observed from equation (1), shorter wavelengths have higher energy content and longer wavelengths have lower energy content.

Distribution of the continuum of energy can be plotted as a function of wavelength (or frequency) and is known as the EMR spectrum



Schematic representation of remote sensing technique

In remote sensing terminology, electromagnetic energy is generally expressed in terms of wavelength, λ.

All matters reflect, emit or radiate a range of electromagnetic energy, depending upon the material characteristics. In remote sensing, it is the measurement of electromagnetic radiation reflected or emitted from an object, is the used to identify the target and to infer its properties.

Principles of Remote Sensing

Different objects reflect or emit different amounts of energy in different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both the material and the incident energy (angle of incidence, intensity and wavelength). Detection and discrimination of objects or surface features is done through the uniqueness of the reflected or emitted electromagnetic radiation from the object.

A device to detect this reflected or emitted electro-magnetic radiation from an object is called a “sensor” (e.g., cameras and scanners). A vehicle used to carry the sensor is called a “platform” (e.g., aircrafts and satellites).

Main stages in remote sensing are the following.

A. Emission of electromagnetic radiation
    - The Sun or an EMR source located on the platform
B. Transmission of energy from the source to the object
    - Absorption and scattering of the EMR while transmission
C. Interaction of EMR with the object and subsequent reflection and emission
D. Transmission of energy from the object to the sensor
E. Recording of energy by the sensor
    - Photographic or non-photographic sensors
F. Transmission of the recorded information to the ground station
G. Processing of the data into digital or hard copy image
H. Analysis of data

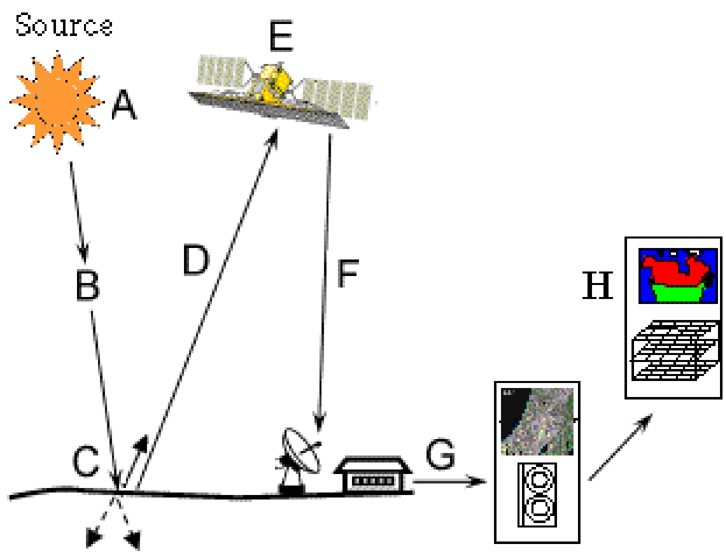


Fig.3 Important stages in remote sensing

Passive/ Active Remote Sensing

Depending on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

In the case of passive remote sensing, source of energy is that naturally available such as the Sun. Most of the remote sensing systems work in passive mode using solar energy as the source of EMR. Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or space borne platforms. In order to ensure ample signal strength received at the sensor, wavelength / energy bands capable of traversing through the atmosphere, without significant loss through atmospheric interactions, are generally used in remote sensing

Any object which is at a temperature above 0o K (Kelvin) emits some radiation, which is approximately proportional to the fourth power of the temperature of the object. Thus the Earth also emits some radiation since its ambient temperature is about 300o K. Passive sensors can also be used to measure the Earth's radiance but they are not very popular as the energy content is very low.

In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform. Most of the microwave remote sensing is done through active remote sensing.

As a simple analogy, passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with camera having built-in flash (Fig. 5).

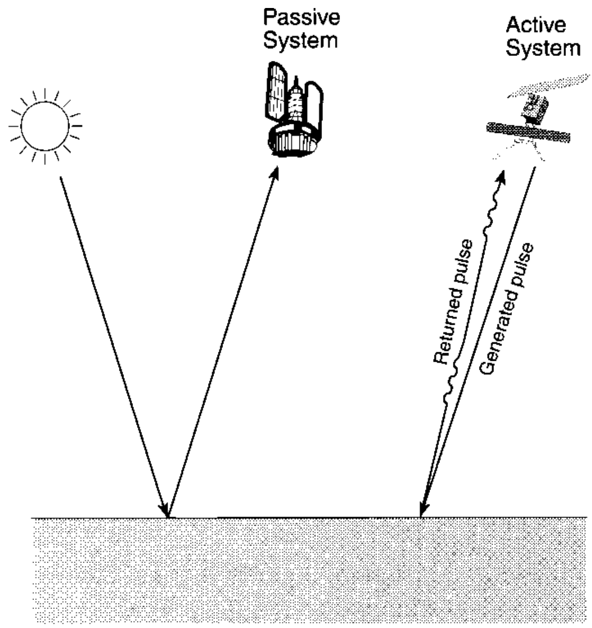


Fig. 5 Schematic representation of passive and active remote sensing

Remote SensingPlatforms

Remote sensing platforms can be classified as follows, based on the elevation from the Earth’s surface at which these platforms areplaced.

- Ground level remotesensing
    - Ground level remote sensors are very close to theground
    - They are basically used to develop and calibrate sensors for different features on the Earth’ssurface.
- Aerial remotesensing
    - Low altitude aerial remotesensing
    - High altitude aerial remotesensing
- Space borne remotesensing
    - Spaceshuttles
    - Polar orbitingsatellites
    - Geo-stationarysatellites

From each of these platforms, remote sensing can be done either in passive or active mode.

Airborne and Space-borne Remote Sensing

In airborne remote sensing, downward or sideward looking sensors mounted on aircrafts are used to obtain images of the earth's surface. Very high spatial resolution images (20 cm or less) can be obtained through this. However, it is not suitable to map a large area. Less coverage area and high cost per unit area of ground coverage are the major disadvantages of airborne remote sensing. While airborne remote sensing missions are mainly one-time operations, space-borne missions offer continuous monitoring of the earth features. LiDAR, analog aerial photography, videography, thermal imagery and digital photography are commonly used in airborne remote sensing.

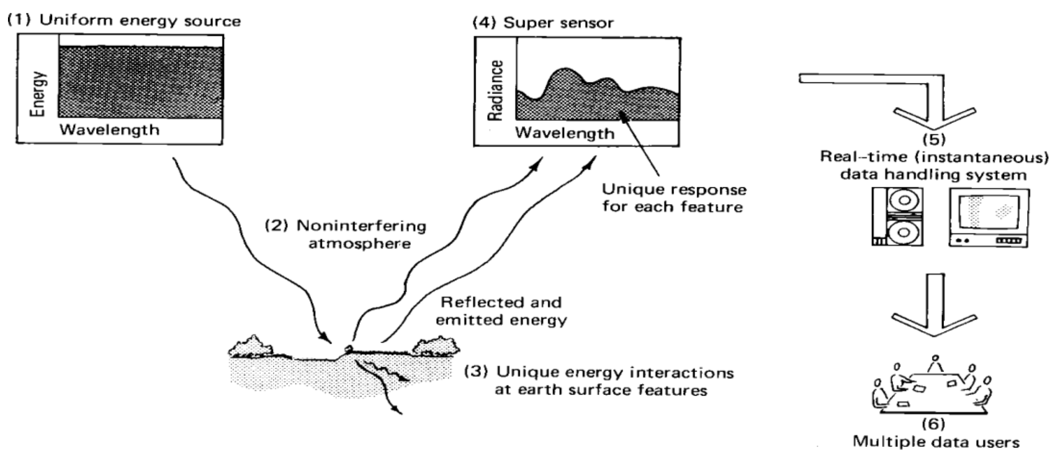
In space-borne remote sensing, sensors mounted on space shuttles or satellites orbiting the Earth are used. There are several remote sensing satellites (Geostationary and Polar

orbiting) providing imagery for research and operational applications. While Geostationary or Geosynchronous Satellites are used for communication and meteorological purposes, polar orbiting or sun-synchronous satellites are essentially used for remote sensing. The main advantages of space-borne remote sensing are large area coverage, less cost per unit area of coverage, continuous or frequent coverage of an area of interest, automatic/ semiautomatic computerized processing and analysis. However, when compared to aerial photography, satellite imagery has a lower resolution.
Landsat satellites, Indian remote sensing (IRS) satellites, IKONOS, SPOT satellites, AQUA and TERRA of NASA and INSAT satellite series are a few examples.

Ideal Remote Sensing System

The basic components of an ideal remote sensing system include:

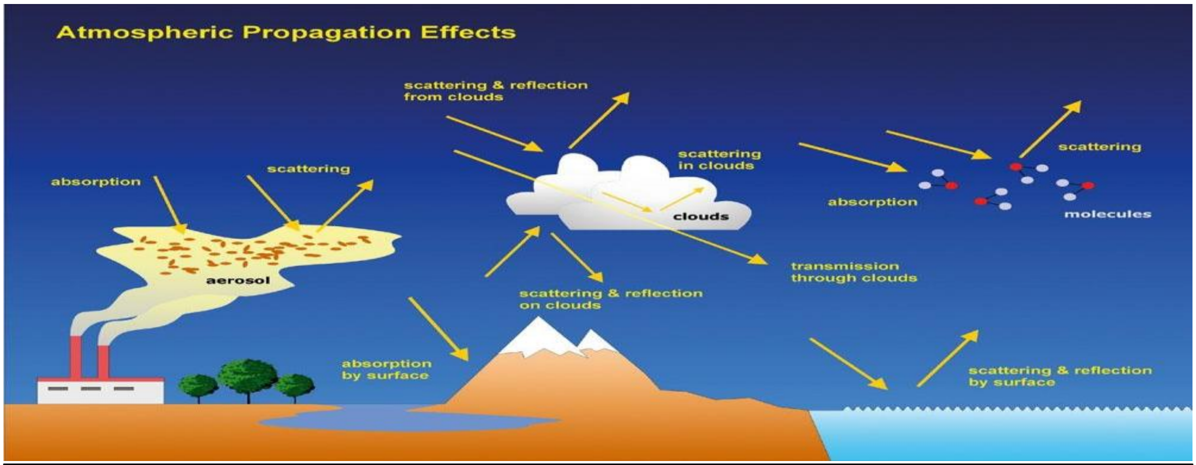
1. A Uniform Energy Source which provides energy over all wavelengths, at a constant, known, high level of output
2. A Non-interfering Atmosphere which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.
3. A Series of Unique Energy/Matter Interactions at the Earth's Surface which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.
4. A Super Sensor which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.
5. A Real-Time Data Handling System which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a particular terrain and hence provide insight into its physical chemical-biological state.
6. Multiple Data Users having knowledge in their respective disciplines and also in remote sensing data acquisition and analysis techniques. The information collected will be available to them faster and at less expense. This information will aid the users in various decision making processes and also further in implementing these decisions.



Characteristics of Real Remote Sensing Systems

Real remote sensing systems employed in general operation and utility have many shortcomings when compared with an ideal system explained above.

1. Energy Source: The energy sources for real systems are usually non-uniform over various wavelengths and also vary with time and space. This has major effect on the passive remote sensing systems. The spectral distribution of reflected sunlight varies both temporally and spatially. Earth surface materials also emit energy to varying degrees of efficiency. A real remote sensing system needs calibration for source characteristics.
2. The Atmosphere: The atmosphere modifies the spectral distribution and strength of the energy received or emitted (Fig. 8). The effect of atmospheric interaction varies with the wavelength associated, sensor used and the sensing application. Calibration is required to eliminate or compensate these atmospheric effects.
3. The Energy/Matter Interactions at the Earth's Surface: Remote sensing is based on the principle that each and every material reflects or emits energy in a unique, known way. However, spectral signatures may be similar for different material types. This makes differentiation difficult. Also, the knowledge of most of the energy/matter interactions for earth surface features is either at elementary level or even completely unknown.
4. The Sensor: Real sensors have fixed limits of spectral sensitivity i.e., they are not sensitive to all wavelengths. Also, they have limited spatial resolution (efficiency in recording spatial details). Selection of a sensor requires a trade-off between spatial resolution and spectral sensitivity. For example, while photographic systems have very good spatial resolution and poor spectral sensitivity, non-photographic systems have poor spatial resolution.
5. The Data Handling System: Human intervention is necessary for processing sensor data; even though machines are also included in data handling. This makes the idea of real time data handling almost impossible. The amount of data generated by the sensors far exceeds the data handling capacity.
6. The Multiple Data Users: The success of any remote sensing mission lies on the user who ultimately transforms the data into information. This is possible only if the user understands the problem thoroughly and has a wide knowledge in the data generation. The user should know how to interpret the data generated and should know how best to use them.



Interactions of the electromagnetic energy with the atmosphere

Advantages and Disadvantages of Remote Sensing

Advantages of remote sensing are:

a) Provides data of large areas

b) Provides data of very remote and inaccessible regions

c) Able to obtain imagery of any area over a continuous period of time through which the any anthropogenic or natural changes in the landscape can be analyzed

d) Relatively inexpensive when compared to employing a team of surveyors

e) Easy and rapid collection of data

f) Rapid production of maps for interpretation

Disadvantages of remote sensing are:

a) The interpretation of imagery requires a certain skill level

b) Needs cross verification with ground (field) survey data

c) Data from multiple sources may create confusion

d) Objects can be misclassified or confused

e) Distortions may occur in an image due to the relative motion of sensor and source