LECTURES NOTE

LAND SURVEY - I

4th SEMESTER

DIPLOMA (CIVIL ENGINEERING)

Sri. Aditya Ranjan Patra

DEPARTMENT OF CIVIL ENGINEERING

BHUBANANANDA ORISSA SCHOOL OF ENGINEERING, CUTTACK

Gmail: patra.aditya134@gmail.com

Th3. LAND SURVEY – I

Name of the Course: Diploma in Civil Engineering			
Course code:		Semester	4th
Total Period:	75	Examination	3 hrs
Theory periods:	5P/week	Class Test:	20
Maximum marks:	100	End Semester Examination:	80

A. RATIONALE

Survey is an essential prerequisite for all types of civil construction activities. This course aims to provide knowledge in area of plane survey and the survey instruments. Besides, the course aims to provide students in map reading and area computations from survey data.

B. COURSE OBJECTIVES

On completion of the course students will be able to

1. Define various survey terminology and carryout necessary corrections for errors
2. Comprehend the principle, purpose, equipment and error corrections in chain and compass surveying
3. Comprehend the principle, purpose, equipment and error corrections in plane table and theodolite surveying
4. Comprehend the map nomenclature and apply skills in map interpretation
5. Gather skill towards leveling and contouring with knowledge of purpose and different methods thereof
6. Compute area and volume using different numerical algebraic methods

C. Topic Wise Distribution of Periods

Chapter	Name of topics	Periods
1	Introduction To Surveying, Linear Measurements	07
2	Chaining and Chain Surveying	07
3	Angular Measurement and Compas Surveying	12
4	Map Reading Cadastral Maps & Nomenclature	07
5	Plane Table Surveying	07
6	Theodolite Surveying and Traversing:	15
7	Levelling and Contouring	15
8	Computation of Area & Volume	05

D. Course Contents

1 INTRODUCTION TO SURVEYING, LINEAR MEASUREMENTS:

1.1 Surveying: Definition, Aims and objectives
1.2 Principles of survey-Plane surveying- Geodetic Surveying- Instrumental surveying.
1.3 Precision and accuracy of measurements, instruments used for measurement of distance, Types of tapes and chains.
1.4 Errors and mistakes in linear measurement – classification, Sources of errors and remedies.
1.5 Corrections to measured lengths due to-incorrect length, temperature variation, pull, sag, numerical problem applying corrections.

2	**CHAINING AND CHAIN SURVEYING :** 2.1 Equipment and accessories for chaining 2.2 Ranging – Purpose, signaling, direct and indirect ranging, Line ranger – features and use, error due to incorrect ranging. 2.3 Methods of chaining –Chaining on flat ground, Chaining on sloping ground – stepping method, Clinometer-features and use, slope correction. 2.4 Setting perpendicular with chain & tape, Chaining across different types of obstacles –Numerical problems on chaining across obstacles. 2.5 Purpose of chain surveying, Its Principles, concept of field book. Selection of survey stations, base line, tie lines, Check lines. 2.7 Offsets – Necessity, Perpendicular and Oblique offsets, Instruments for setting offset – Cross Staff, Optical Square. 2.8 Errors in chain surveying – compensating and accumulative errors causes & remedies, Precautions to be taken during chain surveying.
3	**ANGULAR MEASUREMENT AND COMPAS SURVEYING :** 3.1 Measurement of angles with chain, tape & compass 3.2 Compass – Types, features, parts, merits & demerits, testing & adjustment of compass 3.3 Designation of angles- concept of meridians – Magnetic, True, arbitrary; Concept of bearings – Whole circle bearing, Quadrantal bearing, Reduced bearing, suitability of application, numerical problems on conversion of bearings 3.4 Use of compasses – setting in field-centering, leveling, taking readings, concepts of Fore bearing, Back Bearing, Numerical problems on computation of interior & exterior angles from bearings. 3.5 Effects of earth's magnetism – dip of needle, magnetic declination, variation in declination, numerical problems on application of correction for declination. 3.6 Errors in angle measurement with compass – sources & remedies. 3.7 Principles of traversing – open & closed traverse, Methods of traversing. 3.8 Local attraction – causes, detection, errors, corrections, Numerical problems of application of correction due to local attraction. 3.9 Errors in compass surveying – sources & remedies. Plotting of traverse – check of closing error in closed & open traverse, Bowditch's correction, Gales table
4	**MAP READING CADASTRAL MAPS & NOMENCLATURE:** 4.1 Study of direction, Scale, Grid Reference and Grid Square Study of Signs and Symbols 4.2 Cadastral Map Preparation Methodology 4.3 Unique identification number of parcel 4.4 Positions of existing Control Points and its types 4.5 Adjacent Boundaries and Features, Topology Creation and verification.
5	**PLANE TABLE SURVEYING :** 5.1 Objectives, principles and use of plane table surveying. 5.2 Instruments & accessories used in plane table surveying. 5.3 Methods of plane table surveying – (1) Radiation, (2) Intersection, (3) Traversing, (4) Resection. 5.4 Statements of TWO POINT and THREE POINT PROBLEM. Errors in plane table surveying and their corrections, precautions in plane table surveying.

6 **THEODOLITE SURVEYING AND TRAVERSING:**

6.1 Purpose and definition of theodolite surveying

6.2 Transit theodolite- Description of features, component parts, Fundamental axes of a theodolite, concept of vernier, reading a vernier, Temporary adjustment of theodolite

6.3 Concept of transiting –Measurement of horizontal and vertical angles.

6.4 Measurement of magnetic bearings, deflection angle, direct angle, setting out angles, prolonging a straight line with theodolite, Errors in Theodolite observations.

6.5 Methods of theodolite traversing with – inclined angle method, deflection angle method, bearing method, Plotting the traverse by coordinate method, Checks for open and closed traverse.

6.6 Traverse computation – consecutive coordinates, latitude and departure, Gale's traverse table, Numerical problems on omitted measurement of lengths & bearings

6.7 Closing error – adjustment of angular errors, adjustment of bearings, numerical problems

6.8 Balancing of traverse – Bowditch's method, transit method, graphical method, axis method, calculation of area of closed traverse.

7 **LEVELLING AND CONTOURING :**

7.1 Definition and Purpose and types of leveling– concepts of level surface, Horizontal surface, vertical surface, datum, R. L., B.M.

7.2 Instruments used for leveling, concepts of line of collimation, axis of bubble tube, axis of telescope, Vertical axis.

7.3 Levelling staff – Temporary adjustments of level, taking reading with level, concept of bench mark, BS, IS, FS, CP, HI.

7.4 Field data entry – level Book – height of collimation method and Rise & Fall method, comparison, Numerical problems on reduction of levels applying both methods, Arithmetic checks.

7.5 Effects of curvature and refraction, numerical problems on application of correction.

7.6 Reciprocal leveling – principles, methods, numerical problems, precise leveling.

7.7 Errors in leveling and precautions, Permanent and temporary adjustments of different types of levels.

7.8 Definitions, concepts and characteristics of contours.

7.9 Methods of contouring, plotting contour maps, Interpretation of contour maps, toposheets.

7.10 Use of contour maps on civil engineering projects – drawing cross-sections from contour maps, locating proposal routes of roads / railway / canal on a contour map, computation of volume of earthwork from contour map for simple structure.

7.11 Map Interpretation: Interpret Human and Economic Activities (i.e.: Settlement, Communication, Land use etc.), Interpret Physical landform (i.e.: Relief, Drainage Pattern etc.), Problem Solving and Decision Making

8 **COMPUTATION OF AREA & VOLUME:**

8.1 Determination of areas, computation of areas from plans.

8.2 Calculation of area by using ordinate rule, trapezoidal rule, Simpson's rule.

8.3 Calculation of volumes by prismoidal formula and trapezoidal formula, Prismoidal corrections, curvature correction for volumes.

E. SYLLABUS COVERAGE UPTO INTERNAL ASSESSMENT

Chapters 1, 2, 3, 4, 5

G. RECOMMENDED BOOKS

Sl. No	Name of Authors	Titles of Book	Name of Publisher
1	R.Subramanian	Surveying and Levelling	Oxford
2	Dr.B.C.Punmia.	Surveying,Vol.-I&II	Laxmi Publication
3	R. Agor	A text Book of Surveying & Levelling	Khanna Publishers
4	N.N Basak.	Surveying & Levelling	TMH Publishing

LAND SURVEY - I

1. INTRODUCTION TO SURVEYING, LINEAR MEASUREMENT

1.1 Definitions

Surveying - is the art of determining the relative positions of different objects on the surface of the earth by measuring the horizontal distances between them, and by preparing a map to any suitable scale. Thus, in this discipline, the measurements are taken only in the horizontal plane.

Levelling - is the art of determining the relative vertical distances of different points on the surface of the earth. Therefore, in levelling, the measurements are taken only in the vertical plane.

Ranging - The process of establishing intermediate points on a straight line between two end points is known as ranging. Ranging must be done before a survey line is chained. Ranging may be done by direct observation by the naked eye or by line ranger or by theodolite. Generally, ranging is done by the naked eye with the help of three ranging rods.

Ranging may be of two types:

1. **Direct, and**
2. **Indirect or reciprocal.**

Direct Ranging - When intermediate ranging rods are fixed on a straight line by direct observation from end stations, the process is known as direct ranging. Direct ranging is possible when the end stations are visible. The following procedure is adopted for direct ranging.

Indirect or Reciprocal Ranging - When the end stations are not invisible due to there being high ground between them, intermediate ranging rods are fixed on the line in an indirect way. This method is known, as indirect ranging or reciprocal ranging. The following procedure is adopted for indirect ranging.

Aims and Objectives

The aim of surveying is to prepare a map to show the relative positions of the objects on the surface of the earth. The map is drawn to some suitable scale. It shows the natural features of a country, such as towns, villages, roads, railways, rivers, etc. Maps may also include details of different engineering works, such as roads, railways, irrigation canals, etc.

Surveying may be used for the following various applications.

1. To prepare a topographical map which shows the hills, valleys, rivers, villages towns, forests, etc. of a country.
2. To prepare a cadastral map showing the boundaries of fields, houses and other properties.
3. To prepare an engineering map which shows the details of engineering works such as roads, railways, reservoirs, irrigation canals, etc.
4. To prepare a military map showing the road and railway communications with different parts of a country. Such a map also shows the different strategic points important for the defence of a country.
5. To prepare a contour map to determine the capacity of a reservoir and to find the best possible routes for roads, railways, etc.
6. To prepare a geological map showing areas including underground resources.
7. To prepare an archaeological map including places where ancient relics exist.

1.2 Principles of Survey

The general principles of surveying are given below:

• To work from the whole to the part, and

• To locate a new station by at least two measurements (linear or angular) from fixed reference points.

Classification of surveying

A. Primary Classification - Surveying is primarily classified as under:

1. Plane surveying
2. Geodetic surveying

1. Plane Surveying

Plane surveying, the curvature of the earth is not taken into consideration. This is because plane surveying is carried out over a small area. The line joining any two points is considered a straight line. Plane surveying is conducted by state agencies like the Irrigation Department, Railway Department, etc. Plane surveying is done on an area of less than 250 km^2.

2. Geodetic Surveying

In geodetic surveying, the curvature of the earth is taken into consideration. It is extended over a large area. The line joining any two points is considered a curved line. Geodetic surveying is conducted by the Survey of India department, and is carried out over an area exceeding 250 km^2.

B. Secondary Classification

1. Based on instruments

(a) Chain surveying,
(b) Compass surveying,
(c) Plane table surveying,
(d) Theodolite surveying,
(e) Tacheometric surveying, and
(f) Photographic surveying.

2. Based on methods

(a) Triangulation surveying, and
(b) Traverse surveying.

3. Based on nature of field

(a) Land surveying,
(b) Marine surveying, and
(c) Astronomical surveying.

Again, land surveying is divided into the following classes

1. ***Topographical surveying*,** which is done to determine the natural features of a country.
2. ***Cadastral surveying*,** which is conducted in order to determine the boundaries of fields, estates, houses, etc.
3. ***City surveying*,** which is carried out to locate the premises, streets, water supply and sanitary systems, etc.
4. ***Engineering surveying*,** which is done to prepare detailed drawings of projects involving roads, railways, etc.

1.3 Precision and Accuracy of Measurements

In surveying measurements whatever be the precision and precaution taken in measurements during some errors always creep in. Thus, it is important in surveying measurement to study about the accuracy and errors.

- Accuracy is the degree of perfection obtained.
- The errors in the surveying figures are detected by checking up the conditions of methods for surveying

The sum of interior angles of a triangle should be 180 degrees.

The sum of interior angles of a quadrilateral should be 360 degrees.
Closed traverse should really close.

- Accuracy in surveying depends on precise instruments, precise methods, good planning.

Instruments used for measurement of distance

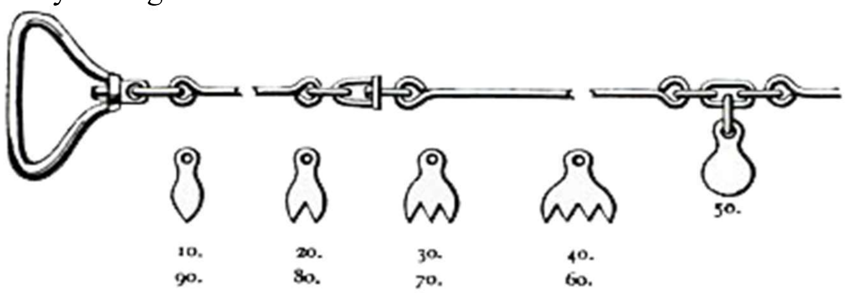
- Direct measurements
- Optical measurements
- Electronic measurements

Direct measurements – The distance is actually measured on the ground with the help of a chain or a tape or any other instruments. Pacing, passometer, pedometer, odometer, chaining is used for this method.
Optical measurements –The observations are taken through telescope and calculations are done for distances, such as in tacheometry or triangulation.
Electronic measurements – The distances are measured with instruments that relay on propagation, reflection and subsequent reception of either radio or light waves. Geodimeter and Tellurometer used for this.

Types of Tapes and chains
Chains
A chain is prepared with 100 or 150 pieces of galvanised mild steel wire of 4 mm diameter. The ends of the pieces are bent to form loops. Then the pieces are connected together with the help of three oval rings, which make the chain flexible. Two brass handles are provided at the two ends of the chain. Tallies are provided at every 10 or 25 links for facility of counting. 'One link' means the distance between the centres of adjacent middle rings.
The following are the different types of chains:

(a) Metric chain,
(b) Steel band,
(c) Engineers' chain,
(d) Gunter's chain, and
(e) Revenue chain

Metric Chain - Metric chains are available in lengths of 20 m and 30 m. The 20 m chain is divided into 100 links, each of 0.2 m. Tallies are provided at every 10 links (2 m). This chain is suitable for measuring distances along fairly level ground. You may see from the arrangement of tallies that the central tally is round and that the other tallies have one, two, three or four teeth. So, each tooth may correspond to two different readings when considered from opposite ends. Therefore, during the measurement, the surveyor should bear in mind the position of the central tally. As per ISI recommendations, tallies should be provided after every 5 m and brass rings after every 1 m. The 30 m chain is divided into 150 links. So, each link is of 0.2 m. The tallies are provided after every 25 links (5 m). A round brass ring is fixed after every metre. This chain is heavy and is also suitable for measuring distances along fairly level ground.



Steel Band - It consists of a ribbon of steel of 16 mm width and of 20 or 30 m length. It has a brass handle at each end. It is graduated in metres, decimetres, and centimetres on one side

and has 0.2 m links on the other. The steel band is used in projects where more accuracy is required.
***Engineers' Chain* -** The engineer's chain is 100 ft long and is divided into 100 links. So, each link is of 1 ft. Tallies are provided at every 10 links (10 ft), the central tally being round. Such chains were previously used for all engineering works.



***Gunters' Chain* -** It is 66 ft long and divided into 100 links. So, each link is of 0.66 ft. It was previously used for measuring distances in miles and furlongs.
***Revenue Chain* -** The revenue chain is 33 ft long and divided into 16 links. It is mainly used in cadastral survey.

Tapes
The following are the different types of tapes:

(a) Cloth or linen tape,
(b) Metallic tape,
(c) Steel tape, and
(d) Invar tape.

***Cloth or Linen Tape* -** Such a tape is made of closely woven linen and is varnished to resist moisture. It is 15 mm wide and available in lengths of 10 and 15 m. This tape is generally used for measuring offsets and for ordinary works.
***Metallic Tape* -** When linen tape is reinforced with brass or copper wires to make it durable then it is called a metallic tape. This tape is available in lengths of 15, 20 and 30 m. It is wound on a leather case with a brass handle at the end. It is commonly used for all survey works.
***Steel Tape* -** The steel tape is made of steel ribbon of width varying from 6 to 16 mm. The commonly available lengths are 10, I5, 20, 30 and 50 m. It is graduated in metres, decimetres and centimetres. It is not used in the field, but chiefly for standardising chains and for measurements in constructional works.
***lnvar Tape* -** Invar tape is made of an alloy of steel (64%) and nickel (36%). Its thermal coefficient is very low. Therefore, it is not affected by change of temperature. It is made in the form of a ribbon of 6 mm width and is available in lengths of 30, 50 and 100 m. It is used at places where maximum precision is required. It is generally used in the triangulation survey conducted by the Survey of India department.

Ranging Rods
Ranging Rod Rods which are used for ranging (i.e., the process of making a line straight) a line is known as ranging rods. Such rods are made of seasoned timber or seasoned bamboo. Sometimes GI pipes of 25 mm diameter are also used as ranging rods. They are generally circular in section, of 25 mm diameter and 2 m length. Sometimes wooden ranging rods are square in section. The rod is divided into equal parts of 20 cm each and the divisions are painted black and white or red and white alternately so that the rod is visible from a long distance. The lower end of the rod is pointed or provided with an iron shoe.

Arrows
Arrows are made of tempered steel wire of 4 mm diameter. One end of the arrow is bent into a ring of 50 mm diameter and the other end is pointed. Its overall length is 400 mm. Arrows are used for counting the number of chains while measuring a chain line.

1.4 Errors & Mistakes in linear Measurements

Errors
Error in chaining may be caused due to variation in temperature and pull, defects in instruments, etc. They may be either

1. **Compensating, or**
2. **Cumulative.**

1. Compensating Errors **-** Errors which may occur in both directions (i.e., both positive and negative) and which finally tend to compensate are known as compensating errors. These errors do not affect survey work seriously. They are proportional to, where L is the length of the line.
Such errors may be caused by,
(a) Incorrect holding of the chain,
(b) Horizontality and verticality of steps not being properly maintained during the stepping operation,
(c) Fractional parts of the chain or tape not being uniform throughout its length,
(d) Inaccurate measurement of right angles with chain and tape.

2. Cumulative Errors **-** Errors which may occur in the same direction and which finally tend to accumulate are said to be cumulative. They seriously affect the accuracy of the work, and are proportional to the length of the line (L). The errors may be **positive or negative**.

Positive Errors - When the measured length is more than the actual length (i.e., when the chain is too short), the error is said to be positive. Such errors occur due to
(a) The length of chain or tape being shorter than the standard length,
(b) Slope correction not being applied,
(c) Correction for sag not being made,
(d) Measurement being taken with faulty alignment, and
(e) Measurement being taken in high winds with the tape in suspension.
Negative Errors - When the measured length of the line is less than the actual length (i.e., when the chain is too long), the error is said to be negative. These errors occur when the length of the chain or tape is greater than the standard length due to the following reasons.
(a) The opening of ring joints,
(b) The applied pull being much greater than the standard pull,
(c) The temperature during measurement being much higher than the standard temperature,
(d) Wearing of connecting rings, and
(e) Elongation of the links due to heavy pull.

Mistakes
Errors occurring due to the carelessness of the chainman are called mistakes. The following are a few common mistakes.
(a) Displacement of arrows: Once an arrow is withdrawn from the ground during chaining, it may not be replaced in proper position, if required due to some reason.
(b) A full chain length may be omitted or added. This happens when arrows are lost or wrongly counted.

(c) A reading may be taken from the wrong end of the chain. This happens when the tooth of the tally is noted without observing the central tally (i.e., when the tooth is noted from the wrong end).
(d) The numbers may be read from the wrong direction; for instance, a '6' may be read as a '9'.
(e) Some numbers may be called wrongly.
For example, 50.2 may be called "fifty-two" without the decimal point being mentioned.
(f) While making entries in the field book, the figures may be interchanged due to carelessness: for instance, 245 may be entered instead of 254.

Precautions against Errors and Mistakes
The following precautions should be taken to guard against errors and mistakes.

1. The point where the arrow is fixed on the ground should be marked with a cross (×).
2. The zero end of the chain or tape should be properly held.
3. During chaining, the number of arrows carried by the follower and leader should always tally with the total numbers of arrows taken.
4. While noting the measurement from the chain, the teeth of the tally should be verified with respect to the correct end.
5. The chainman should call the measurement loudly and distinctly and the surveyor should repeat them while booking.
6. Measurements should not be taken with the tape in suspension during high winds.
7. In stepping operations, horizontality and verticality should be properly maintained.
8. Ranging should be done accurately.
9. No measurement should be taken with the chain in suspension.
10. Care should be taken so that the chain is properly extended.

1.5 Corrections and Numerical Problems Applying Corrections

A. Tape Correction
1. Temperature Correction (Ct) - This correction is necessary because the length of the tape or chain may increase or decrease due to rise or fall of temperature during measurement.
The correction is given by the expression,

$$Ct = \alpha \, (Tm - To) \, L$$

where, *Ct = correction for temperature, in metres*
α = coefficient of thermal expansion
Tm = temperature during measurement in degrees centigrade or Celsius
To = temperature at which the tape was standardised, in degrees centigrade or Celsius
L = length of tape, in metres

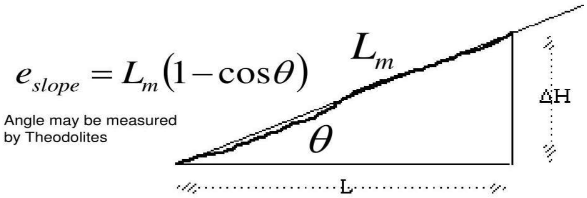
2. Pull Correction (Cp) - During measurement, the applied pull may be either more or less than the pull at which the chain or tape was standardised. Due to the elastic property of materials, the strain will vary according to the variation of applied pull, and hence necessary correction should be applied. This correction is given by the expression,

$$\mathrm{Cp} = \frac{(P - Po)L}{AE}$$

Where, *Cp = pull correction in metres*
P = pull applied during measurement, in kilograms
P0 = pull at which the tape was standardised, in kilograms
L = length of tape, in metre
A = cross-sectional area of tape, in square centimetres
E = modulus of elasticity (Young's modulus)

When E is not given, it may be assumed 2.1 × 106 kg/cm^2.

3. Slope Correction (Ch) –



This correction is always negative
Slope correction is calculated as follows.

4. Sag Correction (Cs) – This correction is necessary when the measurement is taken with the tape in suspension (i.e., in the form of a catenary).

$$C_s = \frac{L(\omega L)^2}{24n^2 P_m^2}$$ when unit weight is given, $$C_s = \frac{LW^2}{24n^2 P_m^2}$$

where, *Cs = sag correction, in metres*
L = length of tape or chain, in metres
ω = weight of tape per unit length, in kilograms per metre
W = total weight of tape, in kilograms
n = number of spans
Pm = pull applied during measurement; in kilograms
The sign of correction is always negative.

5. Normal Tension (Pn) - The tension at which the effect of pull is neutralised by the effect of sag is known as normal tension. At this tension, the elongation due to pull is balanced by the shortening due to sag.

(Considering n = 1) $$\frac{(P_n - P_0)L}{AE} = \frac{L(\omega L)^2}{24\,P_n^2}$$ where, Pn = normal pull or tension

B. Chain Correction

1. Correction Applied to Incorrect Length - TL = $\frac{L'}{L}$ × ML

2. Correction Applied to Incorrect Area - TL = $(\frac{L'}{L})^2$ ×ML

3. Correction Applied to Incorrect Volume - TL = $(\frac{L'}{L})^3$ ×ML

Where, L = standard or true length of chain
L′ = True length ± error = L ± e (e = error in chain or tape, i.e., when it is too long or short)
ML = Measured Length
TL = True Length or Actual length

Numerical

1) The distance between two points, measured with a 20 m chain, was recorded as 327 m. It was afterwards found that the chain was 3 cm too long. What was the true distance between the points?
Ans) 327.49 m
2) The distance between two stations was 1,200 m when measured with a 20 m chain. The same distance when measured with a 30 m chain was found to be 1,195 m. If the 20 m chain was 0.05 m too long, what was the error in the 30 m chain?
Ans) + 0.20 m
3) A line was measured by a 20 m chain which was accurate before starting the day's work. After chaining 900 m, the chain was found to be 6 cm too long. After chaining a total distance of 1,575 m, the chain was found to be 14 cm too long. Find the true distance of the line?
Ans) 1,579.725 m
4) On a map drawn to a scale of 50 m to 1 cm, a surveyor measured the distance between two stations as 3,500 m. But it was found that by mistake, he had used a scale of 100 m to 1 cm. Find the true distance between the stations?
Ans) 1,750 m

2. CHAINING AND CHAIN SURVEYING

2.1 Equipment and accessories for chaining


Chain


Tape


Ranging Rod


Arrows

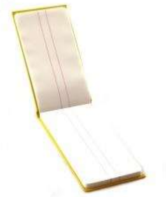

Cross Staff


Pegs

Plumb Bob


Offset rod


Mallet


Field book

2.2 Ranging

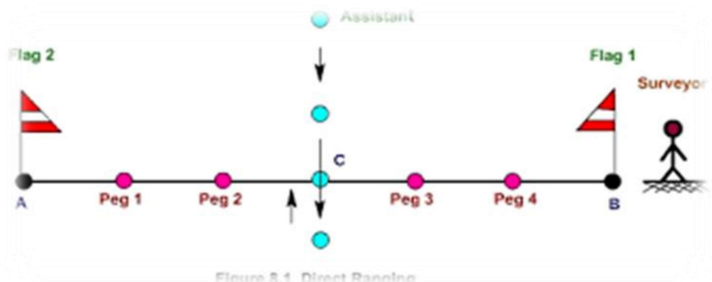
The length of the survey line should be taken straight. If the length of the survey line is less than length of chain, the length can be measured directly. If the length of the survey line is longer than the length of chain (or) if the end station is not clearly visible then, intermediate points are to be established.

The ranging is necessary for getting - **Straight length & correct length.**

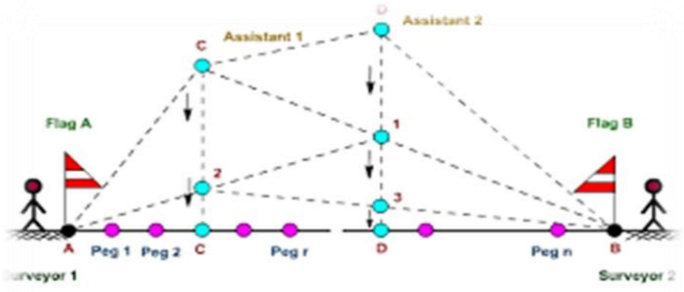
Methods of ranging - Ranging is of two types,

> ***1. Direct, and***
> ***2. Indirect or reciprocal.***

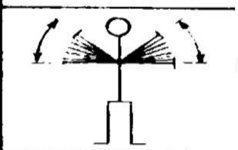
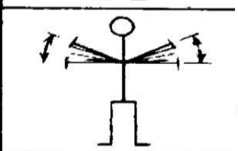
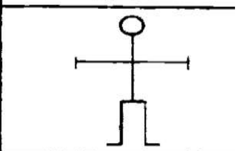
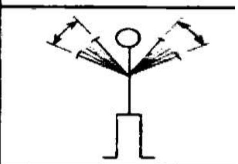
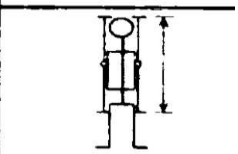
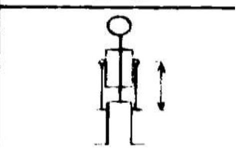
Direct Ranging - When intermediate ranging rods are fixed on a straight line by direct observation from end stations, the process is known as direct ranging. Direct ranging is possible when the end stations are visible. The following procedure is adopted for direct ranging.



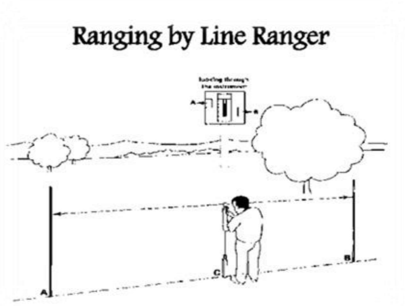
Indirect or Reciprocal Ranging - When the end stations are not invisible due to there being high ground between them, intermediate ranging rods are fixed on the line in an indirect way. This method is known, as indirect ranging or reciprocal ranging. The following procedure is adopted for indirect ranging.

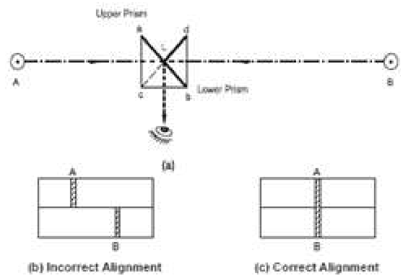


Signaling -

Signal by the surveyor	Action by the assistant	Hand signals
Rapid sweep with right or left hand	Move considerably to the right or left	
Slow sweep with right or left hand	Move slowly to the right or left	
Right or left arm extended	Move continuously to the right or left	
Right or left arm up and moved to the right or left	Plumb the rod to the right or left	
Both hands above head and then brought down	The position of the rod is correct	
Both arms extended forward horizontally and then brought down	Fix the rod	

Line ranger – features and use -





The line range is a small reflecting Instrument used for fisting the intermediate points on the chain line. It consists of two right angled isosceles triangular prisms placed one above the other. To establish an intermediate point I in line within the ranging rods A and B. The observer stands approximately in the line near P and holds the instrument at the level of eye. Rays of light from A after striking the diagonal of lower prism is reflected and enters the surveyor's eye. Similarly a ray of light from B after striking the diagonal of the upper prism is reflected and enters the surveyor's eye.

If the two images of the ranging rod A and B are one over the other, they are in same vertical plane. The point is transferred on ground by plumb bob.

Testing of Line Ranger - Fix the three points AB P in straight line.

The surveyor standing at middle point P will check whether the images of ranging rods held at A and B appear to coincide with each other. If not or of the prism is to be adjusted by adjusting screw till both images coincide with each other.

2.3 Methods of Chaining

Chaining is of two types, *1. On Flat Ground, and*

2. On Sloping Ground.

On Flat Ground -

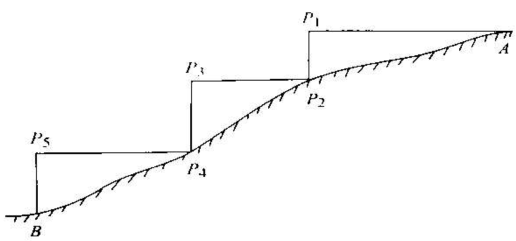
- Before starting the chaining operation, two ranging rods should be find and the chain line, at the top stations. The opposite ranging rod should be fixed near the top of every chain length, during the ranging operation.
- To chain the line, the leader moves forward by dragging the chain and by taking with him a ranging rod and ten arrows.
- The follower stands at the starting station by holding the opposite end of the chain.
- While the chain is completely elongated, the leader holds the ranging rod vertically at arm's length. The follower directs the leader to manoeuvre his rod to the left or right until the ranging rod is precisely in line.
- Then the follower lays the zero ends in the chain by touching the station peg. The leader stretches the chain by moving it up and down with both hands, and at last places it on the road.
- He then inserts an arrow on the bottom at the end of the chain and marks with a cross (x).
- Again, the leader moves forward by dragging the chain with 9 arrows and therefore the ranging rod. To the end of the chain, he fixes another arrow as earlier.
- The leader moves therewithal, the follower picks up the arrows which were inserted by the leader. And during chaining, the surveyor or an assistant should conduct the ranging operation.
- In this way, chaining is sustained. When all the arrows are inserted and therefore the leader has none left with him, the follower hands them over to the leader; this could be noted by the surveyor.

On Sloping Ground –

For all plotting works, horizontal distance between the points is required. Therefore it is necessary to measure the horizontal distance between the points on sloping ground. Chaining on sloping ground gives sloping distances. There are two methods for determining horizontal distance on sloping ground.

- ***Direct method or stepping method***
- ***Indirect method.***

Direct method - This method is applied when the slope of the ground is very steep. In this method, the sloping ground is divided into a number of horizontal and vertical strips, like steps. So, this method is also known as the stepping method. The lengths of horizontal portions are measured and added to get the total horizontal distance between the points. The steps may not be uniform, and would depend on the nature of the ground.

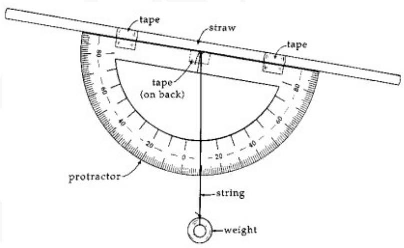


- Suppose the horizontal distance between points A and B is to be measured. The line AB is first ranged properly. Then, the follower holds the zero end of the tape at A. The leader selects a suitable length AP1 so that P1 is at chest height and AP1 is just horizontal. The horizontality is maintained by eye estimation, by tri-square or by wooden set-square. The point P2 is marked on the ground by plumb-bob so that P1 is just over P2. The horizontal length API is noted. Then the follower moves to the position P2 and holds the zero end of the tape at that point. Again the leader selects a suitable length P2P3 in such a way that P2P3 is horizontal and P4P5 vertical. Then the horizontal lengths P2P3 and P4P5 are measured.

Indirect Method - When the slope of the ground surface is long and gentle, the stepping method is not suitable. In such a case, the horizontal distance may be obtained by the following processes:

1. *By measuring the slope with a clinometers,*
2. *By applying hypotenusal allowance, and*
3. *By knowing the difference of level between the points.*

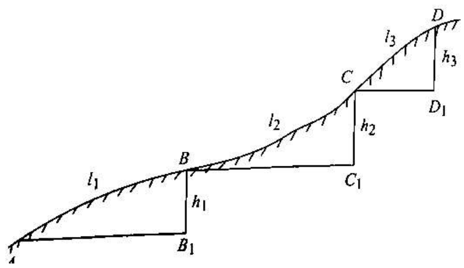
By measuring the slope with a clinometers –



Clinometers are a graduated semicircular protractor. It consists of two pins for sighting the object. A plumb bob is suspended from point O with a thread. When the straight edge is just horizontal, the thread passes through 0. When the straight edge is tilted, the thread remains vertical, but passes through a graduation on the arc which shows the angle of slope. The required horizontal distance = l cos α

By applying hypotenusal allowance –
In this method, the slope of the ground is first found out by using the clinometers or Abney level. Hypotenusal allowance is then made for each tape length.

By Knowing the Difference of Level –



Suppose, A, B, C and D are different points on sloping ground. The difference of level between these points is determined by a levelling instrument. Let the respective differences be h1, h2 and h3. Then the sloping distances AB, BC and CD are measured. Let the distances be l1, l2 and l3 respectively. Total horizontal distance = AB1 + BC1 + CD1.

2.4 Obstructions

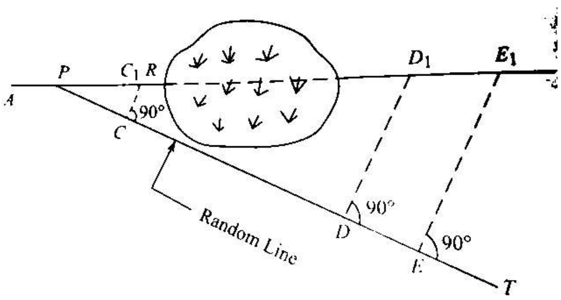
A chain line may be interrupted in the following situations:

1. When chaining is free, but vision is obstructed,
2. When chaining is obstructed, but vision is free, and
3. When chaining and vision are both obstructed.

1. When chaining is free, but vision is obstructed -
Such a problem arises when a rising ground or a jungle area interrupts the chain line. Here, the end stations are not invisible. 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.

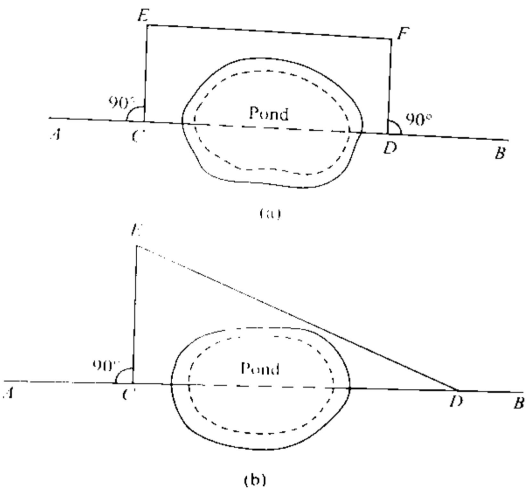


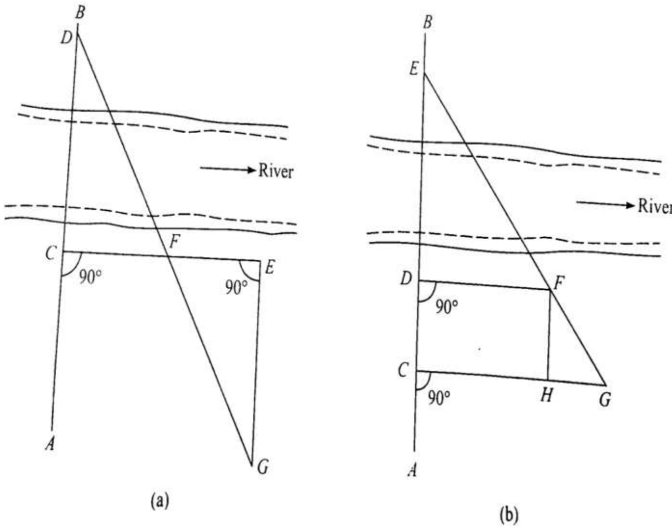
2. When chaining is obstructed, but vision is free -

Such a problem arises when a pond or a river comes across the chain line. The situations may be tackled in the following ways.

Case I When a pond interrupts the chain line; it is possible to go around the obstruction.

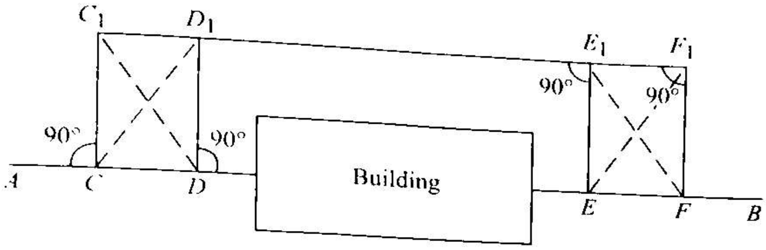
Case II Sometimes it is not possible to go around the obstruction.





3. When chaining and vision are both obstructed -

Such a problem arises when a building comes across the chain line. It is solved in the following manner. Suppose AB is the chain line. Two points C and D are selected on it at one side of the building. Equal perpendiculars CC1 and DD1 are erected. The line C1 D1 is extended until the building is crossed. On the extended line, two points E1 and F1 are selected. Then perpendiculars E1 E and F1 F are so erected that E1 E = F1 F = D1 D = C1 C Thus, the points C, D, E and F will lie on the same straight line AB. Here, DE = D1E1. The distance D1E1 is measured, and is equal to the required distance DE.

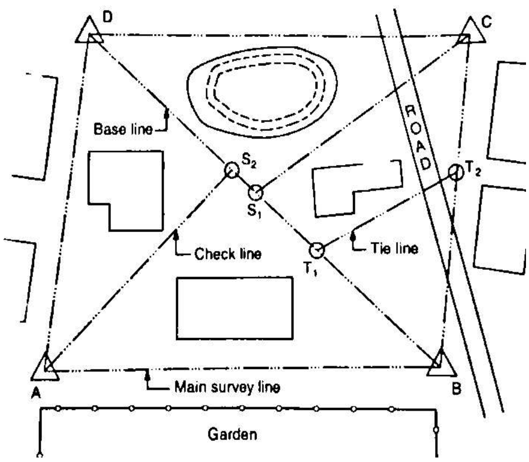


2.5 Purpose of chain surveying

Chain surveying is surveying in which only linear measurements are made in the field. It's the simplest method of surveying. In this survey only linear measurements are taken in the field and the rest work such as plotting calculation are done in the office.

It is suitable for where the ground is fairly level and small extent on open ground to secure data for exact description of the boundaries of piece of land or to take simple details.

It is unsuitable for where area crowded with many details and undulating areas.



Purpose – *To fix the boundaries of the land*

To prepare the plan of the site

To calculate the area of the plot

To divided land into smaller units.

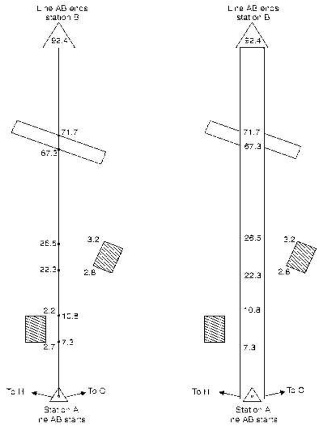
Principle –

- The principle of chain survey or chain triangulation is to provide a skeleton or framework consisting of a number of connected triangles.

- The area to be surveyed is divided into number of small triangles, connected with each other. The sides of the triangles are measured directly in the field with a chain or tape and no angular measurements are taken.
- The triangles are plotted from the measured length of sides. To get good results in plotting, the framework should consist of triangles which are as nearly equilateral as possible. The triangles formed should be well conditioned triangle.

Field book –

The book in which survey work is recorded by measurements and sketches are called the field book. It is an oblong book of size 20cm x 12cm and opening length wise. There are two forms of the field book**- Single line & double line.**



Single Line Field book - In the single line field book, a single red line is ruled down the middle of each page and represents the survey or chain line. The distances are written along the line, while the offsets written opposite them to the right or left according to as they are right or left of survey line. This is convenient for large scale and much detailed dimension work.

Double Line Field book - It is similar to single line, but instead of a single red line, two red lines about 1.25 cm to 1.5 cm apart are ruled at centre. In this column chainages are entered. The space on either side of the column is utilized for drawing sketches, writing offsets and notes located from the chain line. For ordinary work, this is used commonly.

Procedure -

- Each line should be recorded on a separate page. All measurements are recorded as soon as they are taken. The recorder should always face the direction of chaining while booking the field notes. The notes should be complete. Nothing should be left to memory. They should be clear, neat and accurate.
- Figuring should be neat, and writing legible. There should be no overwriting of the figures. Explanatory notes and references to other pages where ever necessary should be added. Entries should be recorded in pencil. The book should be kept clean. No entries should be erased.
- If any entry is wrong, a line should be drawn through it and a correct one is written above it. If an entire page is to be discarded, it should be crossed and marked 'cancelled. A reference to the other page on which the correct notes are written should be made on.
- Sketches of the various features located should be neat. The sketches need not be to scale. Separate page should be run for each tie line, if any. The complete record of the survey should include.
    - Title of the survey.
    - General sketch of the area surveyed. Location sketch of the main and tie stations.
    - Record of the chain lines.
    - The date of the survey.
    - The names of the members of the survey party.
    - The page index of the chain line and stations.

Survey stations –

A survey station is a prominent point on the chain line and can be either at the beginning of the chain line or at the end. Such station is known as main station. However, subsidiary or tie station can also be selected anywhere on the chain line and subsidiary tie lines may be run through them. However, on roads and streets etc., the survey station can be marked or located by making two or preferably three tie measurements with respect to some permanent reference objects near the station.

Survey lines –
The lines joining the main survey stations are called main survey lines. The biggest main survey line is called the base line and the various survey stations are plotted with reference to this. If the area to be surveyed has more than three straight boundaries, the field measurements must be so arranged that they can be plotted by laying down the triangles.

Check lines –
Check lines or proof lines are the lines which are run in the field to check the accuracy of the work. The length of the check line measured in the field must agree with its length on the plan.
A check line may be laid by joining the apex of the triangle to any point on the opposite side or by joining two points on any two sides of a triangle. Each triangle must have a check line.

Tie lines –
A tie line is a line which joins subsidiary or tie stations on the main line. The main object of running a tie line is to take the details of nearby objects but it also serves the purpose of a check line. The accuracy in the location of the objects depends upon the accuracy in laying the tie line.

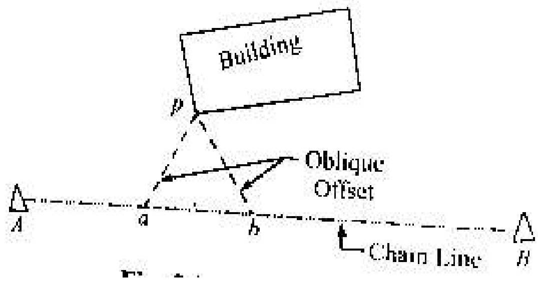
2.7 Offsets

The lateral distance measured from the chain line to the object is called offset. The process of measuring lateral distances from the chain line to the objects which are to be plotted is called as **offsetting.** These are measured on either side of a chain line.

The offsets are usually measured with metallic tape. But if the scale is large and great accuracy is required, a steel tape should be preferably used. For taking short measurement, an offset rod is sometimes used.

Types –
a) Based on length of line *- Short offset(less than 15 cm)*
- Long offset (more than 15 cm)
b) ***Based on direction of chain line*** *- Perpendicular offset*
- Oblique offset

Perpendicular offset – It is also known as rectangular offset or right offset. The distance measured at right angles to the chain line from the objects' is known as perpendicular offset.



Oblique offset – Offset which are other than right angles to the chain line are known as oblique offset. This taken when, the object is at a long distance, accuracy is required.

Instruments for setting offset –

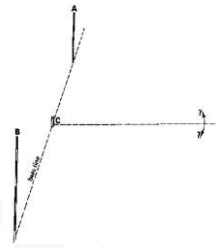
a) Cross staff - Cross staffs are three types; *Open cross staff, Wooden cross stall and French cross staff.*

Open cross staff - The open cross staffs is wooden piece in the shape of cross, each arm of the cross has a sighting vane made of metal, wood. Each of these sighting vanes is provided with a narrow vertical slit in the centre of which is stretched a fine vertical wire. The two wires opposite to each other give a line of sight; there are two lines of sight at right angles to each other. The instrument is fixed to the top of a vertical pole having an iron shoe at its bottom.

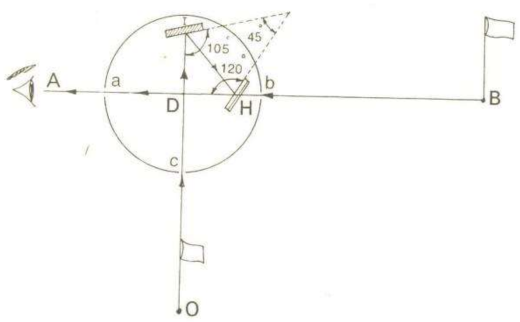
Wooden cross staff - It consists of wooden disc about 150mm square and 35mm thick. The disc has on its top surface has two grooves cut with a saw at right angles to each other. The grooves are about 10mm deep. The cross staff is fixed to the top of a vertical pole or held in hand.

French cross staff - This cross staff is an octagonal brass tube with slits on its eight faces. It has alternate vertical sight slits and opposite to it is a window with horse hair on each of the four sides. The two adjacent lines make an angle of 45°. With this it is possible to set the object at angle of 45° also.

Using of cross staff - Setting of perpendicular 'pl" on chain line AB. The cross staff is held vertically at the point 'p' with one pair of opposite slits directed to the ranging rods at A and B. Looking through the other pair of slits the surveyor directs the assistant to fix a ranging rod at P. Thus the perpendicular is set out on AB as 'pp.



b) Optical Square - It is a compact pocket instrument used for setting out right angles. It is more accurate than cross staff. It is about 50 to 65mm in diameter and 12.5mm in depth. A metal cover protects the instrument when not in use.



Uses of optical square - This is used for taking offsets especially when the offsets are more than 30m. This is also used to set out a right angle at a given point. This is useful for setting out right angles for taking measurements when there are obstacles in chaining and ranging.

2.8 Errors in Chain Surveying

The errors that occur in chaining are classified as: **Compensating & Cumulative.** These errors may be due to natural causes such as say variation in temperature, defects in construction and adjustment of the instrument, personal defects in vision etc.

a) ***Cumulative error -*** The cumulative errors are those which occur in the same direction and tend to add up or accumulate. Cumulative error may be positive or negative. In chaining, these may be caused by the following.

Erroneous length of chain or tape (Cumulative+ or -) - The error due to the wrong length of the chain is always cumulative and is the most serious source of error. If the length of the chain is more, the measured distance will be less and hence the error will be negative. Similarly, if the chain is too short, the measured distance will be more and error will be positive. However, it is possible to apply proper correction if the length is checked from time to time.

Bad Ranging (Cumulative +) - If the chain is stretched out of the line, the measured distance will always be more and hence the error will be positive. For each and every stretch of the chain, the error due to bad ranging will be cumulative and the effect will be too great a result. The error is not very serious in ordinary work if only the length is required. But if offsetting is to be done, the error is very serious. *Sag in chain and variation in temperature* also another type of cause of this error.

b) ***Compensating error -*** The compensating errors are those which are liable to occur in either direction and hence tend to compensate i.e., they are not likely to make the apparent result too large or too small. In chaining, these may be caused by the following.

Careless holding and marking- The follower may sometimes hold the handle to one side of the arrow and sometimes to the other side. The leader may thrust the arrow vertically into the ground or exactly at the end of chain. This causes a variable systematic error. The error of marking due to an inexperienced chainman is often of a cumulative nature, but with ordinary care such errors tend to compensate.

Variation in pull (Compensating, or Cumulative+ or -)- If the pull applied in straightening the chain or tape is not equal to that of the standard pull at which it was calibrated, its length changes. If the pull applied is not measured but is irregular (Sometimes more, sometimes less), the error tends to compensate. A chainman may, however apply too great or too small a pull every time and the error becomes cumulative.

Precaution to be taken during chain survey –

- All measurements are noted as soon as they are taken.
- Over-writing should be avoided.
- Figures and hand-writing should be neat and legible.
- Index-sketch, object-sketch and notes should be clear.
- Reference sketches should be given in the field book, so that the station can be located when required. The field book should be entered in pencil and not in ink.
- If an entry is incorrect or a page damaged, cancel the page and start the entry from a new one.
- Erasing a sketch measurement or note should be avoided.
- The surveyor should face the direction of chaining so that the left-hand and right- hand objects be recorded without any confusion.
- The field-book should be carefully preserved.
- The field-book should contain the following: Name, Location, date of survey, name of party members, page index or chain line.

Numerical

1) The distance between the points measured along a slope is 468 m. find the horizontal distance between them, if the angle of slope between the points is 12°30'.The difference in level is 78 m. The slope is 1 in 4.
Ans) 457 m, 461.45 m, 454 m

2) The required slope correction for a length of 60m along a gradient of 1 in 20 is?
Ans) 7.5 cm (-ve)

3) To continue a survey line AB past an obstacle, a line BC 200 m long was set out perpendicular to AB, and from C angles BCD and BCE was set out of 60° and 45° respectively. Determine the lengths which must be chained off along CD and CE in order that ED may be in AB produced. Also, determine the obstructed length Bev ?
Ans) 400m, 282.84m, 200m

4) A survey line ABC crossing a river at right angles cut its banks at B and C to determine the width BC of the river, the following operation was carried out. A point E was established on the perpendicular BE such that angle CEF is a right angle where F is a point on the survey line. If the chainages of F and B are respectively 1200 m and1320 m, and the distance EB is 90 m, calculate the width of the river and also the chainages of C?
Ans) 67.50m, 1387.50 m

LAND SURVEY - I

3. ANGULAR MEASUREMENT AND COMPAS SURVEYING

3.1 Measurement of Angles with Chain, Tape & Compass.

A compass is provided just below the telescope for taking the magnetic bearing of a line when required. The compass is graduated in such a way that a ‘pointer’, which is fixed to the body of the compass indicates a reading of 0° when the telescope is directed along the north line. In some compasses, the pointer shows a reading of a few degrees when the telescope is directed towards the north. This reading should be taken as the initial reading. The bearing is obtained by deducting the initial reading from the final reading of the compass.
There are kinds of compasses -
(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 ‘0’ 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 the map.
(c)Prismatic Compass - In this compass, the readings are taken with the help of a prism.
(d)Surveyor’s Compass - The surveyor’s compass is similar to the prismatic compass except for the following points.
(a) There is no prism on it. Readings are taken with the naked eye.
(b) It consists of an eye-vane (in place of prism) with a fine sight slit.
(c) The graduated aluminium ring is attached to the circular box. It is not fixed to the magnetic needle.
(d) The magnetic needle moves freely over the pivot. The needle shows the reading on the graduated ring.
(e) The ring is graduated from 0° to 90° in four quadrants. 0° is marked at the north and south, and 90° at the east and west. The letters E (east) and W (west) are interchanged from their true positions.
(f) No mirror is attached to the object vane.

3.2 Compass – Types, parts, merits & demerits, testing & adjustment of compass.

Introduction to compass surveying - Chain surveying can be used when the area to be surveyed is comparatively small and is fairly flat. However, when large areas are involved, methods of chain surveying alone are not sufficient and covalent. In such cases, it becomes essential to use some sort of instruments which enables angles or directions of the survey lines to be observed.
Principle of compass surveying - The principle of compass surveying is traversing**.** In traversing it is not required to form a network of triangles**.** In compass traversing the direction of lines are measured by prismatic or surveyor's compass and the distances are measured by chain or tape. Major types of magnetic compass are**;**

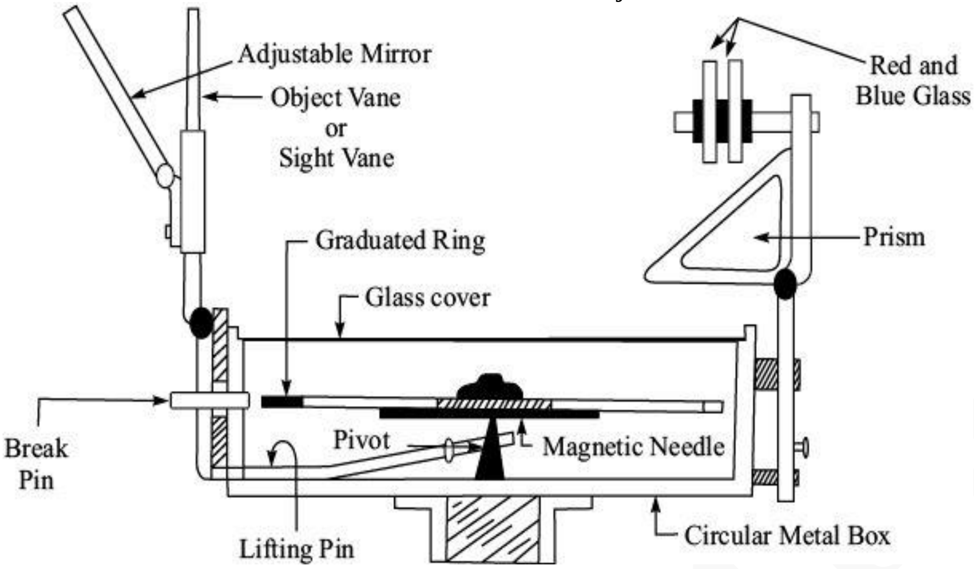
- Prismatic compass
- Surveyor's compass
- Level compass

Features of compass surveying - The principle of compass surveying connected lines. is traversing, which involves a series of connected lines. Such survey does not require the formation of a network of triangles. Some priorities for compass surveying are as following;

- If there is a large area to be surveyed such as the coastal areas or the course line areas of the river.
- If the area is crowded with many details and has many obstacles for conducting chain surveying as triangulation becomes impossible.
- If the surveyor has a specific time limit for conducting the surveying on a large and detailed area.

Parts of compass - Major parts of a Compass are;

- Magnetic needle
- Graduated ring
- Adjustable mirror
- Eye vane
- Glass cove
- Horse hair
- Object vane
- Metal box



Merits –

They are portable and light weight. They have fewer settings to fix it on a station The error in direction produced in a single survey line does not affect other lines. It is suitable to retrace old surveys.

Demerits –

It is less precise compared to other advanced methods of surveying. It is easily subjected to various errors such as errors adjoining to magnetic meridian, local attraction etc. Imperfect sighting of the ranging rods and inaccurate levelling also causes error.

Temporary Adjustment of Prismatic Compass - The following procedure should be adopted while measuring the bearing by prismatic compass.

1. *Fixing the Compass with Tripod Stand* - The tripod stand is placed at the required station with its legs well apart. Then the prismatic compass is held by the left hand and placed over the threaded top of the stand. After this, the compass box is turned clockwise by the right hand. Thus, the threaded base of the compass box is fixed with the threaded top of the stand.

2. *Centring* - Normally, the compass is centred by dropping a piece of stone from the bottom of the compass box. Centring may also be done with the aid of a plumb bob held centrally below the compass box.

3. *Levelling* - Levelling is done with the help of a ball-and-socket arrangement provided on top of the tripod stand. This arrangement is loosened and the box is placed in such a way that the graduated ring rotates freely without touching either the bottom of the box or the glass cover on top.

4. *Adjustment of Prism* - The prism is moved up and down till the figures on the graduated ring are seen sharp and clear.

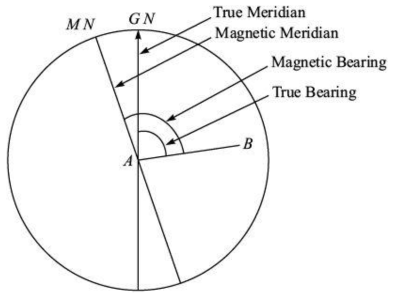
5. *Observation of Bearing* - After centring and levelling the compass box over the station, the ranging rod at the required station is bisected perfectly by sighting through the slit of the prism and horsehair at the sight vane.

3.3 Designation of Angles- Concept of Meridians – Magnetic, True, Arbitrary; Concept of Bearings – Whole Circle Bearing, Quadrantal Bearing, Reduced Bearing, Suitability of Application.

Concept of Meridians - The direction of a survey line can either be established with relation to each other, or with relation to any meridian. The first will give the angle between two lines while the second will give the bearing of the line.

Bearing - Bearing of a line is its direction relative to a given meridian. A meridian is direction such as**;**

- *True Meridian*
- *Magnetic Meridian*
- *Arbitrary Meridian*



True Meridian - True meridian through a point is the line in which a plane, passing that point and the north and south poles, intersects with surface of the earth. Thus, it passes through the true north and south. The direction of true meridian through a point can be established by astronomical observations.

True Bearing - True bearing of a line is the horizontal angle which it makes with the true meridian through one of the extremities of the line, since the direction of true meridian through a point remains fixed, the true bearing of a line is a constant quantity.

Magnetic Meridian - Magnetic meridian through a point is the direction shown by a freely floating and balanced magnetic needle free from all other attractive forces. The direction of magnetic meridian can be established with the help of a magnetic compass.

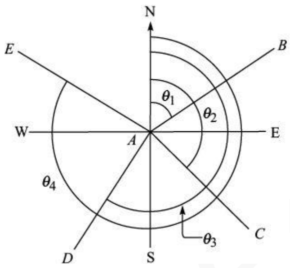
Magnetic Bearing - The magnetic bearing of a line is the horizontal angle which it makes with the magnetic meridian passing through one of the extremities of the line. A magnetic compass is used to measure it.

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

Arbitrary Bearing - Arbitrary bearing of a line is the horizontal angle which it makes with any arbitrary meridian passing through one of the extremities. A theodolite or sextant is used to measure it.

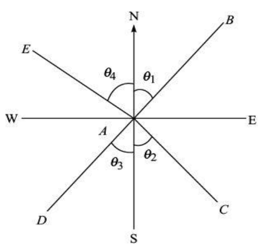
Bearing - The bearing of a line is the horizontal angle which the line makes with some reference direction or meridian (Meridian is a fixed direction on the surface of the earth). The common systems of bearings are

- *Whole Circle Bearing System (W.C.B.) or Azimuthal System.*
- *Quadrantal Bearing (QB) system or Reduced bearing.*



Whole circle bearing system (Azimuthal system) - In this system, the bearing of a line is measured with magnetic north (or with south) in clockwise direction. The value of the bearing thus varies from 0° to 360"**.** The bearing observed with a prismatic compass or theodolite are the whole circle bearing.

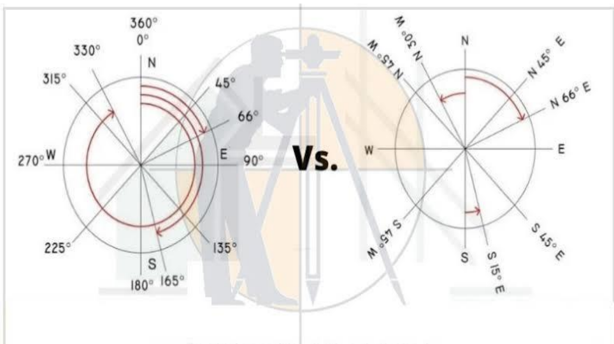
Quadrantal bearing (Q.B.) system - In this system, the bearing of a line is measured eastward or westward from north or south, whichever is nearer. Thus, both North and South are used as reference meridians and the directions can be either clockwise or anticlockwise depending on position of the line. In this system, therefore, the quadrant in which line lies, will have to be mention. These bearings are observed by surveyor's compass.



Reduced Bearing (RB) - When the whole circle bearing of a line is converted to quadrantal bearing, it is termed the 'reduced bearing'. Thus, the reduced bearing is similar to the quadrantal bearing. Its value lies between 0° and 90°, but the quadrants should be mentioned for proper designation.

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

WCB between	Corresponding RB	Quadrant
0° and 90°	RB = WCB	NE
90° and 180°	RB = 180° – WCB	SE
180° and 270°	RB = WCB – 180°	SW
270° and 360°	RB = 360° – WCB	NW



3.4 Use of Compasses – Setting in Field - Concepts of Fore Bearing, Back Bearing.

Setting up of prismatic compass - The following are the adjustments usually necessary in the prismatic compass.

- *Permanent adjustments.*
- *Station or temporary adjustments.*

Permanent adjustments - The permanent adjustment of prismatic compass is to bring the pivot point exactly in the centre of the graduated circle. There are no bubble tubes to be adjusted and the needle cannot be straightened. The sight vanes are generally not adjustable type in prismatic compass.

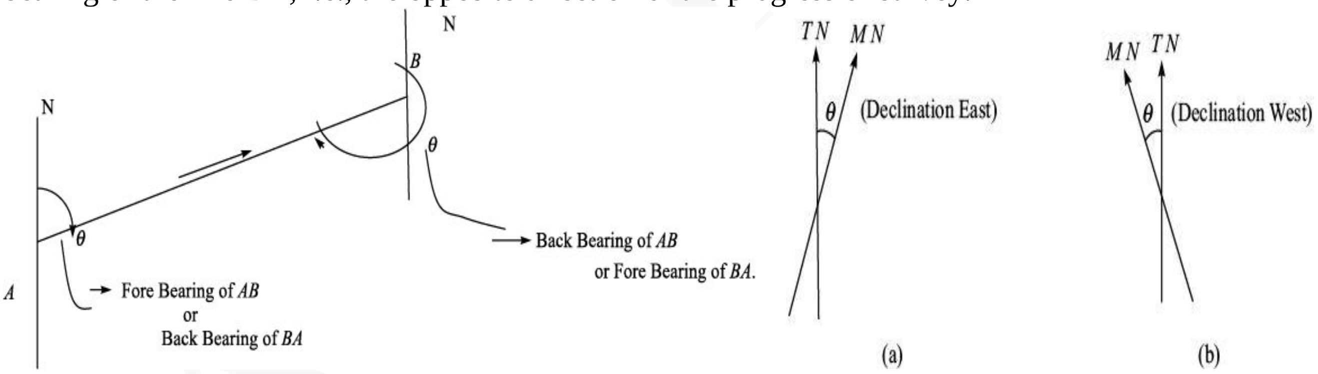
Temporary adjustments - Temporary adjustments are those adjustments which have to be made at every set up of the instrument.

Fore Bearing, Back Bearing - Every line has two bearings: one is observed along the progress of the survey or forward direction, and is called 'fore bearing', and the second is observed in the reverse or opposite direction and is called 'back bearing'.

Consider the line AB shown in Fig. Here, we consider the direction of meridian as upward and the bearing is measured clockwise from the meridian. The bearing as measured at A along the progress of survey A to B is θ. So, the angle or bearing θ is the fore bearing of the line. Fore Bearing and Back Bearing similarly, the bearing as measured at B in the opposite direction of the progress of the survey A to B, along clockwise direction is β. The bearing β is the back bearing of the line. From Fig, it is clear that the fore bearing and back bearing of a line differ exactly by 180°, i.e.

Back bearing = Fore Bearing ± 180°.

Use positive sign when fore bearing is less than 180° and use negative sign when it is more than 180°.In case of quadrantal bearing system, the numerical value of fore bearing and back bearing is equal but the quadrants are just opposite. For example, if the fore bearing is N30° E then it's back bearing is S30°W. We also see from Fig, that the fore bearing of the line AB is equal to the back bearing of the line BA, i.e., the opposite direction of the progress of survey.



3.5 Effects of earth's magnetism – dip of needle, magnetic declination, variation in declination.

Effects of earth's magnetism - The earth acts as a powerful magnet and like any magnet, it forms a field of magnetic force which exerts a directive influence on a magnetized bar of steel or iron. If any slender symmetrical bar magnet is freely suspended at its centre of gravity so that it is free to turn in azimuth, it will align itself in a position parallel, to the lines of magnetic force of the earth at that point. The lines of force of earth's magnetic field run generally from South to North near the equator, they are parallel to earth's surface.

The horizontal projections of lines of force define the magnetic meridian. The angle which these lines of force make with the surface of the earth is called the angle of dip or dip of the needle. In elevation these lines of force (The north end of the needle) are inclined downward towards the north in the northern hemisphere and downward towards south in southern hemisphere.

Dip of the magnetic needle - If a needle is perfectly balanced before magnetisation, it does not remain in the balanced position after it is magnetised. This is due to the magnetic influence of the earth. The needle is found to be inclined towards the pole.

This inclination of the needle with the horizontal is known as the 'dip of the magnetic needle'. One of the effects of the earth's magnetism is to make a perfectly balanced needle. incline downwards after magnetisation towards the nearer of the earth's magnetic poles. This deviation from the horizontal is also known as the dip.

Magnetic declination - Magnetic declination at a place la the horizontal angle between the true meridian and the magnetic meridian shown by the needle at the time of observation**.** Declination based on position.

- *Declination west*
- *Declination east*

If the magnetic meridian is to the right side (or eastern side) of the true meridian declination is said to be eastern or positive.

If the magnetic meridian is to the left side (or western side) of the true meridian, declination is said to be western or negative.

Determination of true bearing - All important surveys are plotted with reference to true meridian, since the direction of magnetic meridian at a place change with time. If, however, the magnetic declination at a place, at the time of observation is known, the true bearing can be calculated from the observed magnetic bearing**.**

True bearing = Magnetic bearing ± Declination.

In above formula, use plus sign if the declination is to the east and minus sign if it is to the west. The above rule is valid for whole circle bearings only. If, however, a reduced bearing has been observed, it is always advisable to draw the diagram and calculate bearing.

Variation of magnetic declination - The value of declination at a place never remains constant but changes from time to time. The magnetic declination at a place is not constant. It varies due to the following reasons:

(a) Secular Variation - The magnetic meridian behaves like a pendulum with respect to the true meridian. After every 100 years or so, it swings from one direction to the opposite direction, and hence the declination varies. This variation is known as 'secular variation'.

(b) Annual Variation - The magnetic declination varies due to the rotation of the earth, with its axis inclined, in an elliptical path around the sun during a year. This variation is known as 'annual variation'. The amount of variation is about 1 to 2 minutes.

(c) Diurnal Variation - The magnetic declination varies due to the rotation of the earth on its own axis in 24 hours. This variation is known as 'diurnal variation'. The amount of variation is found to be about 3 to 12 minutes.

***(d) Irregular Variation* -** The magnetic declination is found to vary suddenly due to some natural causes, such as earthquakes, volcanic eruptions, and so on. This variation is known as 'irregular variation'.

3.6 Errors in Angle Measurement with Compass – Sources & Remedies.

Sources of errors in compass traversing –

Instrumental errors -Instrumental errors occur due to faulty adjustments and due to defective parts of the instruments, they are as follows:

- The needle not being perfectly straight.
- Pivot being bent.
- Sluggish needle.
- Blunt pivot points.
- Improper balancing weight Sight vanes not being vertical.
- Line of sight not passing through the centre of the ring.
- Divisions of the graduated ring not being equal Graduated ring not being horizontal.

Errors due to natural causes - The errors due to natural causes are the following reasons:

- Presence of magnetic substance near or below the station of observation.
- Irregular variations due to magnetic storms, etc.

Observational or personal errors - These errors include;

- Inaccurate levelling of the compass box.
- Inaccurate centring.

- Inaccurate bisection of ranging rods Inaccurate reading and recording.

Remedies to be taken in compass survey – The instrumental and observational errors during a compass survey may be minimized by taking certain precautions.

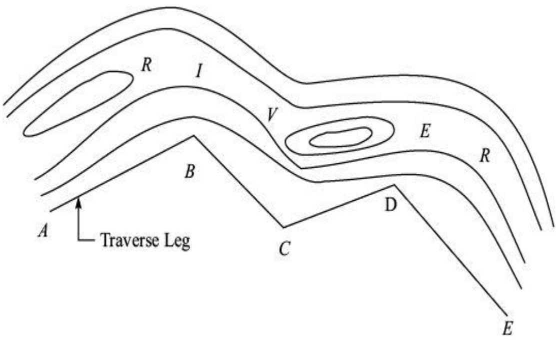
- Set up and level the compass carefully.
- Stop the vibrations of the needle by gently pressing the brake-pin so that it will come to rest soon.
- Always look along the needle and not across it to avoid parallax.
- When the instrument is not in use, its magnetic needle should be kept off the pivot If it is not done, the pivot is subjected to unnecessary wear which may cause sluggishness of the magnetic needle.
- Before taking a reading, the compass box should be gently tapped to ensure that the magnetic needle is freely swinging and has not come to rest due to friction of the pivot.
- Stations should be selected such that these are away from the sources of Local attraction.
- Fore and back bearings of each line should be taken to guard against the local attraction.
- If the compass cannot be set at the end of a line, the bearings may be taken from any intermediate point along that line Two sets of readings should be taken at each station for important details by displacing the magnetic needle after taking one reading.
- Object vane and eye vane must be straightened before making observations.
- If the glass cover has been reduced with a handkerchief, the glass gets charged with electrostatic current and the needle adheres to the glass cover. This may be obviated by applying a moist finger to the glass.
- Surveyor should never carry iron articles, such as a bunch of keys which may cause local attraction.

3.7 Principles of traversing – Open & Closed traverse, Methods of traversing.

Principles of traversing - Traversing is that type of survey in which a number of connected survey lines form the framework and the directions and lengths of the survey lines are measured with the help of an angle (or direction) measuring instrument and a tape (or chain) respectively.

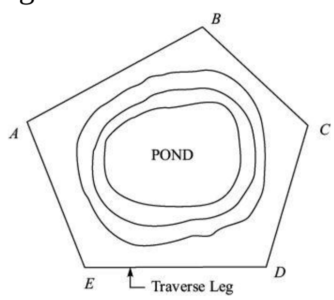
Type of traversing - Two general classes of traverse are;

- Open traverse
- Closed traverse



Open traverse - Open traverse is that type of traverse in which origin point starts at known location and terminate points ends at unknown location. There is no opportunity for checking the accuracy of the ongoing work in open traverse. So, all survey measurements are carefully repeated at the time of the work. The major disadvantages of open traverse are, there is no check on summation of angles & There is no check on positions of intermediate points.

Steps to minimize errors in open traverse are Each distance should be measured twice in both directions and also should be roughly checked by tacheometry method. Angles should be measured by method of repetition and also should be checked by magnetic bearings. An open traverse is usually run for establishing control in preliminary surveys and construction surveys such as roads, pipelines, etc, because the results are always open to doubt.



Closed traverse - Closed traverse is that type of traverse in which origin point and terminate points are known locations. In such traverse, sum of the all-internal angles should be equal to (2n-4) times right angle where n is the number of sides. Closed traverse provides check for both linear and angular measurements and therefore preferred to all other types of traverses.

Methods of traversing - Traverse survey may be conducted by the following methods,

- 1. Chain traversing (by chain angle),
- 2. Compass traversing (by free needle),
- 3. Theodolite traversing (by fast needle) and

- 4. Plane table traversing (by plane table).

Chain traversing - When it is not possible to conduct triangulation, chain traversing is adopted. In this method, the angles between adjacent sides are fixed. No angular measurements are taken. The entire survey is conducted by chain and tape only.

Compass traversing - In this method, by prismatic compass the fore and back bearings of the traverse legs are measured and by chain or tape, the sides of the traverse are measured.

Theodolite traversing - In this traversing theodolite is used to measure the horizontal angles between the traverse legs and by chain or by employing the stadia method the lengths of the legs are measured.

Plane table traversing - In this method, a plane table is set in the clockwise or anticlockwise direction, and the circuit is finally closed. At every traverse station, during traversing, the sides of the traverse are plotted according to suitable scale.

3.8 Local Attraction – Causes, Detection, Errors, Corrections.

Local attraction and their detection - A magnetic needle indicates the north direction when freely suspended or pivoted. But if the needle comes near some magnetic substances, such as iron ore, steel structures, electric cables conveying current; etc. it is found to be deflected from its true direction, and does not show the actual north. This disturbing influence of magnetic substances is known as 'local attraction'.

To detect the presence of local attraction, the fore and back bearings of a line should be taken. If the difference of the fore and back bearings of the line is exactly 180° then there is no local attraction. If the FB and BB of a line do not differ by 180° then the needle is said to be affected by local attraction, provided there is no instrumental error. To compensate for the effect of local attraction, the amount of error is found out and is equally distributed between the fore and back bearings of the line.

For example, consider the case when

Observed FB of AB = 60°30′

Observed BB of AB = 240°0′

Calculated BB of AB = 60°30° + 180°0′ = 240°30′

∴ Corrected BB of AB = 1/2 (240°0′ + 240°30′) = 240°15′

Hence, Corrected FB of AB = 240°15′ – 180°0′ = 60°15′

Sources of local attraction - Magnetite in the ground, Wire carrying electric current, Steel structures, Railroad rails, Underground iron pipes, Keys, Steel-bowed spectacles, Metal buttons, Axes, Chains, Steel tapes.

Method of Application of Correction -

(a) First Method - The interior angles of a traverse are calculated from the observed bearings. Then an angular check is applied. The sum of the interior angles should be equal to (2n – 4) × 90° (n being the number of sides of the traverse). If it is not so, the total error is equally distributed among all the angles of the traverse. Then, starting from the unaffected line, the bearings of all the lines may be corrected by using the corrected interior angles. This method is very laborious and is not generally employed.

(b) Second Method - In this method, the interior angles are not calculated. From the given table, the unaffected line is first detected. Then, commencing from the unaffected line, the bearings of the other affected lines are corrected by finding the amount of correction at each station. This is an easy method, and one which is generally employed.

3.9 Errors in compass surveying – Remedies & Sources (written above).

Remedies of errors in compass surveying –

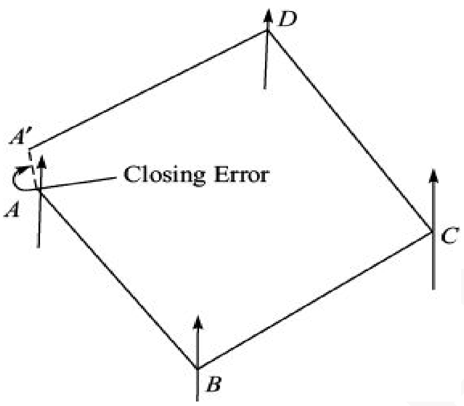
- The glass cover of the compass box gets charged with electricity when dusted off with a handkerchief or by the influence of electric charge in the atmosphere. Consequently, the needle adheres to the glass. This may be avoided by applying a moist finger or cloth to the glass.

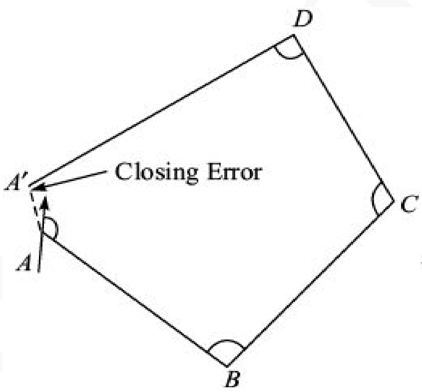
- To avoid local attraction, nothing made of iron or steel such as bunch of keys, iron - buttoms etc. should be carried by the surveyor.
- Set up and level the compass properly. Stop the vibrations of the needle by gently pressing the brake-pin so that it may come to rest soon.
- Always look along the needle and not across it, thus avoiding parallax. In Surveyor's compass always read the north end of the needle.
- For important lines, take duplicate readings at each station. After having taken the first reading, displaced the needle and take the second reading and then take the mean of the two.
- To detect local attraction, take fore and back bearings of the lines. The pivot sharp edge should be protected by keeping the needle off the pivot when compass is not in use or when it is shifted from one station to another.

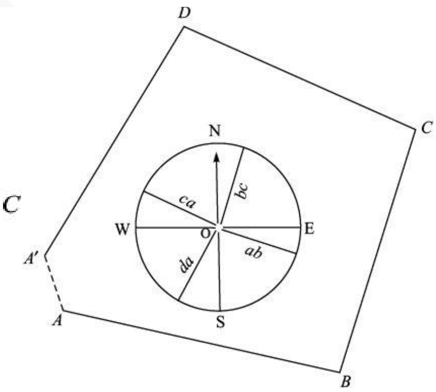
Plotting of traverse – check of closing error in closed & open traverse, Bowditch's correction, Gales table Introduction.

Plotting of compass traverse - There are three types of plotting, they are;

- By parallel meridian (By Parallel Meridian Through Each Station)
- By included angles (By Considering Included Angles)
- Plotting by tangents (By Considering the Central Meridian)







Bowditch's method - When a closed traverse is plotted from the field measurements, the end station of a traverse generally does not coincide exactly with its starting station. This discrepancy is due to the errors in the field observations i.e., magnetic bearings and linear distances. Such an error of the traverse is known as closing error or error of closure**.** When the angular and linear measurements are of equal precision, Graphical adjustment of the traverse may be made**.** This method is based on the Bowditch's Rule".

Corrections are applied to lengths as well as to bearings of the lines in proportion to their lengths. This graphical method is also sometimes known as proportionate method of adjustment.

Gales traverse table - Traverse computations are usually done in a tabular form, a more common form being gales traverse table. For complete traverse computations, the following steps are usually necessary**.** Adjust the interior angles to satisfy the geometrical conditions, I.e., sum of interior angles to be equal to (2N-4) right angles and exterior angles (2N+4) right angles.

In the case of a compass traverse, the bearings are adjusted for local attraction. Starting with observed bearings of one line. Calculate the bearings of all other lines. Reduce all bearings to quadrantal system. Calculate the consecutive co-ordinates (i.e., latitudes and departures).

Numerical

1)The bearings of the lines OA, OB, OC, OD are 30°30 ′, 140°15 ′,220°45 ′ and 310°30 ′, respectively. Find the angles ∠AOB, ∠BOC and ∠COD?
Ans) 109°45′, 80°30′, 89°45′

2)A traverse is done by three stations A, B and C in clockwise order in the form of an equilateral triangle. If the bearing of AB is 80°30 ′, find the bearings of the other sides?

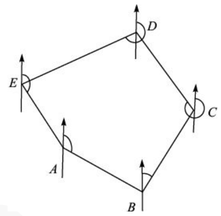
Ans) 200°30′, 320°30′

3)A closed traverse is conducted with five stations A, B, C, D and E taken in anticlockwise order, in the form of a regular pentagon. If the FB of AB is 30°0 ′, find the FBs of the other sides?

Ans) 318°0′, 246°0′, 174°0′, 102°0′

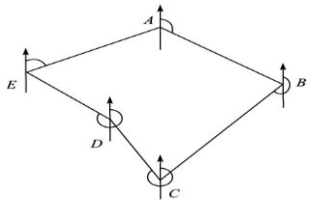
4) The following are the fore and back bearings of the sides of a closed traverse: Calculate the sum of interior angles of the traverse?

Side	FB	BB
AB	150°15′	330°15′
BC	20°30′	200°30′
CD	295°45′	115°45′
DE	218°0′	38°0′
EA	120°30′	300°30′



Ans) 540°

5) The following are the bearings observed in traversing, with a compass, an area where local attraction was suspected. Calculate the interior angles of the traverse and correct them if necessary?

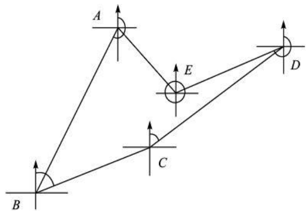


Line	FD	BB
AB	150°0′	330°0′
BC	230°30′	48°0′
CD	306°15′	127°45′
DE	298°00′	120°00′
EA	49°30′	229°30′

Ans) 541°0′, *Correction per angle –12′, 540°*

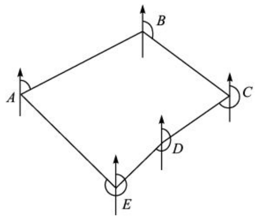
6) The following are the observed bearings of the lines of a traverse ABCDEA with a compass in a place where local attraction was suspected. Find the correct bearings of the lines?

Line	FB	BB
AB	191°45′	13°0′
BC	39°30′	222°30′
CD	22°15′	200°30′
DE	242°45′	62°45′
EA	330°15′	147°45′



Ans) 540°00′

7)The following bearings were observed in traversing, with a compass, an area where local attraction was suspected. Find the amounts of local attraction at different stations, the correct bearings of lines and the included angles. Also draw a sketch of the plot if AB = 100 m, BC = 100 m and CD = 50 m and show in it all the included angles?



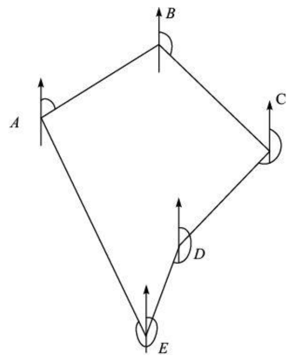
Line	FB	BB
AB	68°15′	248°15′
BC	148°45′	326°15′
CD	224°30′	46°00′
DE	217°15′	38°15′
EA	327°45′	147°45′

Ans) 540°00′

8) Following are the bearings observed while traversing with a compass, an area where local attraction was suspected. Find the correct bearings of the lines and also the true bearings, if the magnetic declination is 10°W?

Ans)

Line	Correct		Declination	True		Remark
	FB	BB	10° W	FB	BB	
AB	59°00′	239°00′	–10°	49°00′	229°00′	True bearing is obtained by deducting declination from magnetic bearingas declination is west.
BC	139°30′	319°30′	–10°	129°30′	309°30′	
CD	217°45′	37°45′	–10°	207°45′	27°45′	
DE	209°15′	29°15′	–10°	199°15′	19°15′	
EA	318°45′	138°45′	–10°	308°45′	128°45′	

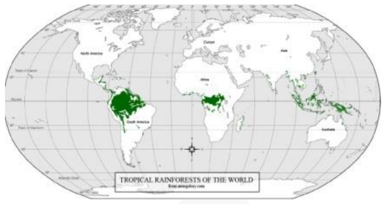


LAND SURVEY - I

4. MAP READING CADASTRAL MAPS & NOMENCLATURE

4.1 Study of Direction, Scale, Grid Reference & Grid Square Study of Signs and Symbols.

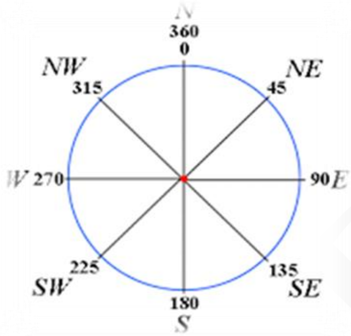
Map - A map is an illustration of an area such as city country, etc. This shows different features of an area. There are different types of map available as follows;

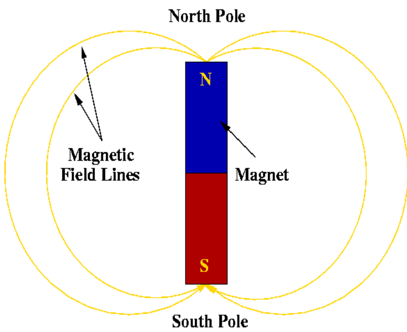


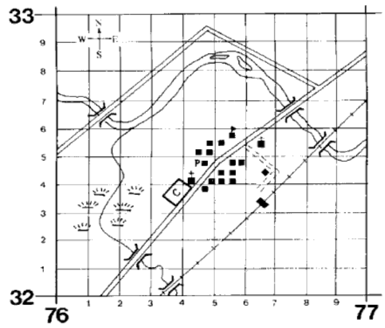
1- Topographical Map
2- Cadastral Map
3- Engineering Map
4- Military Map
5- Contour Map

- A map which shows the natural & artificial features (Such as village, towns, hills, rivers, forests etc) of a peace is known as **topographical map.**
- A map which shows the boundaries of fields, houses, estates of a place is known as **cadastral map.**
- A map which shows the details of engineering work is known as **engineering map.**
- A map which shows different military properties of a place is known as **military map.**
- A map which shows RL of different point is known as **contour map.**

Study of Direction –







Scale - It is not always possible to represent the actual length of an object on a drawing. So it is required to reduce the size of object in some proportion. The Ratio between sizes of object on drawing to the actual size of object is known scale. Scale can be represented as 2 types;

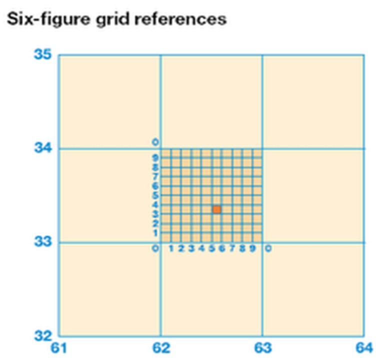
1. ***Representative Fraction (RF) scale.***
2. ***Graphical scale.***

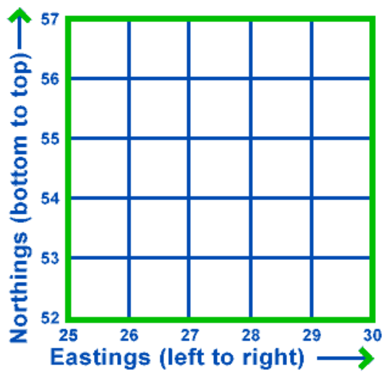
$$RF = \frac{\text{Distance on drawing of object}}{\text{Corresponding actual distance of object}}$$

Note - Both distances is in same unit.

Grid Reference – Grid is a network of horizontal and vertical lines used to identify exact location on a map. The grid which is increase towards north direction is known as northing grid. The grid which is increase towards east direction is known as easting grid. A point at which horizontal line & vertical Line of the grids each other cross is known as co-ordinate. Grid reference is calculated by following methods;

1- 4 figure grid reference line.
2- 6 figure grid reference line.





Signs and Symbols -

S. No.	Object	Symbol	Colour
1.	North line		Black
2.	Main stations or triangulation stations		Red or crimson lake
3.	Traverse stations or substations		Red or crimson lake
4.	Chain line		Red or crimson lake
5.	River		Prussian blue
6.	Canal		Prussian blue
7.	Lake or pond		Prussian blue
8.	Open well		Prussian blue
9.	Tube well		Black
10.	Footpath		Black
11.	Metalled road		Burnt sienna
12.	Unmetalled road		Burnt sienna
13.	Railway line		Black
14.	Railway line (double)		Black
15.	Road bridge or culvert		Black
16.	Railway bridge or culvert		Black
17.	Level crossing		Black and burnt sienna
18.	Wall with gate		Black
19.	Boundary line		Black
20.	Hedge		Green
21.	Wire fencing		Black
22.	Pipe fencing		Prussian blue
23.	Wood fencing		Yellow
24.	Building (*pukka*)		Crimson lake
25.	Building (*katcha*)		Umber
26.	Huts		Yellow
27.	Temple		Crimson lake
28.	Church		Crimson lake
29.	Mosque		Crimson lake
30.	Benchmark		Black
31.	Tree		Green
32.	Jungle		Green
33.	Orchard		Green
34.	Cultivated land		Black and green
35.	Barren land		Black
36.	Rough pasture		Black
37.	Marsh or swamp		Black
38.	Embankment		Black
39.	Cutting		Black
40.	(a) Telegraph line		Black
	(b) Telegraph post		Black
41.	(a) Electric line		Black
	(b) Electric post		Black
42.	Burial ground or cemetery		Crimson lake

4.2 Cadastral Map Preparation Methodology

A map which shows the boundaries of fields, houses & estates of a place is known as cadastral map. Cadastral map is required for following purpose;

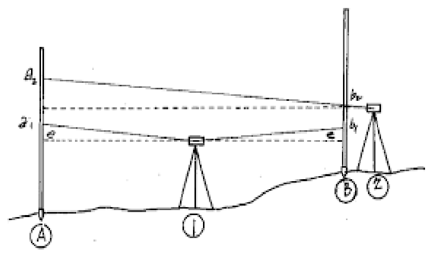
- To record the boundaries & ownership details of a land.
- To collect land taxes.
- To improve or development of a particular area.

Following are the different methods for plotting or preparing a cadastral map;

1- By using chain / Tape Surveying
2- By using plane table
3- By using total station
4- By using remote sensing

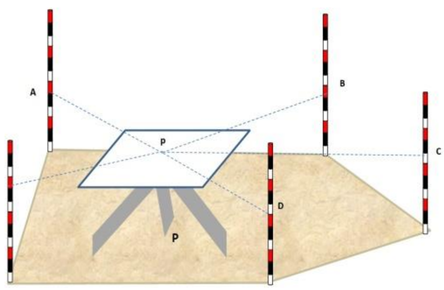
By using chain / Tape Surveying -

Reconnaissance
Marking of stations
Plotting of survey lines
Measurement
Plotting the map



By using plane table -

Selection of points
Fixing of plane table
Leveling & centering
Orientation
Plotting the map

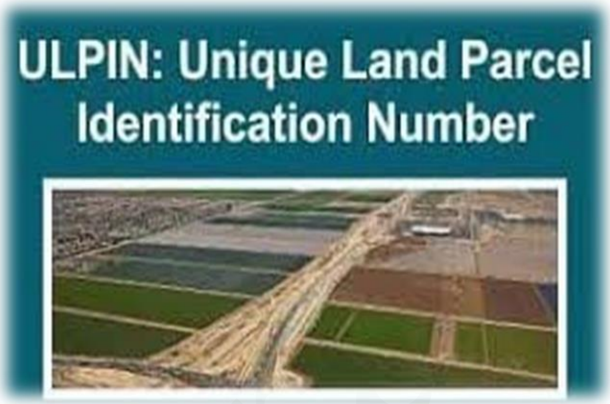


By using total station -

Tripod stand setup
Mounting the total stations
Leveling & centering
Instrument setup
Recording the data
Plotting the map

By using remote sensing – In this method satellite images are used for plotting a map. This method is a quick method but not accurate.

4.3 Unique identification number of parcel



The Unique Land Parcel Identification Number (ULPIN) System will have 14 digits. Alpha - numeric unique ID for each land parcel. The Unique IDs based on Geo reference coordinate of vertices of the parcel would be of international standard and compliance of the Electronic Commerce Code Management Association (ECCMA) standard and Open Geospatial Consortium (OCC) standards and it will provide compatibility so that all states can adopt it easily. Proper land statistics and land accounting through ULPIN will help develop land hank and lead towards Integrated Land Information Management System (ILIMS).

Features -

- The unique ID will be of 14 digits for every plot of land in the country.
- Identification will be based on the longitude and latitude coordinates of the land parcel.
- In the ULPIN system, there will be a unique ID for each land parcel.
- This is the next step in the Digital India Land Records Modernization Programmer (DILRMP), which began in 2008.
- It would be based on the Geo reference coordinate of vertices of the parcel.
- It will provide compatibility so that all states can adopt it easily.
- It will enable in keeping the land records always up-to-date.

Benefits -

- The system would ensure delivery of citizen services of land records through a single window.
- ULPIN land database to be integrated with revenue court records, bank records and Aadhaar.
- ULPIN would also ensure sharing of land records data across departments, financial institutions and all stakeholders.

4.4 Positions of existing Control Points and its types

Positions of existing Control Points - There are many different types of surveys that can be performed for real estate developments and construction projects. A survey may involve finding the existing dimensions of the building marking underground utility locations, or locating property boundaries**.** Each type of survey requires a very different type of professional**.** If a project utilizes survey control, then all those surveys can be coordinated into a unified digital environment that references real-world locations. Sometimes the survey control provided is localized to a specific project and other times it is tied to pre-established systems like a state planes coordinate system. Both methods involve marking various points on site utilizing fixed elements like survey nails, cuts in masonry, checkerboard targets, etc, and then measuring the X, Y and Z values of those points.

Requirements –

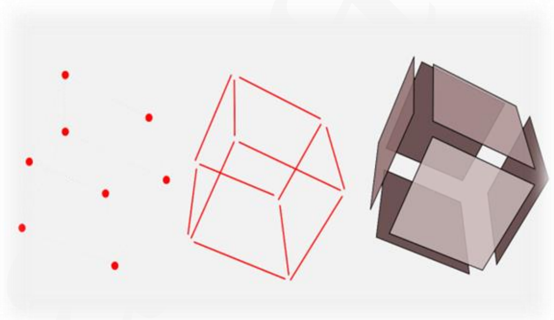
- Projects that span over large areas, or long tunnels.
- Projects that involve multiple trades working together between different software.
- Projects that need property line or legal boundary information.
- Projects that require a high degree of vertical accuracy.

Types –

1. Digital Height Model (DHM)
2. Digital Terrain Model (DTM)
3. Digital Surface Model (DSM)
4. Land Information System (LIS)
5. Land Registry Survey (LRS)
6. Laser Scanning (LS)

Survey Information Level	Public Law Restrictions
• Fixed points	• Spatial planning
• Ground cover	• Motorways/National roads
• Nomenclature	• Railways
• Real estate	• Airports
• Pipelines	• Contaminated sites
• Administrative boundaries	• Groundwater protections
• Permanent ground	• Noise
• Address of buildings	• Forests
• Administrative divisions	

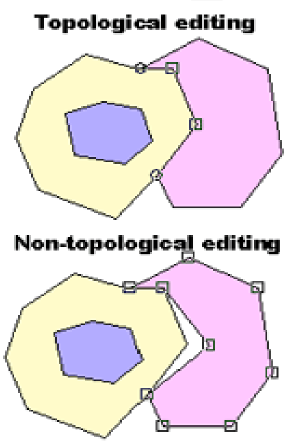
4.5 Adjacent Boundaries and Features, Topology Creation and verification

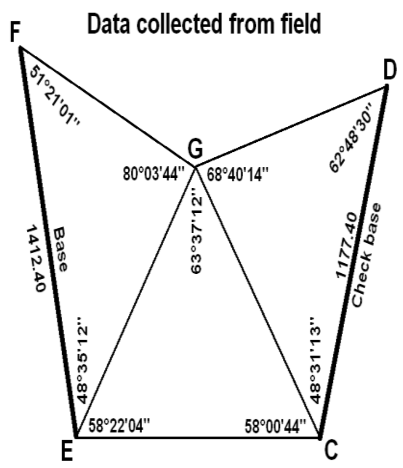


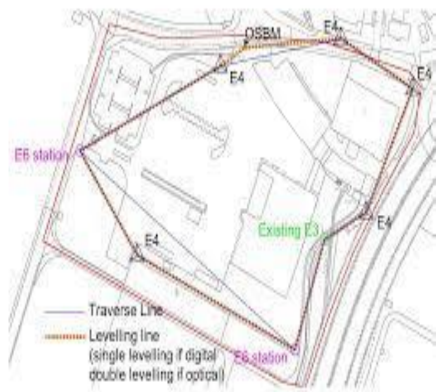
- If you have features that are coincident and share the same location of coordinates, boundaries, or nodes, geo database topology can help you better manage your geographic data.
- Geo database topologies help ensure data integrity. Using a topology provides a mechanism to perform integrity checks on your data and helps you validate and maintain better feature representations in your geo database.
- In addition, you can use topologies to model spatial relationships between features.
- These enable support for a variety of analytic operations, such as finding adjacent features, working with coincident boundaries between features, and navigating along connected features.

Creation –

- **Site/location -** Topography, soil characteristics, usable land area, building setback requirements, landscaping view, street and alley access, railroad and waterway access, zoning.
- **Building size -** round-floor area, total floor area, leasable area, volume, building height, ceiling height, clear span, number of stories, number of units, apartments, etc.
- **Shape -** Floor area/perimeter ratio, number of corners.
- **Construction material -** Foundation, framing, floors, walls (exterior and interior), ceilings.
- **Construction quality** - Quality of materials, workmanship, architecture.
- **Design -** Intended use, architectural style, shape of building, roof type, story height.
- **Other building features -** Number of rooms by type, heating, ventilation, air conditioning, plumbing facilities, fireplaces and similar amenities.







LAND SURVEY - I

5. PLANE TABLE SURVEYING

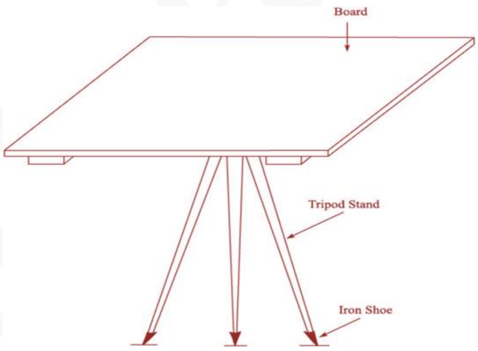
5.1 Objectives, Principles & Use of Plane Table Surveying.

Principles –

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. Plane tabling is a graphical method of surveying. Here, the field work and plotting are done simultaneously and such survey does not involve the use of a field book.

Objectives –

The relative positions of the objects on the ground are represented by their plotted positions on the paper and lie on the respective rays. Plane table survey is mainly suitable for filling interior details when traversing is done by Theodolite.



Uses -

- A rapid method of surveying.
- Less costly than most of the surveying technique.
- A suitable method for measures small-scale land.
- No high cost equipment required.
- A suitable method to work in magnetic fluctuation areas.
- No skilled labor required to plot the map.
- Easy to cross check the measurements.

5.2 Instruments & Accessories Used In Plane Table Surveying.

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

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

The Alidade - There are two types of alidade - ***plain and telescopic.***

A. ***Plain Alidade*** **-** The plain alidade consists of a metal or wooden ruler of length about 50 cm. One of its edges 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. ***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 edge.

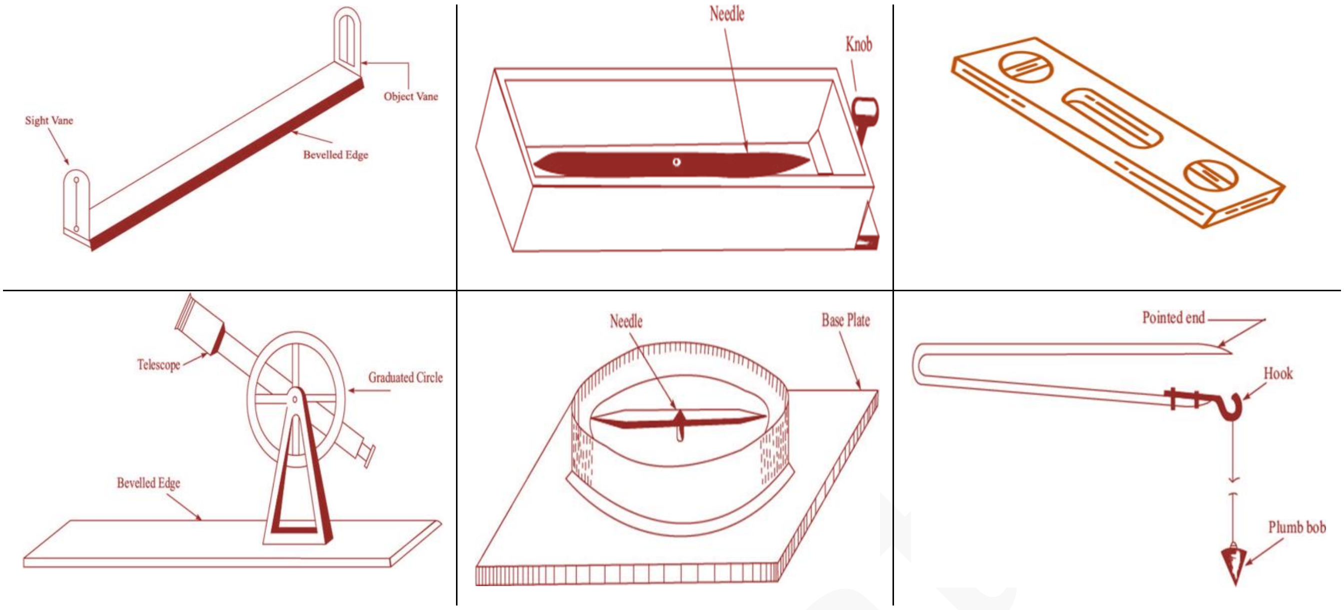
The Spirit Level - The spirit level is a small metal tube containing a small bubble of spirit. The bubble is visible on the top along a graduated glass tube. The spirit level is meant for leveling the plane table.

The Compass - There are two kinds of compasses - (a) the trough and (b) the circular box compass.

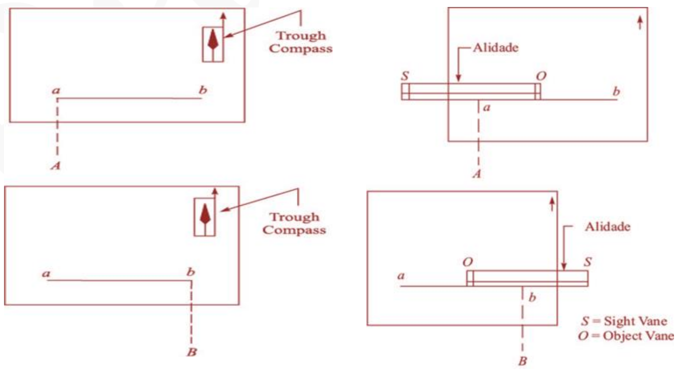
A. ***The Trough Compass*** - The trough compass is a rectangular box made of non-magnetic metal containing a magnetic needle pivoted at the centre. This compass consists of a '0' mark at both ends to locate the N-S direction.

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 the map.

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 carries a hook for suspending a plumb bob. This is meant for centering the table over a station.



Orientation - The method of setting up the plane table at each of the successive stations parallel to the position it occupied at the starting station is known as orientation. Orientation must be done when the plane table is set up at more than one station. But if orientation is not done then the map will not represent the actual positions of the objects. Orientation may be done by magnetic needle and back sighting.



Procedure of setting up a plane table over a station -

***1. Fixing the Table on the Tripod Stand* -** The tripod stand is placed over the required station with its legs well apart. Then the table is fixed on it by a wing nut at the bottom.
***2. leveling the Table* -**The table is leveled by placing the spirit level at different corners and various positions on the table. The bubble is brought to the centre of its run at every positions of the table by adjusting the legs.
***3. Centering the Table* -** The drawing sheet is fixed on the table. A suitable point *P* is selected on the sheet to represent the station *P* on the ground. A pin is then fixed on this selected point. The upper pointed end of the *U*-fork is made in contact with the station pin and the plumb bob which is suspended from the hook at the lower end is brought just over the station *P* by turning the table clockwise or anticlockwise or slightly adjusting the legs. This operation is called centering. The table is then clamped. Care should be taken not to disturb the leveling.
***4. Marking the North Line* -** The trough compass is placed on the right-hand top corner with its north end approximately towards the north. Then the compass is turned clockwise or anticlockwise so that the needle coincides exactly with the 0–0 mark. Now a line representing the north line is drawn through the edge of the compass. It should be ensured that the table is not turned.
***5. Orientation* -** When plane table survey is to be conducted by connecting several stations, the orientation must be performed at every successive station. It may be done by a magnetic needle or by the back sighting method. The back sighting process is always preferred, because it is reliable. During orientation, it should always be remembered that the requirements of centering, leveling and orientation must be satisfied simultaneously.

5.3 Methods of Plane Table Surveying

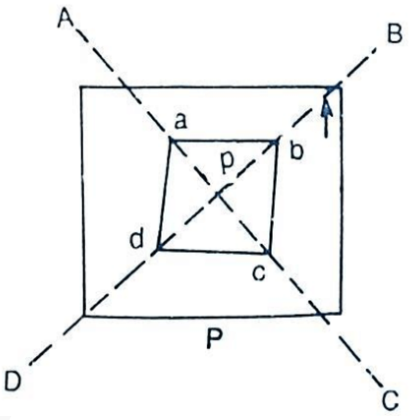
The following are the four methods of plane tabling;

(1) Radiation,
(2) Intersection,
(3) Traversing,
(4) Resection.

Radiation Method - This method is suitable for locating the objects from a single station. In this method, rays are drawn from the station to the objects, and the distances from the station to the objects are measured and plotted to any suitable scale along the respective rays.

Procedure

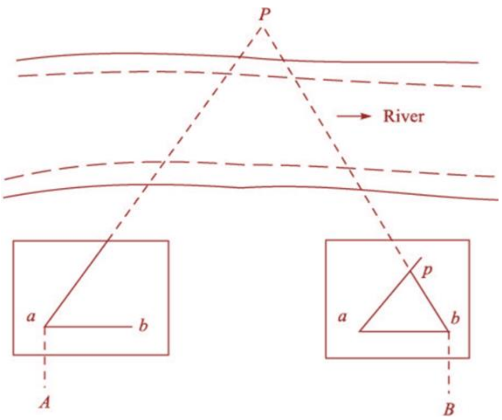
- Suppose P is a station on the ground from where the objects A, B, C and D are visible.
- The plane table is set up over the station P. A drawing sheet is fixed on the table, which is then leveled and centered. A point p is selected on the sheet to represent the station P.
- The north line is marked on the right-hand top corner of the sheet with trough compass or circular box compass.
- With the alidade touching p, the ranging rods at A, B, C and D are bisected and the rays drawn.
- The distances PA, PB, PC, and PD are measured and plotted to any suitable scale to obtain the points a, b, c, and d, representing the objects A, B, C and D on paper.



Intersection Method - This method is suitable for locating inaccessible points by the intersection of the rays drawn from two instrument stations.

Procedure

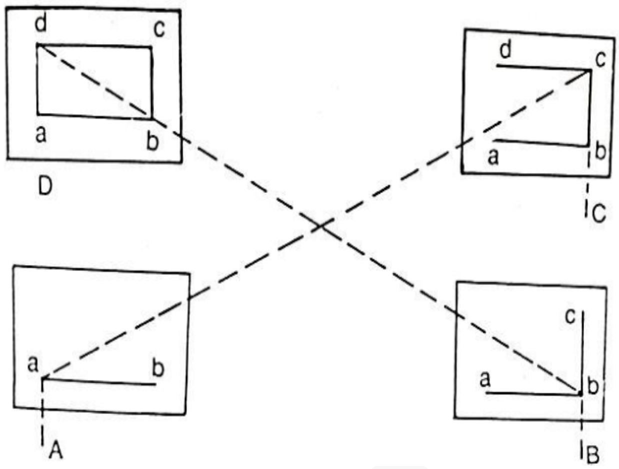
- Suppose A & B are two stations and P is an object on the far bank of a river. Now it is required to fix the position of P on the sheet by the intersection of rays, drawn from A and B.
- The table is set up at A. It is leveled and centered so that a point a on the sheet is just over the station A. The north line is marked on the right-hand top corner. The table is then clamped.
- With the alidade touching a, the object P and the ranging rod at B are bisected, and rays are drawn through the fiducially edge of the alidade.
- The distance AB is measured and plotted to any suitable scale to obtain the point b.
- The table is shifted and centered over B and leveled properly. Now the alidade is placed along the line and orientation is done by back sighting. At this time, it should be remembered that the centering, leveling and orientation must be perfect simultaneously.
- With the alidade is touching b, the object P is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point p. This point p is the required plotted position of P.



Traversing Method - This method is suitable for connecting the traverse stations. This is similar to compass traversing or theodolite traversing. But here, fielding and plotting are done simultaneously with the help of the radiation and intersection methods.

Procedure

- Suppose A, B, C and D are the traverse stations. The table is set up at the station A. A suitable point is selected on the sheet in such a way that the whole area may be plotted in the sheet. The table is centered, leveled and clamped. The north line is marked on the right-hand top corner of the sheet.
- With the alidade touching the point a, the ranging rod at B is bisected and a ray is drawn. The distance AB is measured and plotted to any suitable scale.
- The table is shifted and centered over B. It is then leveled, oriented by back-sighting and clamped.

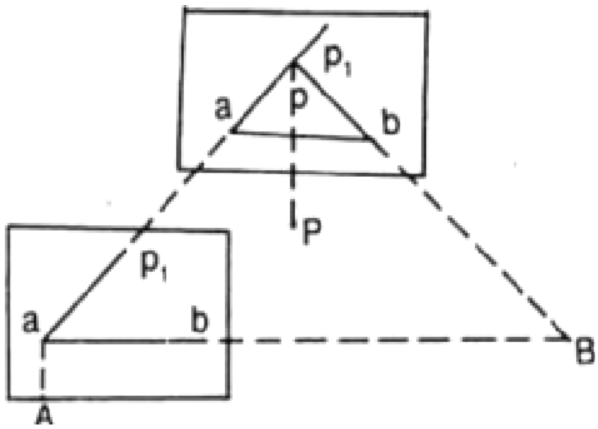


- With the alidade touching the point b, the ranging rod at C is bisected and a ray is drawn. The distance BC is measured and plotted to the same scale.
- The table is shifted and set up at C and the same procedure is repeated. In this manner, all stations of the traverse are connected.
- At the end, the finishing point may not coincide with the starting point and there may be some closing error. This error is adjusted graphically by Bowditch's rule.
- After making the corrections for closing error, the table is again set up at A. After centering, leveling and orientation, the surrounding details are located by radiation.
- The table is then shifted and set up at all the stations of the traverse and after proper adjustments the details are located by the radiation and intersection methods.

Resection Method - This method is suitable for establishing new stations at a place in order to locate missing details.

Procedure

- Suppose it is required to establish a station at the position P. Let us select two points A and B on the ground. The distance AB is measured and plotted to any suitable scale. This line AB is known as the base line.
- The table is set up at A. It is leveled, centered and oriented by bisecting the ranging rod at B. The table is then clamped.
- With the alidade touching point a, the ranging rod at P is bisected and a ray is drawn. Then a point P1 is marked on this ray by estimating with the eye.
- The table is shifted and centered in such a way that P1 is just over P. It is then oriented by back sighting the ranging rod at A.
- With the alidade touching the point b, the ranging rod at B is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point P. This point represents the position of the station P on the sheet. Then the actual position of the station P is marked on the ground by U-fork and plumb bob.

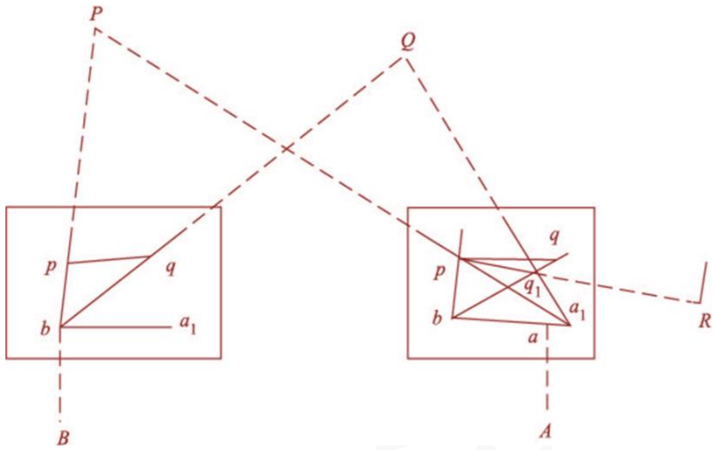


Special Methods of Resection - Sometimes, after the completion of plane table traversing, it may be noticed that an important object has not been located due to oversight. If no station pegs are found on the field, some special methods of resection are applied in order to establish a new station for plotting the missing object. The methods are based on;

(1) The two-point problem, and
(2) The three-point problem.

The Two-point Problem - In this problem, two well-defined points whose positions have already been plotted on the plan are selected. Then, by perfectly bisecting these points, a new station is established at the required position.

Procedure

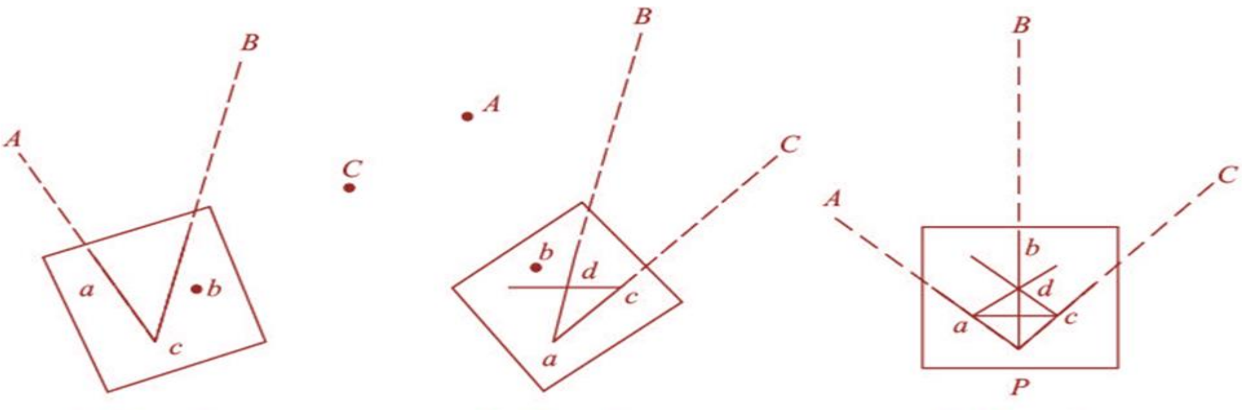


- Suppose P and Q are two well-defined points whose positions are plotted on map as p and q. It is required to locate a new station at A by perfectly bisecting P and Q.
- An auxiliary station B is selected at a suitable position. The table is set up at B, and leveled and oriented by eye estimation. It is then clamped.
- With the alidade is touching p and q, the points P and Q are bisected and rays are drawn. Suppose these rays intersect at b.
- With the alidade centered on b, the ranging rod-at A is bisected and a ray is drawn. Then, by eye estimation, a point $a1$ is marked on this ray.
- The table is shifted and centered on A, with $a1$ just over A. It is leveled and oriented by back sighting. With the alidade touching p, the point P is bisected and a ray is drawn. Suppose this ray intersects the line ba, at the point $a1$, as was assumed previously.
- With the alidade centered on $a1$, the point Q is bisected and a ray is drawn. Suppose this ray intersects the ray bq at a point $q1$. The triangle $pqq1$ is known as the *triangle of error*, and is to be eliminated.
- The alidade is placed along the line $pq1$ and a ranging rod R is fixed at some distance from the table. Then, the alidade is placed along the line pq and the table is turned to bisect R. At this position, the table is said to be perfectly oriented.
- Finally, with the alidade centered on p and q, the points P and Q are bisected and rays are drawn. Suppose these rays intersect at a point a. This would represent the exact position of the required station A. Then the station A is marked on the ground.

The Three-point Problem - In this problem, three well-defined points are selected whose positions have already been plotted on the map. Then, by perfectly bisecting these three well-defined points, a new station is established at the required position. No auxiliary station is required in order to solve this problem. The table is directly placed at the required position. The problem may be solved by three methods;

(a) Graphical or Bessel's method,
(b) Mechanical method,
(c) Trial-and-error method.

Graphical Method –

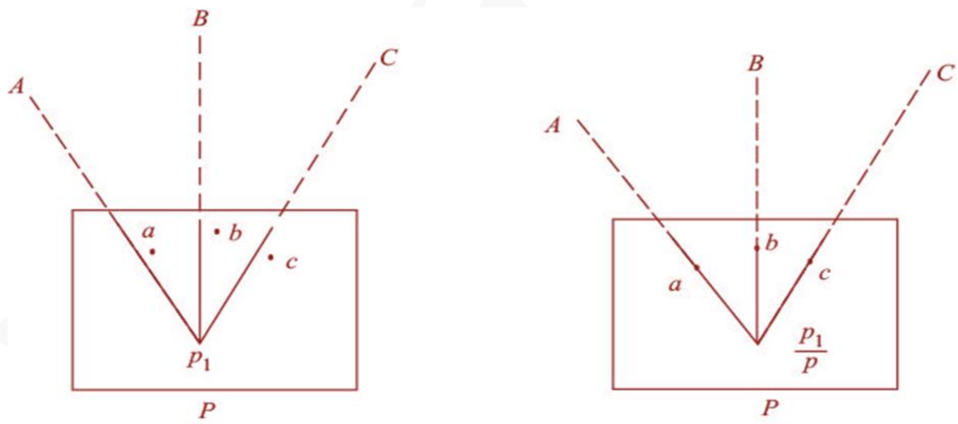


1st Operation (a) 2nd Operation (b) 3rd Operation (c)

- Suppose *A*, Band *C* are three well-defined points which have been plotted as *a*, *b*, and *c*. Now it is required to locate a station at *P*.
- The table is placed at the required station *P* and leveled. The alidade is placed along the line *ca* and the point *A* is bisected. The table is clamped. With the alidade centered on *C*, the point *B* is bisected and ray is drawn
- Again the alidade is placed along the line *ac* and the point *C* is bisected and the table is clamped. With the alidade touching *a*, the point *B* is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point *d*.
- Alidade is placed along *db* and the point *B* is bisected. At this position, the table is said to be perfectly oriented. Now the rays *Aa*, *Bb* and *Cc* are drawn.
- These three rays must meet at a point *p* which is the required point on the map. This point is transferred to the ground by a *U*-fork and plumb bob.

Mechanical Method -

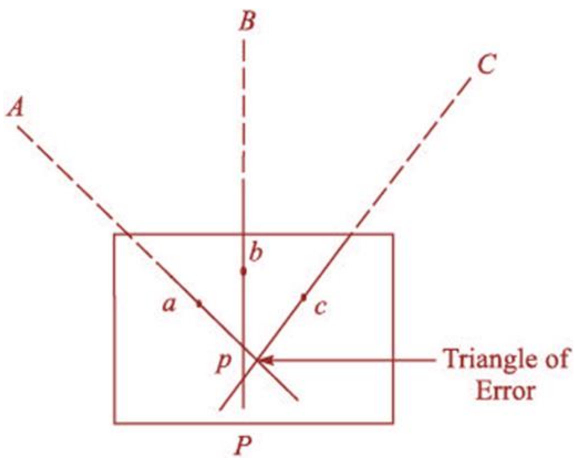
- Suppose *A*, *B* and *C* are three well-defined points which have been plotted on the map as *a*, *b*, and *c*. It is required to locate a station at *P*.
- The table is placed at *P* and leveled. A tracing paper is fixed on the map and a point *p* is marked on it.
- With the alidade centered on *P*, the points *A*, *B* and *C* are bisected and rays are drawn. These rays may not pass through the points *a*, *b* and *c* as the orientation is done approximately.
- Tracing paper is unfastened and moved over the map in such a way that the three rays simultaneously pass through the plotted positions *a*, *b*, and *c*. Then the point *p* is pricked with a pin to give an impression *p* on the map. *p* is the required point on the map. The tracing paper is then removed.



(a) (b)

- Then the alidade is centered on *p* and the rays are drawn towards *A*, *B* and *C*. These rays must pass through the points *a*, *b* and *c*.

Method of Trial and Error -



- Suppose *A*, *B* and *C* are three well-defined points which have been plotted as *a*, *b*, and *c* on the map. Now it is required to establish a station at *P*.
- The table is set up at *P* and leveled. Orientation is done by eye estimation.
- With the alidade, rays *Aa*, *Bb* and *Cc* are drawn. As the orientation is approximate, the rays may not intersect at a point, but may form a small triangle through the triangle of error.
- To get the actual point, this triangle of error is to be eliminated. By repeatedly turning the table clockwise or anticlockwise, the triangle is eliminated in such a way that the rays *Aa*, *Bb*, and *Cc* finally meet at a point *p*.
- This is the required point on the map. This point is transferred to the ground by U-fork and plumb bob.

5.4 Errors in Plane Table Surveying & Their Corrections, Precautions in Plane Table Surveying.

Instrumental Errors

- The surface of the table may not be perfectly level.
- The fiducially edge of the alidade might not be straight.
- The vanes may not be vertical.
- The horsehair may be loose and inclined.
- The table may be loosely joined with the tripod stand.
- The needle of the trough compass may not be perfectly balanced.
- Also it may not be able to move freely due to sluggishness of the pivot point.

Personal Errors

- The leveling off the table may not be perfect.
- The table may not be centered properly.
- The orientation of the table may not be proper.
- The table might not be perfectly clamped.
- The objects may not be bisected perfectly.
- The alidade may not be correctly centered on the station point.
- The rays might not be drawn accurately.
- The alidade may not be centered on the same side of the station point throughout the work.

Plotting Errors

- A good-quality pencil with a very fine pointed end may not have been used.
- An incorrect scale may be used by mistake.
- Errors may result from failure to observe the correct measurement from the scale.
- Unnecessary hurry at the time of plotting may lead to plotting errors.

The following precautions should be taken while using the plane table -

- Before starting the work the equipments for survey work should be verified.
- Defective accessories should be replaced by perfect equipment.
- The centering should be perfect.
- The leveling should be proper.
- The orientation should be accurate.
- The alidade should be centered on the same side of the station-pin until the work is completed.
- While shifting the plane table from one station to another, the tripod stand should be kept vertical to avoid damage to the fixing arrangement.
- Several accessories have to be carried. So, care should be taken to ensure that nothing is missing.
- The pencil should have a sharp point.
- The distances of the objects or lines should be written temporarily along the respective rays until the plotting is completed.
- Only the selected scale should be on the table.
- Measurements should be taken carefully from the scale while plotting.
- The stations on the ground are marked *A*, *B*, *C*, *D*, etc. while the station points on the map are marked *a*, *b*, *c*, *d*, etc.

6. THEODOLITE SURVEYING AND TRAVERSING

6.1 Purpose & Definition of Theodolite Surveying

The theodolite is an intricate instrument used mainly for accurate measurement of horizontal and vertical angles up to 10″ or 20″, depending upon the least count of the instrument. Because of its various uses, the theodolite is sometimes known as a universal instrument.

The following are the different purposes for which the theodolite can be used:

1. Measuring horizontal angles
2. Measuring vertical angles
3. Measuring deflection angles
4. Measuring magnetic bearings
5. Measuring the horizontal distance between two points
6. Finding the vertical height of an object
7. Finding the difference of elevation between various points
8. Ranging a line

Theodolites may be of two types

(i) ***Transit***
(ii) ***Non-transit.***

In the *transit theodolite,* the telescope can be resolved through a complete revolution about its horizontal axis in a vertical plane.
In the *non-transit theodolite,* the telescope cannot be resolved through a complete revolution in the vertical plane. But it can be resolved to a certain extent in the vertical plane, in order to measure the angle of elevation or depression.

Theodolites may also be classified as;

(i) Vernier theodolites - when fitted with a vernier scale, and
(ii) Micrometer theodolites - when fitted with a micrometer.

The size of the theodolite is defined according to the diameter of the main horizontal graduated circle.
For example, in a "10 cm theodolite", the diameter of the main graduated circle is 10 cm, in engineering survey; 8 cm to 12 cm theodolites are generally used.

6.2 Transit Theodolite

- ***Centring*** - The setting of a theodolite exactly over a station mark by means of a plumb-bob is known as centring. The plumb-bob is suspended from a hook fixed below the vertical axis.
- ***Transiting*** - The method of turning the telescope about its horizontal axis in a vertical plane through 180° is termed as transiting. In other words, transiting results in a change in face.
- ***Face Left*** - Face left means that the vertical circle of the theodolite is on the left of the observer at the time of taking readings. The observation taken in the face left position is called *face-left observation*.
- ***Face Right*** - This refers to the situation when the vertical circle of the instrument is on the right of the observer when the reading is taken. The observation taken in the face right position is known as *face-right observation*.
- ***Telescope Normal*** - The face left position is known as 'telescope normal' or 'telescope direct'. It is also referred to as *bubble up*.

- ***Telescope Inverted*** **-** The face right position is called 'telescope inverted' or 'telescope reversed'. It is also termed *bubble down*.
- ***Changing Face*** **-** The operation of bringing the vertical circle from one side of the observer to the other is known as changing face.
- ***Swinging the Telescope*** **-** This indicates turning of the telescope in a horizontal plane. It is called 'right swing' when the telescope is turned clockwise and *left swing* when the telescope is turned anticlockwise.
- ***Line of Collimation*** **-** It is an imaginary line passing through the intersection of the cross-hairs at the diaphragm and the optical centre of the object glass and its continuation.
- ***Axis of the Telescope*** **-** This axis is an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece.
- ***Axis of the Bubble Tube*** **-** It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.
- ***Vertical Axis*** **-** It is the axis of rotation of the telescope in the horizontal plane.
- ***Horizontal Axis*** **-** It is the axis of rotation of the telescope in the vertical plane. It is also known as the *turnnion axis*.
- ***Temporary Adjustment*** **-** The setting of the theodolite over a station at the time of taking any observation is called temporary adjustment. This adjustment is necessary for every set up of the instrument. (See Sec. 9.5 for a detailed description.)
- ***Permanent Adjustment*** **-** When the desired relationship between the fundamental lines of a theodolite is disturbed then some procedures are adopted to establish this relationship. This adjustment is known as permanent adjustment.
- ***Least Count of the Vernier*** **-** This is the difference between the value of the smallest division of the main scale and that of the smallest division of the vernier scale. It is the smallest value that can be measured by a theodolite.
- ***Magnification or Magnifying Power of Telescope*** **-** The magnifying power of a telescope is the ratio of the focal length of the objective to that of the eyepiece.

  If f = focal length of objective

  f_1 = focal length of eyepiece

  Magnifying power = $\frac{f}{f1}$
- ***Diaphragm*** **-** The diaphragm is a brass ring consisting of cross-hairs, or one containing a glass disc with fine lines engraved on it. It is placed in position by turning four capstan-headed screws, and can be moved up, down or sideways when required. It is fixed in front of the eyepiece. The cross-hairs may be made of spider web or fine platinum wire; they may also be in the form of a fine scratch mark engraved on glass.
- ***Sensitiveness of Bubble Tube*** **-** The ability of a bubble tube to show a very small deviation of the bubble from its horizontal position is termed as the sensitiveness of the bubble tube.

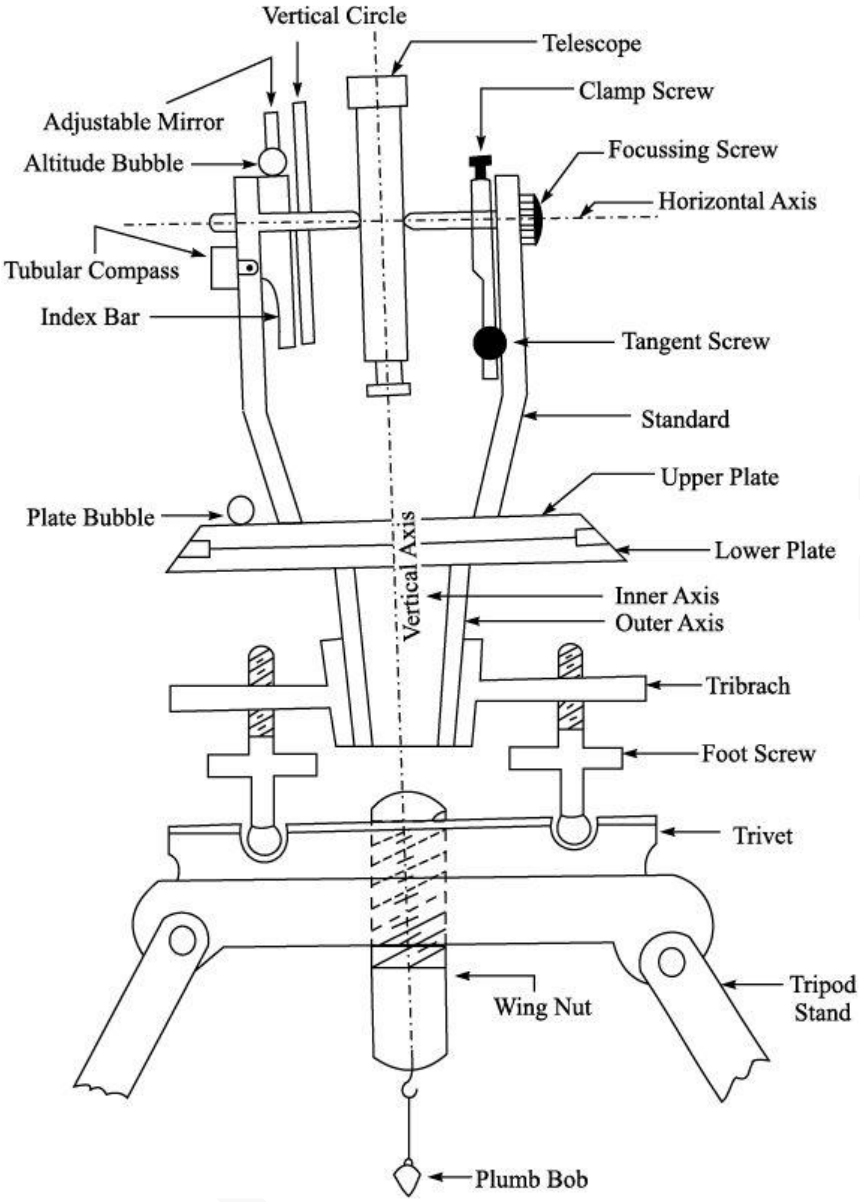
The Following Are the Essential Parts of a Theodolite;

1. Trivet **-** It is a circular plate having a central, threaded hole for fixing the theodolite on the tripod stand by a wing nut. It is also called the *base plate*. Three foot screws are secured to this plate by means of a ball-and-socket arrangement.

2. Foot Screws **-** These are meant for leveling the instrument. The lower part of the foot screws are secured in the trivet by means of a ball-and-socket arrangement, and the upper threaded part passes through the threaded hole in the tribrach plate.

3. Tribrach **-** It is a triangular plate carrying three foot screws at its ends.

4. Leveling Head **-** The trivet, foot screws and the tribrach constitute a body which is known as the leveling head.



5. Spindles - The theodolite consists of two spindles or axes - one inner and the other outer. The inner axis is solid and conical, and the outer is hollow. The two spindles are coaxial.

6. Lower Plate - The lower plate is attached to the outer axis, and is also known as the *scale plate*. It is bevelled and the scale is graduated from 0 to 360° in a clockwise direction. Each degree is again subdivided into two, three or four divisions; thus, the value of one small division may be 30′, 20′ or 15′ respectively. The lower plate is provided with a clamp screw and a tangent screw which control its movements. When the clamp screw is tightened, this plate is fixed with the outer axis. For fine adjustment of the lower plate, the tangent screw is rotated to the extent required. The size of the theodolite is designated according to the diameter of the lower plate.

7. Upper Plate - The upper plate contains the vernier scales *A* and *B*. It is attached to the inner axis. Its motion is controlled by the upper clamp screw and the upper tangent screw. When the clamp screw is tightened, the vernier scales are fixed with the inner axis, and for fine adjustment of the scales the tangent screw is rotated.

8. Plate Bubble - Two plate bubbles are mounted at right angles to each other on the upper surface of the vernier plate. One bubble is kept parallel to the horizontal axis of the theodolite. Sometimes one plate bubble is provided on the vernier plate. The bubbles are meant for leveling the instrument at the time of measuring the horizontal angles.

9. Standard or A-frame - Two frames (shaped like the letter '*A*') are provided on the upper plate to support the telescope, the vertical circle and the vernier scales. These frames are known as standards or *A*-frames.

10. Telescope - The telescope is pivoted between the standards at right angles to the horizontal axis. It can be rotated about its horizontal axis in a vertical plane. The telescope is provided with a focusing screw, clamping screw and tangent screw.

11. Vertical Circle - The vertical circle is rigidly fixed with the telescope and moves with it. It is divided into four quadrants. Each quadrant is graduated from 0 to 90° in opposite directions, with the 'zero' mark at the ends of the horizontal diameter of the vertical circle. The line joining the 'zero' marks, corresponds to the line of collimation. The subdivisions of the vertical circle are similar to these of the horizontal circle. The vertical circle can be clamped or finely adjusted with the help of the clamping screw and the tangent screw provided along with the telescope.

12. Index Bar or T-frame - The index bar is provided on the standard in front of the vertical circle. It carries two verniers (*C* and *D*) at the two ends of the horizontal arm. The vertical leg of the index bar is provided with a clip screw at the lower end by means of which the altitude bubble can be brought to the centre.

13. Altitude Bubble - A long sensitive bubble tube is provided on the top of index bar. The bubble it contains is known as the altitude bubble. This bubble is brought to the centre by the clip screw at the time of measuring the vertical angle. A mirror is provided on the top of the bubble to help observe it when the instrument is set up above normal height.

14. Compass - Sometimes a circular box compass is mounted on the vernier scale between the standards. In modern theodolites, an adjustable trough compass or tubular compass can be fitted with a screw to the standard. The compass is provided for taking the magnetic bearing of a line.

Temporary Adjustment of Theodolite
Such adjustment involves the following steps.

1. Setting the Theodolite over the Station - The tripod stand is placed over the required station. The theodolite is then lifted from the box and fixed on top of the stand by means of a wing nut or according to the fixing arrangement provided along with the instrument.

2. Approximate Leveling by Tripod Stand - The legs of the tripod stand are placed well apart and firmly fixed on the ground. Then, approximate leveling is done using this stand. To do this, two legs are kept firmly fixed on the ground and the third is moved in or out, clockwise or anticlockwise, so that the bubble is approximately at the centre of its run.

3. Centering - Centering is the process of setting the instrument exactly over a station. At the time of approximate leveling by means of the tripod stand, it should be ensured that the plumb bob suspended from the hook under the vertical axis lies approximately over the station peg. Then, with the help of the shifting head (movable capstan nut), the centering is done accurately so that the plumb bob is exactly over the nail of the station peg.

4. Leveling - Before starting the leveling operation, all the foot screws are brought to the centre of their run. Then the following procedure is adopted:

(a) The plate bubble is placed parallel to any pair of foot screws (say the first and second foot screws). By turning both these screws equally inwards or outwards, the bubble is brought to the centre.

(b) The plate bubble is turned through 90° so that it is perpendicular to the line joining the first and second foot screws. Then by turning the third foot screw either clockwise or anticlockwise the bubble is brought to the centre.
(c) The process is repeated several times, so that the bubble remains in the central position of the plate bubble, both directions perpendicular to each other.
(d) The instrument is rotated through 360° about its vertical axis. If the bubble still remains in the central position, the adjustment of the bubble is perfect and the vertical axis is truly vertical.

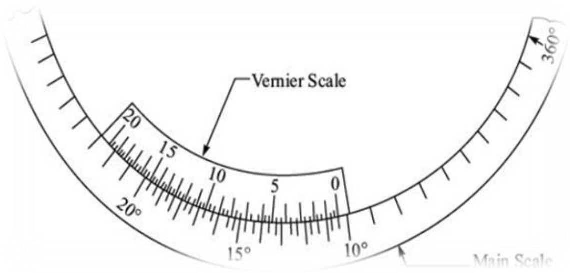
5. Focusing the Eyepiece - The eyepiece is focused so that the cross-hairs can be seen clearly. To do this, the telescope is directed towards the sky or a piece of white paper is held in front of the object glass, and the eyepiece is moved in or out by turning it clockwise or anticlockwise until the cross-hairs appears distinct and sharp.

6. Focusing the Object Glass - This is done to bring a sharp image of the object or target in the plane of cross-hairs and to eliminate parallax.
To do this, the telescope is directed towards the object or target and the focusing screw is turned clockwise or anticlockwise until the image appears clear and sharp and there is no relative movement between the image and cross-hairs. The absence of relative movement can be verified by moving the eye up and down.

7. Setting the Vernier - The vernier *A* is set to 0° and vernier *B* to 180°. To do this, the lower clamp is fixed. The upper clamp is loosened and the upper plate turned until the arrow of vernier *A* approximately coincides with zero (i.e. the 360° mark) and that of vernier *B* approximately coincides with the 180° mark. Then the upper clamp is tightened, and by turning the upper tangent screw, the arrows are brought to a position of exact coincidence.

6.3 Concept of transiting –Measurement of Horizontal and Vertical angles.

Direct Method of Measuring Horizontal Angle



Suppose an angle *AOB* is to be measured. The following procedure is adopted:
1. The instrument is set up over *O*. It is centered and leveled perfectly according to the procedure described for temporary adjustment. Suppose the instrument was initially in the face left position.

2. The lower clamp is kept fixed. The upper clamp is loosened, and by turning the telescope clockwise vernier *A* is set to 0° and vernier *B* to approximately 180°. The upper clamp is then tightened. Now by turning the upper tangent screw, verniers *A* and *B* are set to exactly 0° and 180° by looking through the magnifying glass.

3. The upper clamp is tightly fixed. The lower one is loosened and the telescope is directed to the left-hand object *A*. The ranging rod at *A* is bisected approximately by properly focusing the telescope and eliminating parallax. The lower clamp is tightened, and by turning the lower tangent screw the ranging rod at *A* is accurately bisected.

4. The lower clamp is kept fixed. The upper clamp is loosened and the telescope is turned clockwise to approximately bisect the ranging rod at *B* by properly focusing the telescope. The upper clamp is tightened, and the ranging rod at *B* bisected accurately by turning the upper tangent screw.

5. The readings on verniers *A* and *B* are noted. Vernier *A* gives the angle directly. But in the case of vernier *B*, the angle is obtained by subtracting the initial reading from the final reading.

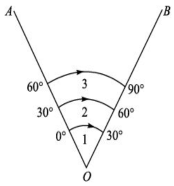
6. The face of the instrument is changed and the previous procedure is followed. The mean of the observations (i.e. face left and face right) is the actual angle *AOB*. The two observations are taken to eliminate any possible error due to imperfect adjustment of the instrument.

There are two methods of measuring horizontal angles those of **Repetition** and **Reiteration.**

Repetition Method

In this method, the angle is added a number of times. The total is divided by the number of readings to get the angle. The angle should be measured clockwise in the face left and face right positions, with three repetitions at each face. The final reading of the first observation will be the initial reading of the second observation, and so on.

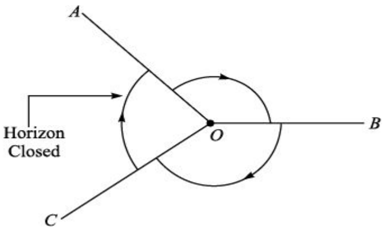
$$AOB = \frac{Accumulated\ angle}{No\ of\ readings} = {}^{90}/_{3} = 30°$$



Station	Object	Angle	Observation	Reading on vernier A	Reading on vernier B	Angle on vernier A	Angle on vernier B	Mean angle of vernier	Mean angle of observation	Remark
1	2	3	4	5	6	7	8	9	10	II
O	*A*	∠*AOB*	Face left	0°0′0″	180°0′0″	30°20′20″	30°20′40″	30°20′30″		
	B			30°20′20″	210°20′40″					
O	*A*	∠*AOB*	Face left	0°0′0″	180°0′0″	0°20′40″	30°20′420″	30°20′30″	30°20′30″	
	B			30°20′40″	210°20′20″					

Reiteration Method

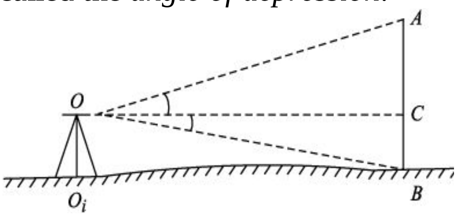
This method is suitable when several angles are measured from a single station. In this method, all the angles are measured successively and finally the horizon is closed (i.e. the angle between the last station and first station is measured.) So, the final reading of the leading vernier should be the same as its initial reading. If the discrepancy is small, the error is equally distributed among all the observed angles. If it is large, the readings should be cancelled and new sets taken. Suppose it is required to measure angle *AOB* and angle *BOC* from station *O*.



Station	Object	Face	Angle	No. of readings	Initial angle on vernier A	Initial angle on vernier B	Final reading on vernier A	Final reading on vernier B	Angle on vernier A	Angle on vernier B	Mean angle of vernier	Mean angle of observation	Remark
1	2	3	4	5	6	7	8	9	10	11	12	13	14
O	*A* *B*	Left	∠*AOB*	1	0°0′0″	180°0′0″	30°40′0″	210°40′20″					
				2	30°40′0″	210°40′20″	61°40′0″	240°20′20″	30°26′46″	30°20′6″	30°23′26″		
				3	61°40′0″	240°20′20″	91°20′20″	271°0′20″				30°23′24″	
O	*A* *B*	Right	∠*AOB*	1	0°0′0″	180°0′0″	30°40′20″	210°40′0″					
				2	30°40′20″	210°40′0″	61°40′20″	240°20′40″	30°26′46″	30°20′0″	30°23′23″		
				3	61°40′20″	240°20′40″	91°20′20″	271°0′0″					

Measuring Vertical Angles

The vertical angle is the one between the horizontal line (i.e. line of collimation) and the inclined line of sight. When it is above the horizontal line, it is known as the *angle of elevation*. When this angle is below the horizontal line, it is called the *angle of depression*.



Inst. Station	Station bisected	Observation	Reading on vernier A	Reading on vernier B	Angle	Angle on vernier A	Angle on vernier B	Mean angle of vernier A and B	Mean angle of observation	Correction (–ve)	Corrected angle	Remark
1	2	3	4	5	6	7	8	9	10	11	12	13
O	*A*	Face left. right swing (clockwise)	0°0′0″	180°0′0″	∠*AOB*	100°40′40″	100°40′20″	100°40′30″				
	B		100°40′40″	280°40′20″								
	C		161°20′40″	341°20′40″	∠*BOC*	60°40′0″	60°40′20″	60°40′10″	∠*AOB* = 100°40′15″	–5″	∠*AOB* = 100°40′10″ ∠*BOC* = 60°40′15″ ∠*COA* = 198°39′35″	The error is distributed equally among all the angles
	A		0°0′20″	180°0′20″	∠*COA*	198°39′40″	198°39′40″	198°39′40″		–5″		
O	*A*	Face right. left swing (anticlock-wise)	0°0′0″	180°0′0″					∠*BOC* = 60°40′20″	–5″		
	C		161°20′20″	341°20′20″	∠*COA*	198°39′40″	198°39′40″	198°39′40″				
	B		100°40′20″	280°39′40″	∠*BOC*	60°40′20″	60°40′40″	60°40′30″	∠*COA*= 198°39′40″			
	A		0°0′0″	180°0′0″	∠*AOB*	100°40′20″	100°39′40″	100°40′0″				

Total angle = 360°0′15″ Total angle = 360°0′0″

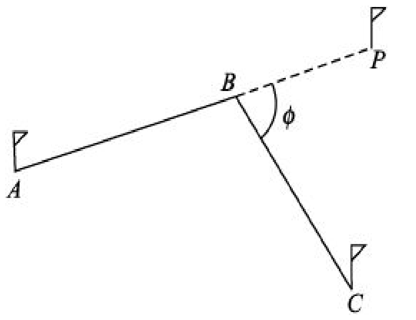
Error = −15″

Correction per angle = –5″

6.4 Measurement of magnetic bearings, deflection angle, direct angle, setting out angles, prolonging a straight line with theodolite, Errors in Theodolite observations.

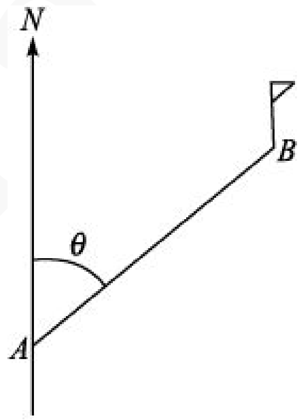
Measurement of Deflection Angle

The deflection angle is the angle by which a line is deflected from its original direction. In other words, it is the angle which a survey line makes with the extension of the preceding line. The deflection may be towards the right or the left, depending upon whether the angle is measured in the clockwise or anticlockwise direction from the extension of the preceding line. Deflection angles are measured for designing horizontal curves in railways, highways, etc.



Measurement of Magnetic Bearing

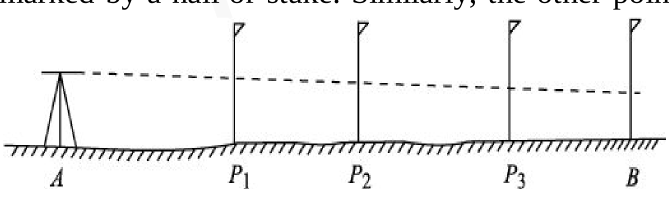
1. The theodolite is set up at *A*, and centered and levelled properly. Vernier *A* is set at 0° and vernier *B* at 180°.The upper clamp is fixed. Now a trough compass or tubular compass is fixed on the left hand standard (*A*-frame) with a fixing screw. In some theodolites, a circular compass is provided over the vernier scale between the standards. However, the needle of the compass is released.
2. By loosening the lower clamp, the telescope is rotated until it points to the north (i.e. the magnetic needle coincides with the '0–0' mark). At this time, the position of the telescope is said to be perfectly oriented along the magnetic meridian.
3. The lower clamp is fixed and the upper clamp loosened. Then by turning the telescope clockwise, the ranging rod at *B* is bisected with the help of the upper tangent screw. The readings on both the verniers are taken. The mean of these readings is the magnetic bearing of *AB*. The face of the instrument is changed, and the magnetic bearing of *AB* is measured in a similar manner. The mean of the two observations will give the correct magnetic bearing of the line.

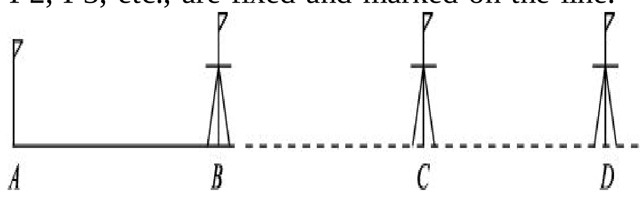


Ranging & Extending a Line

A. Ranging a Line

Ranging is the process of establishing intermediate points on a straight line between the terminal points. Let *AB* be the straight line on which intermediate points are to be fixed by theodolite.
1. The theodolite is centered over *A* and leveled properly. The upper clamp is fixed, and the lower clamp loosened. By turning the telescope the ranging rod at *B* is perfectly bisected with the help of the lower tangent screw. The lower clamp is now tightened.
2. Looking through the telescope, the observer directs the assistant to move the ranging rod to the left or right until it is on the straight line *AB*. Then the assistant fixes the ranging rod at *P*1.
3. Then by lowering the telescope the observer finds the exact point *P*1 on the ground which is marked by a nail or stake. Similarly, the other points *P*2, *P*3, etc., are fixed and marked on the line.





B. Extending a Line

The following procedure is adopted if the line *AB* is to be extended:
1. The theodolite is set up at *B*, and centered and leveled perfectly.
2. The telescope is directed towards *A* and the ranging rod at *A* is perfectly bisected. The upper and lower clamps are fixed. The telescope is transited. Looking through it, a ranging rod is fixed at *C* beyond the point *B*, along the line *AB*.
3. Now the theodolite is shifted and set up at *C* after removing the ranging rod. It is centered and leveled. Then a back sight reading is taken on *B*. The upper and lower clamps are fixed.
4. The telescope is transited and the next point *D* is fixed on the line by a ranging rod.
5. Similarly, other points are fixed on the line.

6.5 Methods of Theodolite Traversing

The following are the different methods of traversing:
1. Included-angle method
2. Deflection-angle method
3. Fast-angle (or magnetic bearing) method

A. Included-Angle Method
This method is most suitable for closed traverse. The traverse may be taken in clockwise or anticlockwise order. Generally, a closed traverse is taken in the anticlockwise. In this method the bearing of the initial line is taken. After this, the included angles of the traverse are measured. These angles may be interior or exterior.
Procedure
1. The theodolite is set up and centered over *A*. The plate bubble is levelled. Vernier *A* is set at 0 and vernier *B* at 180°. The upper clamp is fixed.
2. The telescope is oriented along the north line with the help of the tubular compass fitted to the instrument. Then the magnetic bearing of *AB* is measured.
3. Again vernier *A* is set at 0° and the upper clamp is kept fixed.
4. The lower clamp is loosened and the ranging rod at *E* is bisected. Now, this clamp is tightened and the upper one opened. By turning the telescope clockwise, the ranging rod at *B* is bisected. The readings on the verniers are noted. The face of the instrument is changed and *A* is measured once more. The mean of the two observations gives the correct value of *A*.
5. Similarly, the other angles are measured by centering the theodolite at *B*, *C*, *D* and *E*.
The arithmetical check is applied as follows: $(2n - 4) \times 90°$ = Sum of interior angles. If there is any discrepancy, the error is distributed among the angles.
6. For plotting the traverse, latitudes and departures of the traverse legs are calculated. The interior details are marked by applying the plane-table or transit-and-tape method (which will be described later).

B. Deflection-Angle Method
This method is suitable for open traverse and is mostly employed in the survey of rivers, coast lines, roads, railways, etc. Suppose an open traverse starts from *A*. The following procedure is adopted:
1. The theodolite is set up at *A*, and then centered and leveled. After this, the bearing of the line *AB* is measured in the usual manner.
2. The theodolite is now shifted and centered over *B*. The plate bubble is levelled and vernier *A* set at 0°. Then a back sight is taken on *A*. The telescope is transited and by turning it clockwise the ranging rod at *C* is bisected. The vernier readings are taken. Then the deflection angle ϕ1 is determined—it is the average value of the angles obtained from verniers *A* and *B*.
3. Similarly, the other deflection angles ϕ2 and ϕ3 are measured.
4. A field book is prepared in which the deflection angles and offsets are clearly noted.

C. Fast-Angle Method
This method is used to measure the magnetic bearings and lengths of traverse legs. However, the angles between the lines are not measured. Suppose *ABCDA* is a closed traverse. The following procedure is adopted:
1. The theodolite is set up at *A*. The vernier *A* is set at 0°. The telescope is oriented along the north line with the help of the trough compass or tubular compass fitted to the theodolite. The lower clamp is fixed.
2. The upper clamp is loosened and the ranging rod at *B* is bisected. The reading on vernier *A* gives the fore bearing of *AB*: say it is 30°. The back bearing of the line *DA* is also measured from *A*. Now the upper clamp is also fixed. The traverse is considered in clockwise direction.
3. The instrument is shifted and set up at *B* with vernier *A* fixed at the reading of 30°. The lower clamp is loosened and the ranging rod at *A* is bisected. The telescope is now transited. The upper

clamp is then released and the ranging rod at *C* bisected. Now the reading on vernier *A* gives the bearing of *BC*: say it is 100°.
4. Again the instrument is shifted and set up at *C* with vernier *A* fixed at 100°. The same process is repeated to get the fore bearing of *CD*.
5. Similarly, the fore bearings of the remaining sides are measured. At the end of the traverse the *FB* and *BB* of *DA* should differ by 180°.

Sources of Error in Theodolites

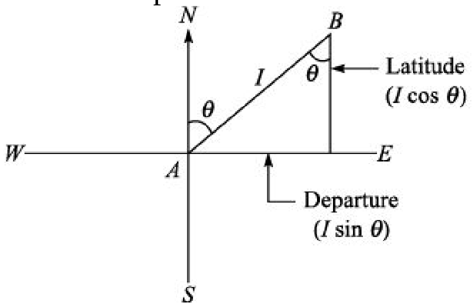
A. Instrumental Errors
The following are the major causes of instrumental error:
1. Non-adjustment of Plate Bubble
The axis of the plate bubble may not be perpendicular to the vertical axis. So, when the plate levels are centered, the vertical axis may not be truly vertical. In such a case, the horizontal circle would be inclined and the angles will be measured in an inclined plane. This would cause an error in the angle measured. This error may be eliminated by leveling the instrument with reference to the altitude bubble also.
2. Line of Collimation not being Perpendicular to Horizontal Axis
In this case, a cone is formed when the telescope is revolved in the vertical plane, and this causes an error in the observation. This error is eliminated by reading the angle from both faces (left and right), and taking the average of the readings.
3. Horizontal Axis not being Perpendicular to Vertical Axis
If the horizontal axis is not perpendicular to the vertical axis, there is an angular error. This is eliminated by reading the angle from both faces.
4. Line of Collimation not being parallel to Axis of Telescope
If the line of collimation is not parallel to the axis of the telescope, there is an error in the observed vertical angle. This error is eliminated by taking readings from both faces.
5. Eccentricity of Inner and Outer Axes
This condition causes an error in vernier readings. This error is eliminated by taking readings from both verniers and considering the average of the readings.
6. Graduations not being Uniform
The error due to this condition is eliminated by measuring the angles several times on different parts of the circle.
7. Verniers being Eccentric
The zeroes of the verniers should be diametrically opposite to each other. When vernier *A* is set at 0°, vernier *B* should be at 180°. But in some cases, this condition may not exist. This error is eliminated by reading both verniers and taking the average.

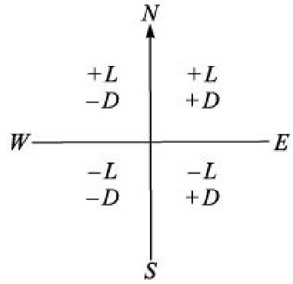
B. Personal Errors
1. The centering may not be done perfectly, due to carelessness.
2. The leveling may not be done carefully according to usual procedure.
3. If the clamp screws are not properly fixed, the instrument may slip.
4. The proper tangent screw may not be operated by mistake.
5. The focusing in order to avoid parallax may not be perfectly done.
6. The object or ranging rod may not be bisected accurately.
7. The verniers may not be set in proper place.
8. Errors would also result if the verniers are not read because of oversight.

C. Natural Errors
1. High temperature causes error due to irregular refraction.
2. High winds cause vibration in the instrument, and this may lead to wrong readings on the verniers.

6.6 Traverse computation

The theodolite traverse is not plotted according to interior angles or bearings. It is plotted by computing the latitudes and departures of the points (consecutive coordinates) and then finding the independent coordinates of the points. The latitude of a line is the distance measured parallel to the North-South line and the departure of a line is measured parallel to the East-West line.





The latitude and departure of lines are also expressed in the following ways:

Northing = latitude towards north = $+L$

Southing = latitude towards south = $-L$

Easting = departure towards east = $+D$

Westing = departure towards west = $-D$

WCB between	Corresponding *RB*	Quadrant
0° and 90°	$RB = WCB$	NE
90° and 180°	$RB = 180° - WCB$	SE
180° and 270°	$RB = WCB - 180°$	SW
270° and 360°	$RB = 360° - WCB$	NW

Check for Closed Traverse

1. The algebraic sum of latitudes must be equal to zero.
2. The algebraic sum of departures must also be equal to zero.

Check for Closed Traverse

1. Sum of northings = sum of southings
2. Sum of eastings = sum of westings

1. Consecutive Coordinates The latitude and departure of a point calculated with reference to the preceding point for what are called consecutive coordinates.

2. Independent Coordinates The coordinates of any point with respect to a common origin are said to be the independent coordinates of that point. The origin may be a station of the survey or a point entirely outside the traverse.

Line	Length (L)	Reduced bearing (θ)	Latitude (L cos θ)	Departure (L sin θ)
AB	L	N θ E	$+L \cos\theta$	$+L \sin\theta$
BC	L	S θ E	$-L \cos\theta$	$+L \sin\theta$
CD	L	S θ W	$-L \cos\theta$	$-L \sin\theta$
DA	L	N θ W	$+L \cos\theta$	$-L \sin\theta$

Line	Length	Reduced bearing	Consecutive Coordinates			
	(L)	(θ)	Northing (+)	Southing (–)	Easting (+)	Westing (–)
AB	L	N θ E	$L \cos\theta$		$L \sin\theta$	
BC	L	S θ E		$L \cos\theta$	$L \sin\theta$	
CD	L	S θ W		$L \cos\theta$		$L \sin\theta$
DA	L	N θ W	$L \cos\theta$			$L \sin\theta$

6.7 Closing Error – Adjustment of Angular Errors, Adjustment of Bearings

In a closed traverse, the algebraic sum of latitudes must be equal to zero, and so should the algebraic sum of departures. But due to the errors in field measurements of angles and lengths, sometimes the finishing point may not coincide with the starting point of a closed traverse. The distance by which a traverse fails to close is known as ***closing error*** or ***error of closure.***

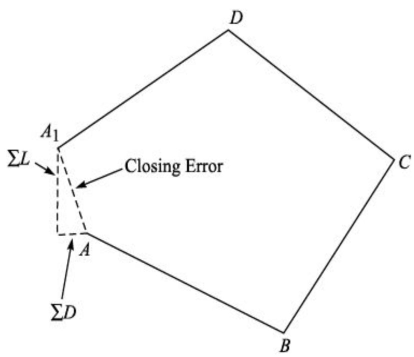
Closing error, $AA1 = \sqrt{(\Sigma L)^2 + (\Sigma D)^2}$

where L = latitude

and D = departure

Relative closing error = $\dfrac{\text{closing error}}{\text{perimeter of traverse}}$

Permissible angular error = least count × $\sqrt{N}$



Where, N = number of sides, $\tan\theta = \frac{\Sigma D}{\Sigma L}$

θ indicates the direction of closing error.
N = number of sides of traverse.

6.8 Balancing of traverse – Bowditch's method, transit method, graphical method, axis method, calculation of area of closed traverse.

In case of a closed traverse, the algebraic sum of latitudes must be equal to zero and that of departures must also be equal to zero in the ideal condition. In other words, the sum of the northings must equal that of the southings, and the sum of the eastings must be the same as that of the westings. But in actual practice, some closing error is always found to exist while computing the latitude and departures of the traverse stations. The total errors in latitude and departure are determined. These errors are then distributed among the traverse stations proportionately, according to the following rules.

1. Bowditch's Rule

By this rule, the total error (in latitude or departure) is distributed in proportion to the lengths of the traverse legs. This is the most common method of traverse adjustment.

(a) Correction to latitude of any side

$$= \frac{\text{length of that side}}{\text{perimeter of traverse}} \times \text{total error in latitude}$$

(b) Correction to departure of any side

$$= \frac{\text{length of that side}}{\text{perimeter of traverse}} \times \text{total error in departure}$$

2. Transit Rule

(a) Correction to latitude of any side

$$= \frac{\text{latitude of that side}}{\text{arithmetical sum of all latitudes}} \times \text{total error in latitude}$$

(b) Correction to departure of any side

$$= \frac{\text{departure of that side}}{\text{arithmetical sum of all departures}} \times \text{total error in departure}$$

3. Third Rule

(a) Correction to northing of any side

$$= \frac{\text{northing of that side}}{\text{sum of northings}} \times \frac{1}{2}(\text{total error in latitude})$$

(b) Correction to southing of any side

$$= \frac{\text{southing of that side}}{\text{sum of southings}} \times \frac{1}{2}(\text{total error in latitude})$$

(c) Correction to easting of any side

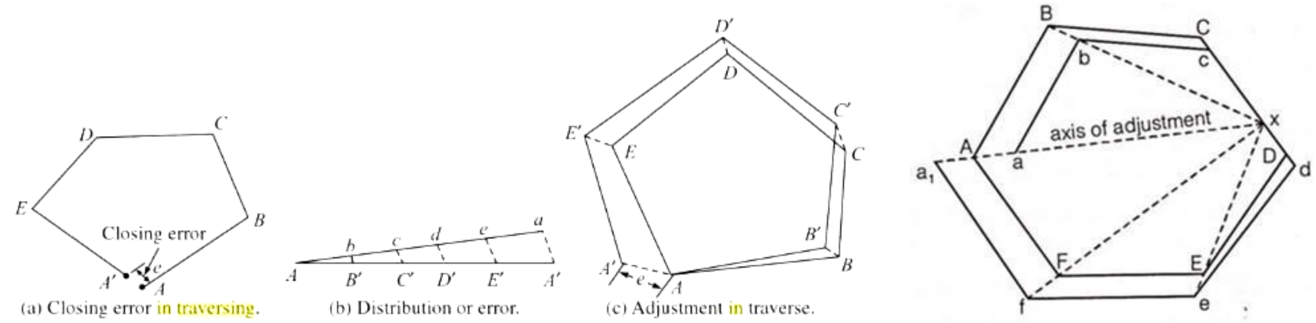
$$= \frac{\text{easting of that side}}{\text{sum of eastings}} \times \frac{1}{2}(\text{total error in departure})$$

(d) Correction to westing of any side

$$= \frac{\text{westing of that side}}{\text{sum of westings}} \times \frac{1}{2}(\text{total error in departure})$$

Note *If the error is positive, correction will be negative, and vice versa.*

4. Graphical Method



(a) Closing error in traversing. (b) Distribution or error. (c) Adjustment in traverse.

5. Axis Method

This method is used to balance a traverse where angles are measured more precisely than the lengths and thus this axis method is used for correction of lengths only.

Gales Traverse Table

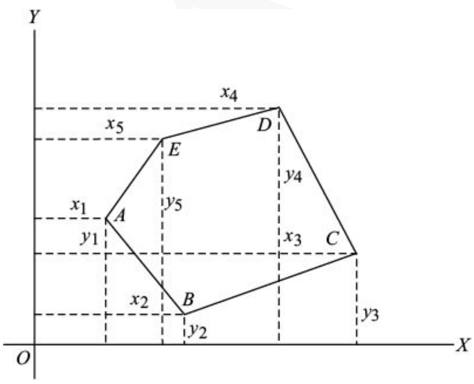
The traverse table in which all information is tabulated is called Gale's Traverse Table. It consists of Length, Whole Circle Bearing, Reduced Bearing, Consecutive Coordinates, Corrected Angles, and Independent Coordinates.

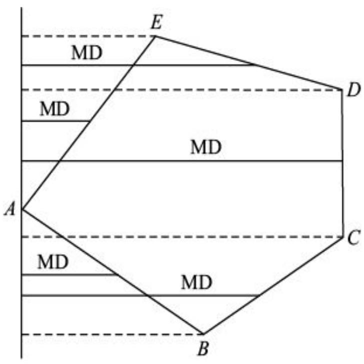
GALE'S TABLE												
ST	Dist (m)	Horizontal angle	Bearing	Consective co-ordinate		Correction		Corrected co-ordinate		Independent co-oridinate		Remarks
				Lat	Dep	Lat	Dep	Lat	Dep	Lat	Dep	

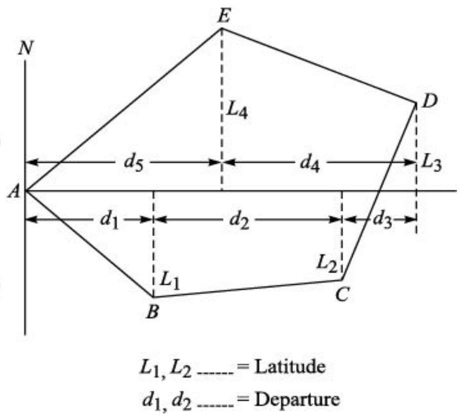
Calculation of Traverse Area

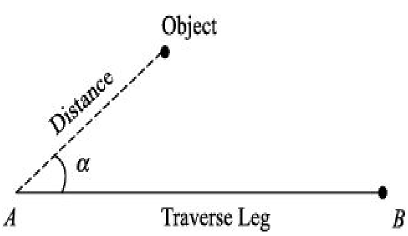
The area of a closed traverse may be calculated from;

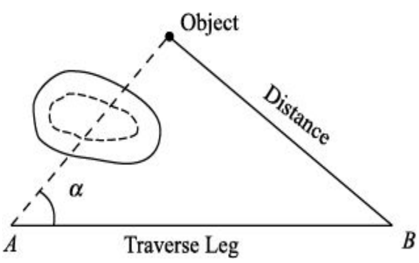
- **The coordinates (x and y),**
- **The latitude and double meridian distance, and**
- **The departure and total latitudes.**

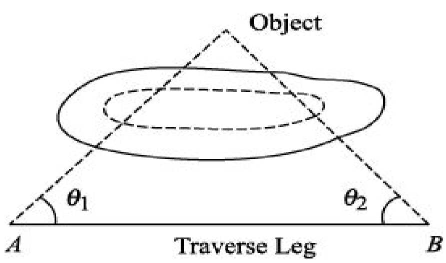












LAND SURVEY - I

7. LEVELLING AND CONTOURING

7.1 Definition & Purpose & Types of Leveling – Concepts of Level Surface, Horizontal Surface, Vertical Surface, Datum, R. L., B.M.

Object

The aim of leveling is to determine the relative heights of different objects on or below the surface of the earth and to determine the undulation of the ground surface.

Uses

Leveling is done for the following purposes:

1. To prepare a contour map for fixing sites for reservoirs, dams, barrages, etc., and to fix the alignment of roads, railways, irrigation canals, and so on.
2. To determine the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth.
3. To prepare a longitudinal section and cross-sections of a project (roads, railways, irrigation canals, etc.) in order to determine the volume of earth work.
4. To prepare a layout map for water supply, sanitary or drainage schemes.

1. Leveling

The art of determining the relative heights of different points on or below the surface of the earth is known as leveling. Thus, leveling deals with measurements in the vertical plane.

2. Level Surface

Any surface parallel to the mean spherical surface of the earth is said to be a level surface. Such a surface is obviously curved. The water surface of a still lake is also considered a level surface.

3. Level Line

Any line lying on a level surface is called a level line. This line is normal to the plumb line (direction of gravity) at all points.

4. Horizontal Plane

Any plane tangential to the level surface at any point is known as the horizontal plane. It is perpendicular to the plumb line which indicates the direction of gravity.

5. Horizontal Line

Any line lying on the horizontal plane is said to be a horizontal line. It is a straight line tangential to the level line.

6. Vertical Line

The direction indicated by a plumb line (the direction of gravity) is known as the vertical line. This line is perpendicular to the horizontal line.

7. Vertical Plane

Any plane passing through the vertical line is known as the vertical plane.

8. Datum Surface or Line

This is an imaginary level surface or level line from which the vertical distances of different points (above or below this line) are measured. In India, the datum adopted for the Great Trigonometrically Survey (GTS) is the Mean Sea Level (MSL) at Karachi.

9. Reduced Level (RL)

The vertical distance of a point above or below the datum line is known as the reduced level (RL) of that point. The RL of a point may be positive or negative according as the point is above or below the datum.

10. Line of Collimation

It is an imaginary line passing through the intersection of the cross-hairs at the diaphragm and the optical centre of the object glass and its continuation. It is also known as the line of sight.

11. Axis of the Telescope

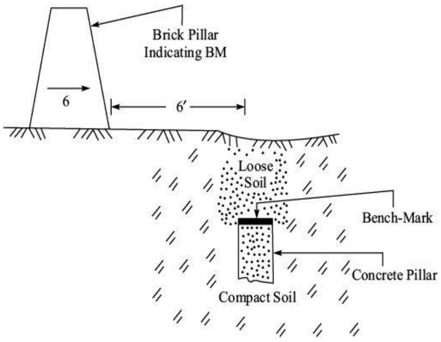
This axis is an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece.

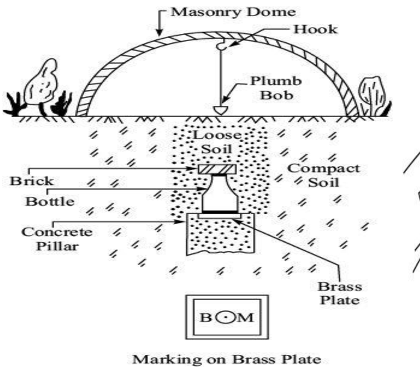
12. Axis of Bubble Tube

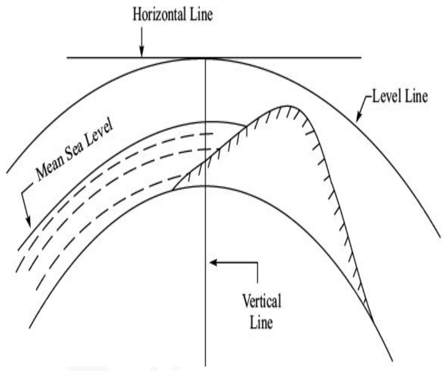
It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.

13. Bench-Marks (BM)

These are fixed points or marks of known RL determined with reference to the datum line. These are very important marks. They serve as reference points for finding the RL of new points or for conducting leveling operations in projects involving roads, railways, etc. Bench-marks may be of four types: **(a) GTS, (b) permanent, (c) temporary, and (d) arbitrary.**







14. Back sight Reading (BS)

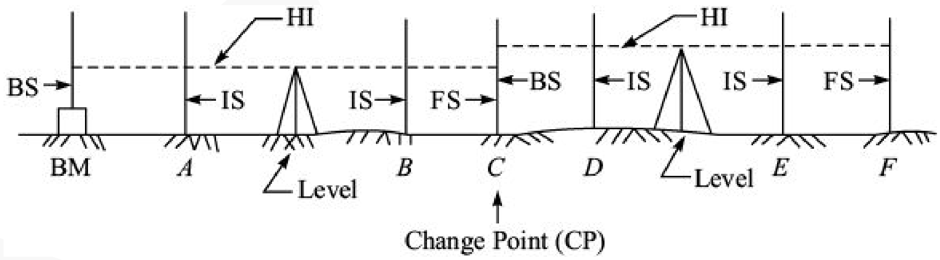
This is the first staff reading taken in any set-up of the instrument after the leveling has been perfectly done. This reading is always taken on a point of known RL, i.e. on a bench-mark or change point.

15. Foresight Reading (FS)

It is the last staff reading in any set-up of the instrument, and indicates the shifting of the latter.

16. Intermediate Sight Reading (IS)

It is any other staff reading between the BS and FS in the same set-up of the instrument.



17. Change Point (CP)

This point indicates the shifting of the instrument. At this point, an FS is taken from one setting and a BS from the next setting.

18. Height of Instrument (HI)

When the leveling instrument is properly leveled, the RL of the line of collimation is known as the height of the instrument. This is obtained by adding the BS reading to the RL of the BM or CP on which the staff reading was taken.

19. Focusing

The operation of setting the eyepiece and the object glass a proper distance apart for clear vision of the object is known as focusing. This is done by turning the focusing screw clockwise or anticlockwise. The function of the object glass is to bring the object into focus on the diaphragm, and that of the eyepiece is to magnify the cross-hairs and object. Focusing is done in two steps as follows.

(a) Focusing the eyepiece a sheet of white paper is held in front of the telescope and the eye-piece is turned clockwise or anticlockwise slowly until the cross-hairs appear distinct and clear.

(b) Focusing the Object Glass The telescope is directed to the object and the focusing screw is turned clockwise or anticlockwise until the image is clear and sharp.

20. Parallax

The apparent movement of the image relative to the cross-hairs is known as parallax. This occurs due to imperfect focusing, when the image does not fall in the plane of the diaphragm. The parallax is tested by moving the eye up and down. If the focusing is not correct, the image moves up and down relative to the cross-hairs. If the focusing is perfect, the image appears fixed to the cross-hairs. The parallax may be eliminated by properly focusing the telescope.

7.2 Instruments Used For Leveling, Concepts of Line of Collimation, Axis of Bubble Tube, Axis of Telescope, Vertical Axis.

Different Types of Levels

The following are the different types of levels:

1. Dumpy Level

The telescope of the dumpy level is rigidly fixed to its supports. It cannot be removed from its supports, nor can it be rotated about its longitudinal axis. The instrument is stable and retains its permanent adjustment for a long time. This instrument is commonly used.

2. Wye Level (Y-level)

The telescope is held in two '*Y*' supports. It can be removed from the supports and reversed from one end of the telescope to the other end. The '*Y*' supports consist of two curved clips which may be raised. Thus, the telescope can be rotated about its longitudinal axis.

3. Cooke's Reversible Level

This is a combination of the dumpy level and the *Y*-Level. It is supported by two rigid sockets. The telescope can be rotated about its longitudinal axis, withdrawn from the socket and replaced from one end of the telescope to the other end.

4. Cushing's Level

The telescope cannot be removed from the sockets and rotated about its longitudinal axis. The eye-piece and object glass are removable and can be interchanged from one end of the telescope to the other end.

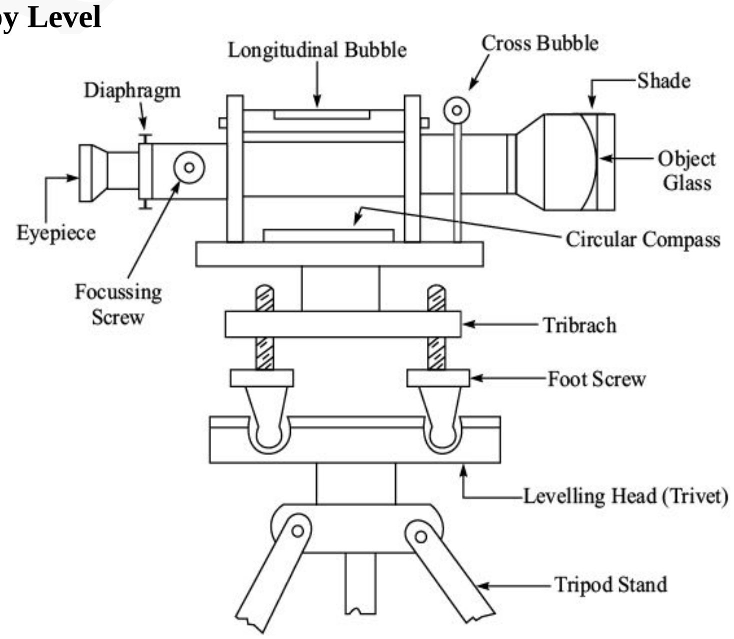
5. Modern Tilting Level

The telescope can be tilted slightly about its horizontal axis with the help of a tilting screw. In this instrument, the line of collimation is made horizontal for each observation by means of the tilting screw.

6. Automatic Level

This is also known as the self-aligning level. This instrument is leveled automatically within a certain tilt range by means of a compensating device (the tilt compensator).

Description of Dumpy Level



1. Tripod Stand
The tripod stand consists of three legs which may be solid or framed. The legs are made of light and hard wood. The lower ends of the legs are fitted with steel shoes.
2. Leveling Head
The leveling head consists of two parallel triangular plates having three grooves to support the foot screws.
3. Foot Screws
Three foot screws are provided between the trivet and tribrach. By turning the foot screws, the tribrach can be raised or lowered to bring the bubble to the centre of its run.
4. Telescope
The telescope consists of two metal tubes, one moving within the other. It also consists of an object glass and an eyepiece on opposite ends. A diaphragm is fixed with the telescope just in front of the eyepiece.
5. Bubble Tubes
Two bubble tubes, one called the *longitudinal bubble tube* and other the *cross-bubble tube,* are placed at right angles to each other. These tubes contain spirit bubble. The bubble is brought to the centre with the help of foot screws. The bubble tubes are fixed on top of the telescope.
6. Compass
A compass is provided just below the telescope for taking the magnetic bearing of a line when required. The compass is graduated in such a way that a 'pointer', which is fixed to the body of the compass, indicates a reading of 0° when the telescope is directed along the north line.

7.3 Leveling Staff – Adjustments of Level, Taking Reading with Level

The leveling staff is a graduated wooden rod used for measuring the vertical distances between the points on the ground and the line of collimation. Leveling staves are classified into two groups: **(i) the target staff, and (ii) the self-reading staff.**

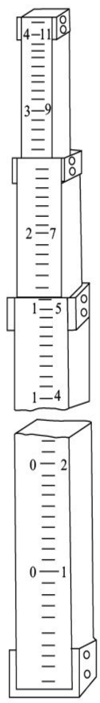


Fig. 5.6 Telescopic Metric Staff

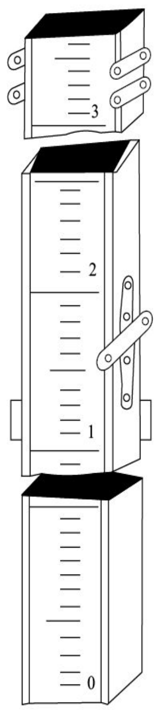


Fig. 5.7 Folding Metric Staff

1. Target Staff
The target staff consists of a movable target. The target is provided with a vernier which is adjusted by the staff man, according to directions from the level man, so that the target coincides with the collimation hair. After this, the reading is taken by either the staff man or the level man. This staff is used for long sightings.

2. Self-reading Staff
The following are the different types of self-reading staffs:

(a) Sop with Telescopic Staff - such a staff is arranged in three lengths placed one into the other. The top portion is solid and of 1.25 m length, the central box portion is hollow and of 1.25 m length, and the bottom box portion is hollow and 1.5 m long. The total length of the staff is 4 m.

(b) Folding Metric Staff - This staff is made of well-seasoned timber, and is of 75 mm width, 18 mm thickness, and 4 m length. It is divided into two parts of 2 m length having a locking arrangement.

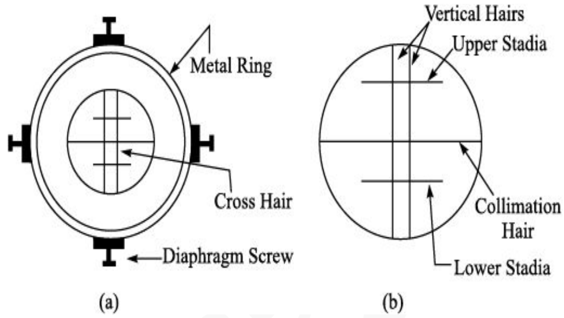
(c) One-Length Staff - the one-length staff is solid and made of seasoned timber. It is 3 m long and graduated in the same way as the telescopic staff.

(d) Invar Staff - The invar staff is also 3 m long. An invar band is fitted to a wooden staff. The band is graduated in millimeters. It is used for precise leveling work.

Diaphragm - The diaphragm is a brass ring fitted inside the telescope, just in front of the eyepiece. It can be adjusted by four screws. The ring carries the cross-hairs, which get magnified when viewed through the eyepiece. The cross-hairs may be marked in the following ways:
1. with spider webs stretched across the ring,
2. By very fine scratch marks made in a glass fitted with the ring, or
3. By means of platinum wires or silk threads stretched across the ring.

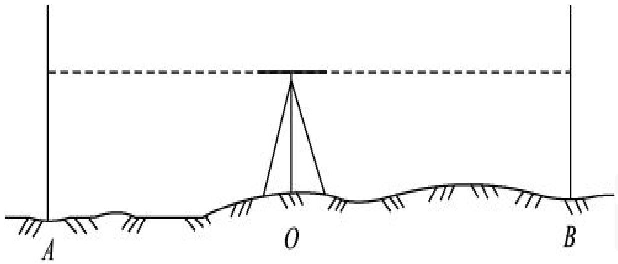
Temporary Adjustment of Level

- *Selection of Suitable Position*
- *Fixing Level with Tripod Stand*
- *Approximate Leveling by Legs of Tripod Stand*
- *Perfect Leveling by Foot Screws*
- *Focusing the Eyepiece*
- *Focusing the Object Glass*
- *Taking the Staff Readings*

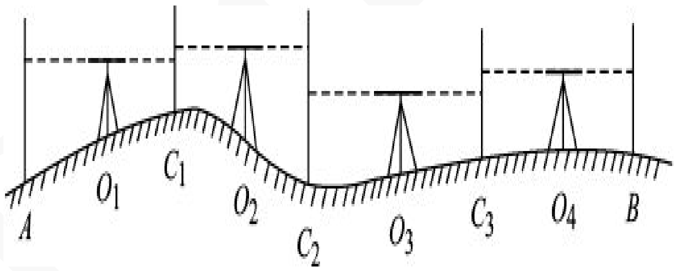


Types of Leveling Operations

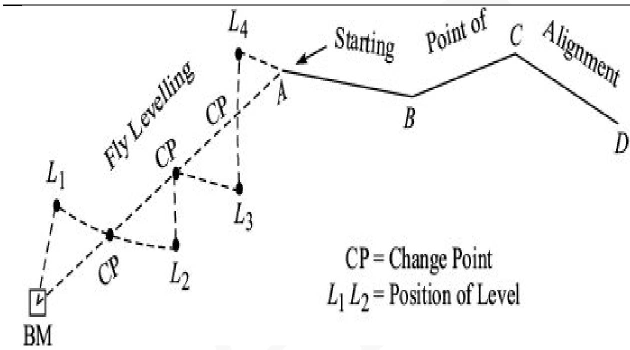
There are six types of leveling;



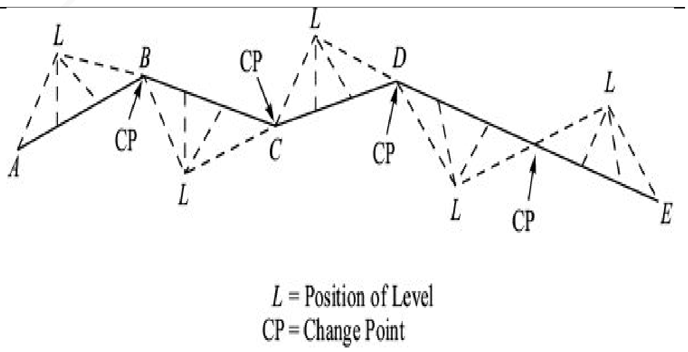
Simple leveling



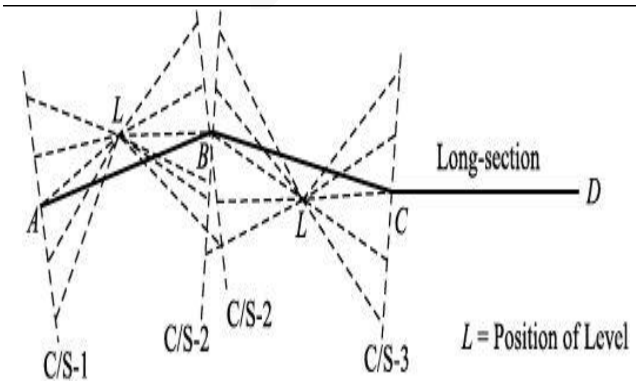
Differential leveling



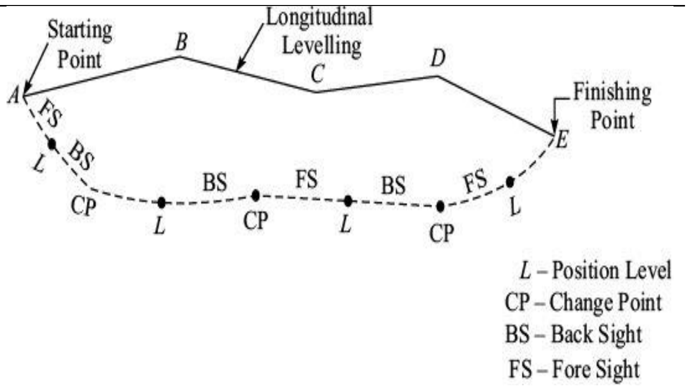
Fly leveling



Longitudinal/profile leveling



Cross sectional leveling



Check leveling

7.4 Field Data Entry – Level Book – Height of Collimation Method and Rise & Fall Method, Comparison.

The following are the two systems of calculating reduced level:

1. The collimation system or height of instrument system (HI)

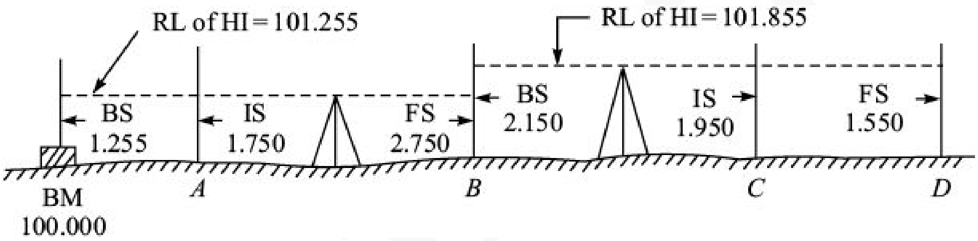
2. The rise-and-fall system

The Collimation System

The reduced level of the line of collimation is said to be the height of the instrument. In this system, the height of the line of collimation is found out by adding the back sight reading to the RL of the BM on which the BS is taken. Then the RL of the intermediate points and the change point are obtained by subtracting the respective staff readings from the height of the instrument (HI).

The level is then shifted for the next setup and again the height of the line of collimation is obtained by adding the back sight reading to the RL of the change point (which was calculated in the first set-up). So, the height of the instrument is different in different setups of the level.

Two adjacent planes of collimation are correlated at the change point by an FS reading from one setting and a BS reading from the next setting. It should be remembered that in this system, the RLs of unknown points are to be found out by deducting the staff readings from the RL of the height of the instrument.



(a) RL of HI in first setting = 100.000 + 1.255 = 101.255

RL of *A* = 101.255 – 1.750 = 99.505

RL of *B* = 101.255 – 2.150 = 99.105

(b) RL of HI in second setting = 99.105 + 2.750 = 101.855

RL of *C* = 101.855 – 1.950 = 99.905

RL of *D* = 101.855 – 1.550 = 100.305 and so on.

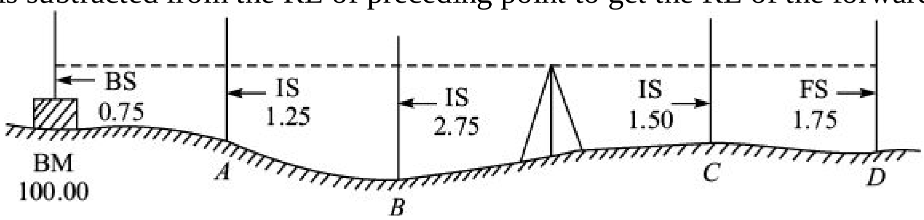
Arithmetical check: ΣBS – ΣFS = Last RL – 1st RL

The difference between the sum of back sights and that of foresights must be equal to the difference between the last RL and the first RL. This check verifies the calculation of the RL of the HI and that of the change point. There is no check on the RLs of the intermediate points.

The Rise-And-Fall System

In this system, the difference of level between two consecutive points is determined by comparing each forward staff reading with the staff reading at the immediately preceding point. If the forward staff reading is smaller than the immediately preceding staff reading, a rise is said to have occurred.

The rise is added to the RL of the preceding point to get the RL of the forward point. If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall. The fall is subtracted from the RL of preceding point to get the RL of the forward point.



Point *A* (with respect to BM) = 0.75 – 1.25 = –0.50 (fall)   RL of *A* = 100.00 – 0.50 = 99.50

Point *B* (with respect to *A*) = 1.25 – 2.75 = –1.50 (fall)   RL of *B* = 99.50 – 1.50 = 98.00

Point *C* (with respect to *B*) = 2.75 – 1.50 = +1.25 (fall)   RL of *C* = 98.00 + 1.25 = 99.25

Point *D* (with respect to *C*) = 1.50 – 1.75 = –0.25 (fall)   RL of *D* = 99.25 – 0.25 = 99.00

Arithmetical check: ΣBS – ΣFS = Σ rise – Σ fall = last RL – 1st RL

In this method, the difference between the sum of BSs and that of FSs, the difference between the sum of rises and that of falls and the difference between the last RL and the first RL must be equal.

Comparison of the Two Systems

HI Method	R&F Method
It is rapid as it involves few calculations.	It is laborious, involving several calculations.
There is no check on the RL of intermediate points.	There is a check on the RL of intermediate points.
Errors in intermediate RLs cannot be detected.	Errors in intermediate RLs can be detected as all the points are correlated.
There are two checks on the accuracy of RL calculation.	There are three checks on the accuracy of RL calculation.
This system is suitable for longitudinal leveling where there are a number of intermediate sights.	This system is suitable for fly leveling where there are no intermediate sights.

7.5 Effects of Curvature and Refraction, Application of Correction.

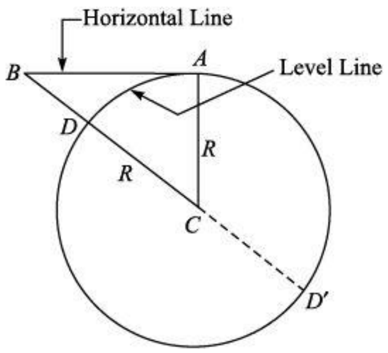
Following are the different types of correction;

- Curvature Correction
- Refraction Correction
- Combined Correction
- Visible Horizon Distance
- Dip of Horizon

Curvature Correction

For long sights, the curvature of the earth affects staff readings. The line of sight is horizontal, but the level line is curved and parallel to the mean spherical surface of the earth. The vertical distance between the line of sight and the level line at a particular place is called the curvature correction. Due to curvature, objects appear lower than they really are.

Curvature correction is always subtractive (i.e. negative).



The formula for curvature correction is derived as follows;

Let $AB = D$ = horizontal distance in kilometers.

$BD = Cc$ = curvature correction

$DC = AC = R$ = radius of earth

DD' = diameter, considered 12,742 km

From right-angled triangle ABC

$BC^2 = AC^2 + AB^2$

$(R + Cc)^2 = R^2 + D^2$ or $R^2 + 2RCc + C^2$

$c = R^2 + D^2$ or $Cc \times 2R = D^2$

($C2c$ is neglected as it is very small in comparison to the diameter of the earth.)

Curvature correction $Cc = \dfrac{D^2}{2R}$

$Cc = \dfrac{D^2 \times 1{,}000}{12{,}742} = 0.0785\,D^2$ m (negative)

Hence, True staff reading = Observed staff reading – Curvature correction

Refraction Correction

Rays of light are refracted when they pass through layers of air of varying density. So, when long sights are taken, the line of sight is refracted towards the surface of the earth in a curved path. The radius of this curve is seven times that of the earth under normal atmospheric conditions. Due to the effect of refraction, objects appear higher than they really are. But the effect of curvature varies with atmospheric conditions. However, on an average, the refraction correction is taken as one-seventh of the curvature correction.

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

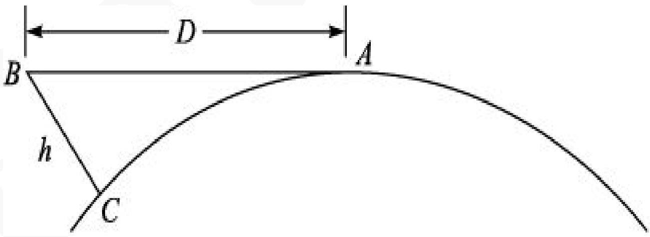
Refraction correction, C_r = × 0.0785 D^2 = 0.0112 D^2 m (positive)
Refraction correction is always additive (i.e. positive).
True staff reading = Observed staff reading + Refraction correction

Combined Correction
The combined effect of curvature and refraction is as follows:
Combined correction = Curvature correction + Refraction correction
= –0.0785 D^2 + 0.0112 D^2
= –0.0673 D^2 m

$$\frac{D^2}{2R} - \frac{1}{7} \times \frac{D^2}{2R} = \frac{6}{7} \cdot \frac{D^2}{2R} \text{ (negative)}$$

So, combined correction is always subtractive (i.e. negative).
True staff reading = Observed staff reading – Combined correction

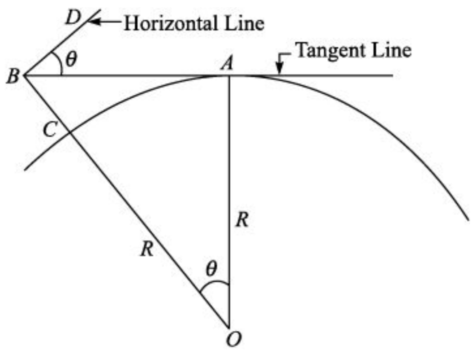
Visible Horizon Distance
Let $AB = D$ = visible horizon distance in kilometers, h = height of the point above mean sea level, in meters.



Considering curvature and refraction corrections,
$h = 0.0673\ D^2$

$$D = \sqrt{\frac{h}{0.0673}}$$

Dip of Horizon



$AB = D$ = tangent to the earth at A
BD = horizontal line perpendicular to OB
θ = dip of horizon
The angle between the horizontal line and the tangent line is known as the dip of the horizon. It is equal to the angle subtended by the arc CA at the centre of the earth.

$$\text{Dip} \quad \theta = \frac{\text{arc } CA}{\text{radius of the earth}}, \text{ in radians}$$

∴ θ = in radians (Taking CA approx. equal to AB). Here, D and R must be expressed in the same units.

7.6 Reciprocal Leveling – Principles, Methods, Precise Leveling.

In reciprocal leveling, the level is set up on both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks. In this case, it is found that the errors are completely eliminated and the true difference of level is equal to the mean of the two apparent differences of level.

Procedure

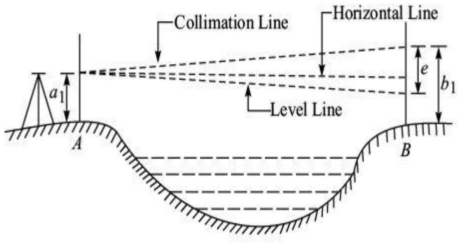
1. Suppose A & B are two points on the opposite banks of a river. The level is set up very near A and after proper temporary adjustment, staff readings are taken at A and B. Suppose the readings are $a1$ and $b1$.

2. The level is shifted and set up very near B and after proper adjustment, staff readings are taken at A and B. Suppose the readings are $a2$ and $b2$.

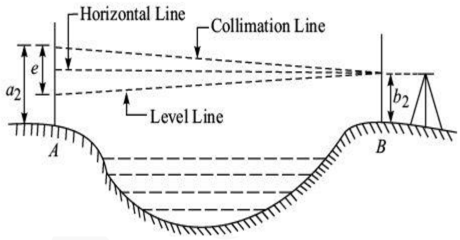
Let h = true difference of level between A and B
e = combined error due to curvature, refraction and collimation (The error may be positive or negative, here the error is assumed positive).

In the first case,
Correct staff reading at $A = a1$ (as the level is very near A)
Correct staff reading at $B = b1 - e$
True difference of level between A and B,
$h = a1 - (b1 - e)$ (fall from B to A)

In the second case,
Correct staff reading at $B = b2$ (as level is near B)
Correct staff reading at $A = a2 - e$
So, true difference of level,
$h = (a2 - e) - b2$
$2h = a1 - (b1 - e) + (a2 - e) - b2$
$= a1 - b1 + e + a2 - e - b2 = (a1 - b1) + (a2 - b2)$



(a)



$$h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

It may be observed that the error is eliminated and that the true difference is equal to the mean of the two, apparent differences of level between A and B.

7.7 Errors in Leveling and Precautions, Permanent and Temporary Adjustments of Different Types of Levels.

The following are the different sources of error in leveling:

1. Instrumental Errors
(a) The permanent adjustment of the instrument may not be perfect. That is, the line of collimation may not be parallel to the axis of the bubble tube.
(b) The internal arrangement of the focusing tube is not perfect.
(c) The graduation of the leveling staff may not be perfect.

2. Personal Errors
(a) The instrument may not be leveled perfectly.
(b) The focusing of the eyepiece and object glass may not be perfect and the parallax may not be eliminated entirely.
(c) The position of the staff may be displaced at the change point at the time of taking FS and BS readings.
(d) The staff may appear inverted when viewed through the telescope. By mistake, the staff readings may be taken upwards instead of downwards.
(e) The reading of the stadia hair rather than the central collimation hair may be taken by mistake.
(f) A wrong entry may be made in the level book.
(g) The staff may not be properly and fully extended.

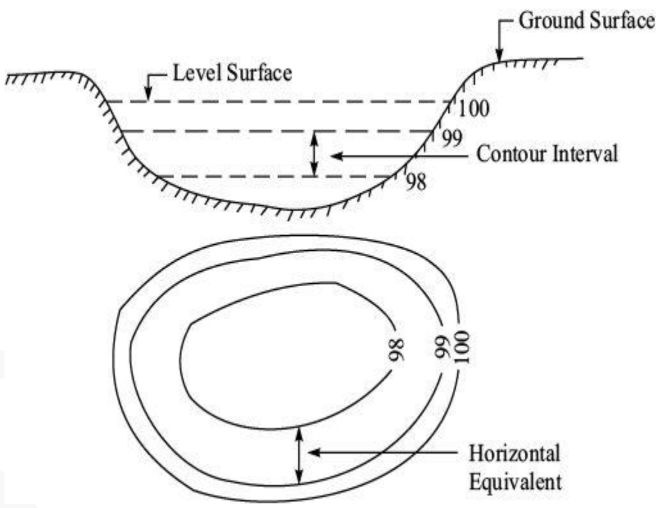
3. Errors due to Natural Causes
(a) When the distance of sight is long, the curvature of the earth may affect the staff reading.
(b) The effect of refraction may cause a wrong staff reading to be taken.
(c) The effect of high winds and a shining sun may result in a wrong staff reading.

The precision of leveling is ascertained according to the error of closure. The permissible limit of closing error depends upon the nature of work for which the leveling is to be done. Permissible closing error is expressed as $E = C\sqrt{D}$
Where, E = closing error in meters,
C = the constant, and
D = distance in kilometers.

The following are the permissible errors for different types of leveling;
1. Rough leveling—$E = \pm 0.100 \sqrt{D}$
2. Ordinary leveling—$E = \pm 0.025 \sqrt{D}$
3. Accurate leveling—$E = \pm 0.012 \sqrt{D}$
4. Precise leveling—$E = \pm 0.006 \sqrt{D}$

7.8 Definitions, Concepts and Characteristics of Contours.

Contouring is, basically, a leveling operation. The equipment is the same for leveling and contouring. The main objective of contouring is to determine the points on the ground having the same reduced level (RL). The contour lines join the points of same elevation directly or by interpolation technique. It gives the topographical features of the ground, comparing different contour lines of different elevations for a closed area. Based on the topographical features, calculations for engineering projects can be carried out. There are different methods of drawing such closed or open contour lines within a specific area.



Contour Line

The line of intersection of a level surface with the ground surface is known as the contour line or simply the contour. It can also be defined as a line passing through points of equal reduced levels.
A map showing only the contour lines of an area is called a *contour map*.

Contour Interval

The vertical distance between any two consecutive contours is known as a contour interval. Suppose a map includes contour lines of 100 m, 98 m, 96 m, and so on. The contour interval here is 2 m. This interval depends upon (i) the nature of the ground (i.e. whether flat or steep), (ii) the scale of the map, and (iii) the purpose of the survey.

Horizontal Equivalent

The horizontal distance between any two consecutive contours is known as horizontal equivalent. It is not constant. It varies according to the steepness of the ground. For steep slopes, the contour lines run close together, and for flatter slopes they are widely spaced.

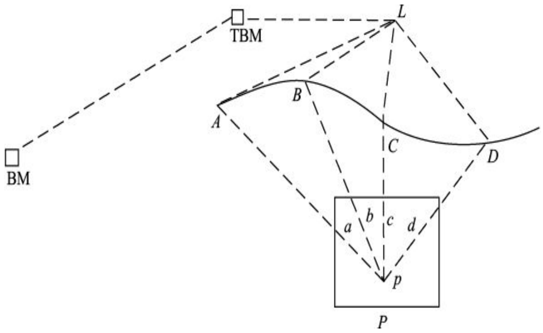
Uses of Contour Map

The following are the specific uses of the contour map:
1. The nature of the ground surface of a country can be understood by studying a contour map. Hence, the possible route of communication between different places can be demarcated.
2. A suitable site or an economical alignment can be selected for any engineering project.
3. The capacity of a reservoir or the area of a catchment can be approximately computed.
4. The indivisibility or otherwise of different points can be established.
5. A suitable route for a given gradient can be marked on the map.
6. A section of the ground surface can be drawn in any direction from the contour map.
7. Quantities of earth work can be approximately computed.

Object of Preparing Contour Map

The general map of a country includes the locations of roads, railways, rivers, villages, towns, and so on. But the nature of the ground surface cannot be realized from such a map. However, for all engineering projects involving roads, railways, and so on, knowledge of the nature of ground surface is required for locating suitable alignments and estimating the volume of earth work. Therefore, the contour map is essential for all engineering projects. This is why contour maps are prepared.

7.9 Methods of Contouring, Plotting Contour Maps, Interpretation of Contour Maps, Top sheets.



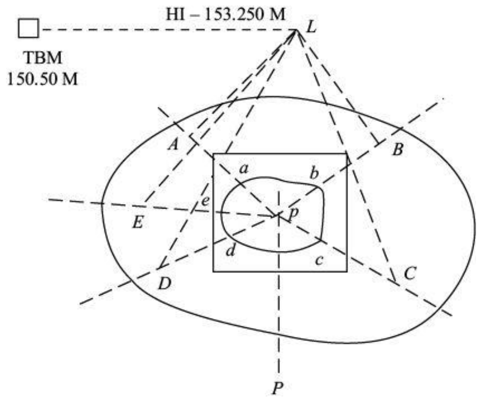
Direct Method
There may be two cases, as outlined below.

Case I When the area is oblong and cannot be controlled from a single station in this method, the various points on any contour are located on the ground by taking levels. Then these points are marked by pegs. After this, the points are plotted on the map, to any suitable scale, by plane table. This method is very slow and tedious. But it gives accurate contour lines.

Procedure
1. Suppose a contour map is to be prepared for an oblong area. A temporary bench-mark is set up near the site by taking fly-level readings from a permanent bench-mark.
2. The level is then set up at a suitable position *L* from where maximum area can be covered.
2. The plane table is set up at a suitable station *P* from where the above area can be plotted.
4. A back sight reading is taken on the TBM. Suppose the RL of the TBM is 249.500 m and that the BS reading is 2.250 m. Then the RL of HI is 251.750 m. If a contour of 250.000 m is required, the staff reading should be 1.750 m. If a contour of 249.000 m is required, the staff reading should be 2.750 m, and so on.
5. The staff man holds the staff at different points of the area by moving up and down, or left and right, until the staff reading is exactly 1.750. Then the points are marked by pegs. Suppose, these points are *A*, *B*, *C*, *D* …
6. A suitable point *p* is selected on the sheet to represent the station *P*. Then, with the alidade touching *p*, rays are drawn to *A*, *B*, *C* and *D*. The distances *PA*, *PB*, *PC* and *PD* are measured and plotted to a suitable scale. In this manner, the points *a*, *b*, *c* and *d* of the contour line of RL 250.000 m are obtained. These points are joined to obtain the contour of 250.000 m.
7. Similarly, the points of the other contours are located.
8. When required, the leveling instrument and the plane table are shifted and set up in a new position in order to continue the operation along the oblong area.

Case II When the area is small and can be controlled from a single station. In this case, the method of radial lines is adopted to obtain contour map. This is also very slow and tedious, but gives the actual contour lines.

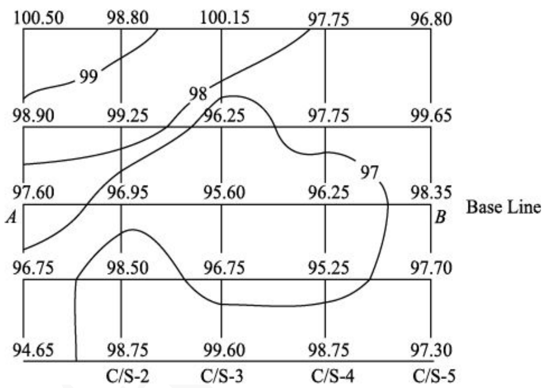
Procedure



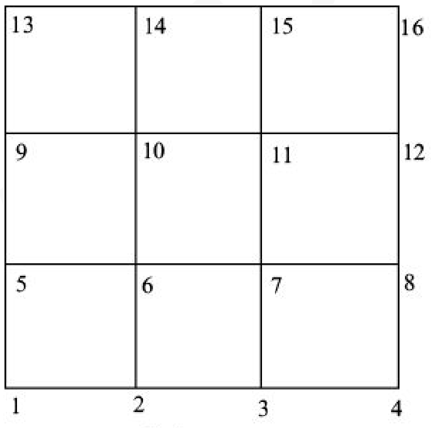
1. The plane table is set up at a suitable station *P* from where the whole area can be commanded.
2. A point *p* is suitably selected on the sheet to represent the station *P*. Radial lines are then drawn in different directions.
3. A temporary bench-mark is established near the site. The level is set up at a suitable position *L* and a BS reading is taken on the TBM. Let the HI in this setting be 153.250 m. So, to find the contour of 152.000 m RL, a staff reading of 1.250 m is required at a particular point, so that the RL of contour of that point comes to 152.000 m. RL = HI – Staff reading = 153.250 – 1.250 = 152.000 m.
4. The staff man holds the staff along the rays drawn from the plane table station in such a way that the staff reading on that point is exactly 1.250. In this manner, points *A*, *B*, *C*, *D* and *E* are located on the ground, where the staff readings are exactly 1.250.
5. The distances *PA*, *PB*, *PC*, *PD* and *PE* are measured and plotted to any suitable scale. Thus the points *a*, *b*, *c*, *d* and *e* are obtained which are joined in order to obtain a contour of 152.000.
6. The other contours may be located in similar fashion.

Indirect Method In this method, the RLs of different points (spot levels) are taken at regular intervals along a series of lines set up on the ground. The positions of these points are plotted on a sheet to any suitable scale. The spot levels are noted at the respective points. Then the points of contour lines are found out by interpolation, after which they are joined to get the required contour lines. Although very quick, this method gives only the approximate positions of the contour lines. This method can be adopted in two ways: (i) cross-sections, and (ii) squares.

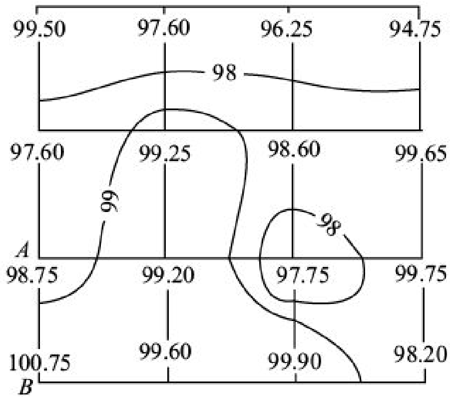
Using Cross Sections - In this method, a base line, centre line or profile line is considered. Cross sections are taken perpendicular to this line at regular intervals (say 50 m, 100 m, etc.). After this, points are marked along the cross sections at regular intervals (say, 5 m, 10 m, etc). A temporary bench-mark is set up near the site. Staff readings are taken along the base line and the cross sections. The readings are entered in the level book; the base line and the cross sections should also be mentioned. The RL of each of the points calculated. Then the base line and cross sections are plotted to a suitable scale. Subsequently, the RLs of the respective points are noted on the map, after which the required contour line is drawn by interpolation. This method is suitable for route survey, when cross sections are taken transverse to the longitudinal section.



Using Squares - In this method, the area is divided into a number of squares. The size of these squares depends upon the nature and extent of the ground. Generally, they have a sides varying from 5 to 20 m. The corners of the squares are numbered serially, as 1, 2, 3 … A temporary bench-mark is set up near the site, and the level is set up at a suitable position. The staff readings on the corners of the squares are taken and noted in the level book maintaining the sequence of the serial numbers of the corners. The RLs of all the corners are calculated. The skeletons of the squares are plotted to a suitable scale. The respective RLs are noted on the corners, after which the contour lines are drawn by interpolation.



Skeleton



RLs Noted as Per Skeleton

Contour Gradient

During preliminary survey for roads in a hilly area, the required points are first established along the gradient. The line joining these points is known as the *contour gradient* or *grade contour*. Initially, the points are established approximately by an *Abney level*, and then accurately fixed by a leveling instrument.

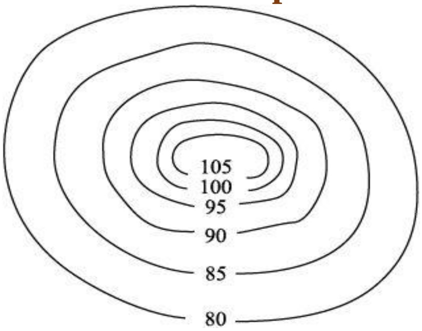
Method of Interpolation of Contours

The process of locating the contours proportionately between the plotted points is termed *interpolation*.

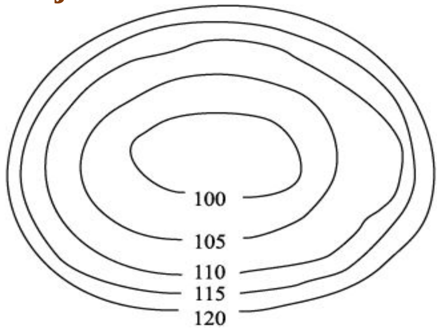
Interpolation may be done by;

1. Arithmetical calculation
2. The graphical method

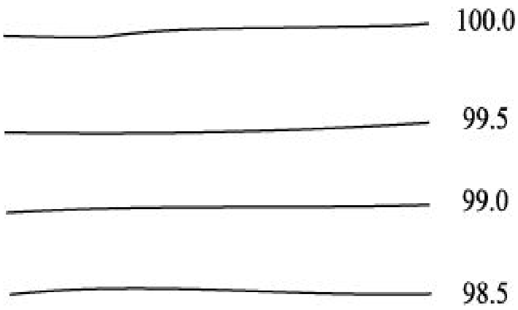
7.10 Use of Contour Maps on Civil Engineering Projects



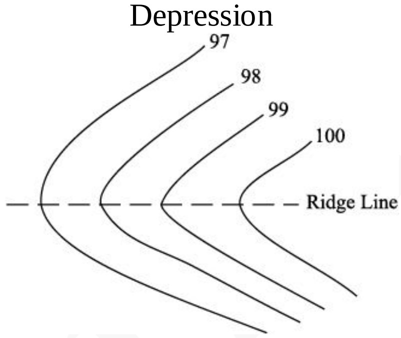
Hill



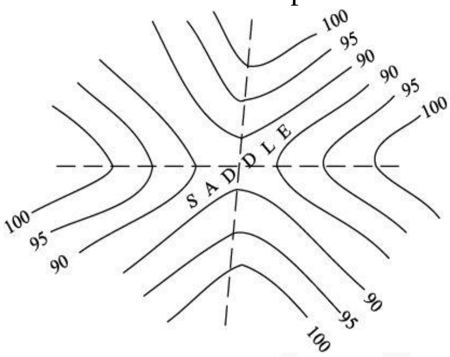
Depression



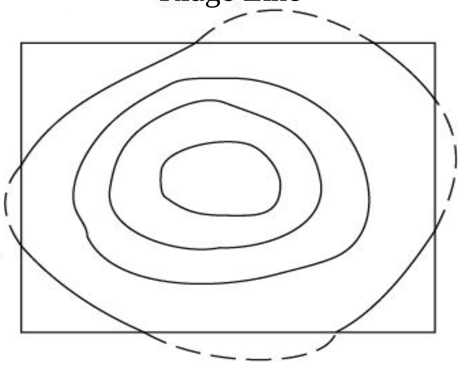
Uniform Slope



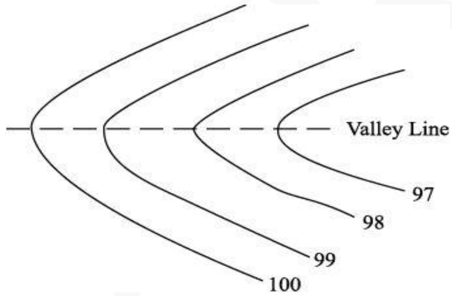
Ridge Line



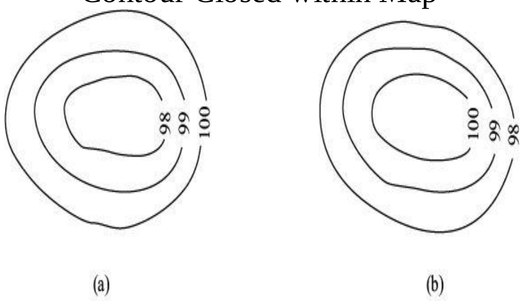
Saddle



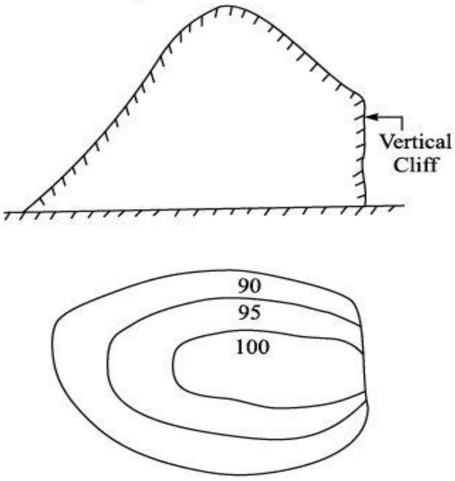
Contour Closed within Map



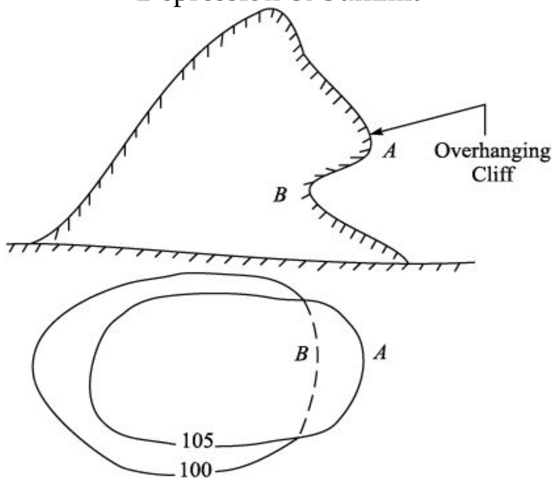
Valley Line



Depression & Summit



Vertical Cliff



Overhanging Cliff

7.11 Map Interpretation

Map interpretation involves the study of factors that explain the causal relationship among several features shown on the map. For example, the distribution of natural vegetation and cultivated land can be better understood against the background of landform and drainage.

Deriving accurate meanings from maps is called map interpretation. Knowledge of map language and sense of direction are essential in reading and interpreting topo-sheets.

We must first look for the north line and the scale of the map and orient ourselves accordingly. We must have a thorough knowledge of the legends / key given in the map depicting various features.

All topo-sheets contain a table showing conventional signs and symbols used in the map. We must be acquainted with conventional symbols, signs and colors.

The following procedure is followed in map interpretation;

(a) Finding from the index number of the topographical sheet, the location of the area in India. This would give an idea of the general characteristics of the major and minor physiographic divisions of the area.

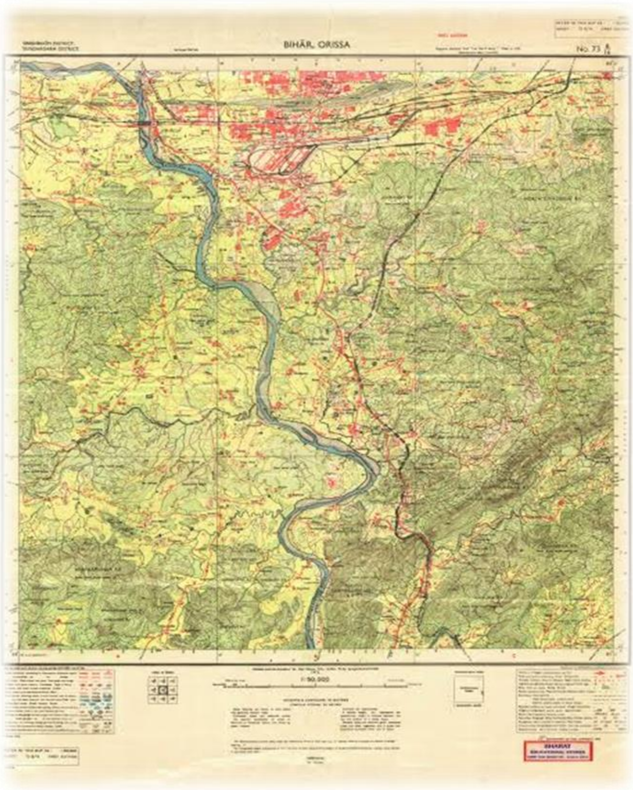
(b) Find the scale of the map and the contour interval, which will give the extent and general landform of the area.

(i) Major landforms - as shown by contours and other graphical features.
(ii) Drainage and water features - the main river and its important tributaries.
(iii) Land use - i.e. forest, agricultural land, wastes, sanctuary, park, school, etc.
(iv) Settlement and Transport pattern.

(d) Explain the distributional pattern of each of the features separately drawing attention to the most important aspect.

(e) Superimpose pairs of these maps and note down the relationship, if any, between the two patterns. For example, if a contour map is superimposed over a land use map, it provides the relationship between the degree of slope and the type of the land used.

f) Aerial photographs and satellite imageries of the same area and of the same scale can also be compared with the topographical map to update the information.



Topo sheets - Top sheets is a topographic map which is a two dimensional representation of a three dimensional land surface.

Topographic maps are differentiated from the other maps in that they show both the horizontal and vertical position of the terrain.

Topo sheets are also used by the tourism industry for preparing tourist maps. It provides the information about various attractive features of an area as well as the location of important monuments or places of interest.

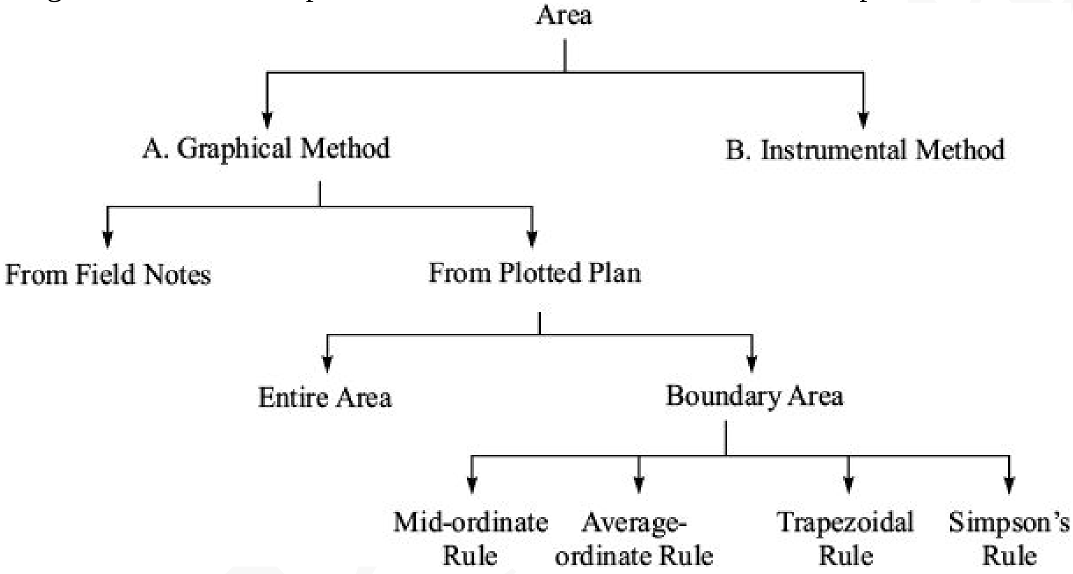
Industrialists also rely on using topographical maps for setting up an industry in an area.

LAND SURVEY - I

8. COMPUTATION OF AREA & VOLUME

8.1 Determination of Areas, Computation of Areas from Plans.

The term ‘area’ in the context of surveying refers to the area of a tract of land projected upon the horizontal plane, and not to the actual area of the land surface.
Area may be expressed in the following units:
1. Square meters
2. Hectares (1 hectare = 10,000 m^2)
3. Square feet
4. Acres (1 acre = 4840 sq. yd. = 43.560 sq. ft.)
The following is a hierarchical representation of the various methods of computation of area.



Computation of Area from Field Notes
This is done in two steps.
Step 1
In cross-staff survey, the area of field can be directly calculated from field notes. During survey work the whole area is divided into some geometrical figures, such as triangles, rectangles, squares and trapeziums, and then the area is calculated as follows:

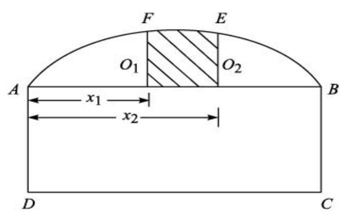
1. Area of triangle = $\sqrt{s(s-a)(s-b)(s-c)}$

Where *a*, *b* and *c* are the sides,

and $s = \dfrac{a+b+c}{2}$

Or Area of triangle = 1/2 × *b* × *h, where b* = base and *h* = altitude
2. Area of rectangle = *a* × *b, where a* & *b* are the sides.
3. Area of square = a^2, where *a* is the side of the square.
4. Area of trapezium = 1/2 (*a* + *b*) × *d, where a* and *b* are the parallel sides, and *d* is the perpendicular distance between them.

Step 2
*o*1, *o*2 = ordinates & *x*1, *x*2 = chainages



Area of shaded portion = $\dfrac{o_1+o_2}{2} \times (x_2 - x_1)$

Similarly, the areas between all pairs of ordinates are calculated and added to obtain the total boundary area.
Hence, Total area of the field = Area of geometrical figure + Boundary areas
(step 1 + step 2) = Area of *ABCD* + Area of *ABEFA*

8.2 Calculation of Area by Using Ordinate Rule, Trapezoidal Rule, Simpson's Rule.

The area may be calculated in the two following ways;

Case I - Considering the Entire Area
The entire area is divided into regions of a convenient shape, and calculated as follows:

- **By Dividing the Area into Triangles -** The triangles are so drawn as to equalize the irregular boundary line. Then the bases and altitudes of the triangles are determined according to the scale to which the plan was drawn. After this, the areas of these triangles are calculated (area = 1/2 × base × altitude).

- **By Dividing the Area into Squares** In this method, squares of equal size are ruled out on a piece of tracing paper. Each square represents a unit area, which could be 1 cm2 or 1 m2. The tracing paper is placed over the plan and the number of full squares is counted. The total area is then calculated by multiplying the number of squares by the unit area of each square.

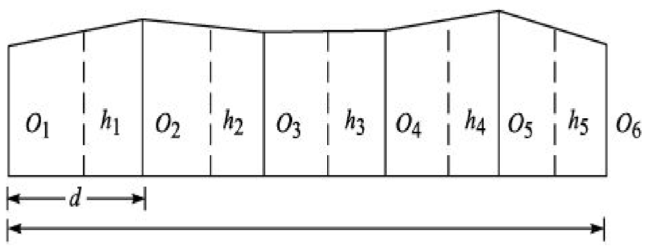
- **By Drawing Parallel Lines and Converting them to Rectangles** In this method, a series of equidistant parallel lines are drawn on a tracing paper. The constant distance represents a meter or centimeter. The tracing paper is placed over the plan in such a way that the area is enclosed between the two parallel lines at the top and bottom. Thus the area is divided into a number of strips. The curved ends of the strips are replaced by perpendicular lines (by give and take principle) and a number of rectangles are formed. The sum of the lengths of the rectangles is then calculated. *Then,* ***Required area = Σ Length of rectangles*** × ***Constant distance.***

Case II
In this method, a large square or rectangle is formed within the area in the plan. Then ordinates are drawn at regular intervals from the side of the square to the curved boundary. The middle area is calculated in the usual way. The boundary area is calculated according to one of the following rules;

1. *The mid-ordinate rule*
2. *The average-ordinate rule*
3. *The trapezoidal rule*
4. *Simpson's rule*

(a) Mid-ordinate Rule

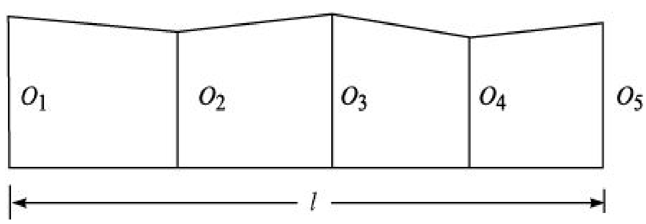
Let *O*1, *O*2, *O*3, …, *On* = ordinates at equal intervals
l = length of base line
d = common distance between ordinates
*h*1 *h*2, …, *hn* = mid-ordinates
Area of plot = *h*1 × *d* + *h*2 × *d* + … + *hn* × *d*
= *d*(*h*1 + *h*2 + … + *hn*)
i.e. Area = Common distance × sum of mid-ordinates



(b) Average-ordinate Rule

Let *O*1 *O*2, …, *On* = ordinates or offsets at regular intervals
l = length of base line
n = number of divisions
n + 1 = number of ordinates

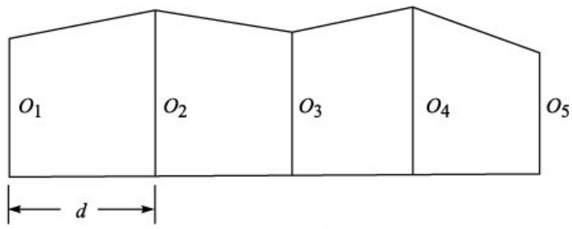
Area = $\frac{O_1 + O_2 + \cdots + O_n}{O_{n+1}} \times l$



i.e. Area = $\dfrac{\text{sum of ordinates}}{\text{no. of ordinates}} \times \text{length of base line}$

(c) Trapezoidal Rule

While applying the trapezoidal rule, boundaries between the ends of ordinates are assumed to be straight. Thus the areas enclosed between the base line and the irregular boundary line is considered as trapezoids.



Let $O1$ $O2$, …, On = ordinates at equal intervals

d = common distance

First area = $\dfrac{O_1 + O_2}{2} \times d$

Second area = $\dfrac{O_2 + O_3}{2} \times d$

Third area = $\dfrac{O_3 + O_4}{2} \times d$

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

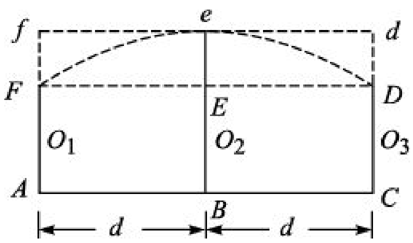
Total area = $\{O1 + 2O2 + \ldots + 2On - 1 + On\}$ $\dfrac{\text{common distance}}{2}$ {(1st ordinate + last ordinate + 2 (sum of other ordinate)}

Thus, the trapezoidal rule may be stated as follows:

To the sum of the first and the last ordinate, twice the sum of intermediate ordinates is added. This total sum is multiplied by the common distance. Half of this product is the required area. ***Limitation*** *- There is no limitation for this rule. This rule can be applied for any number of ordinates.*

(d) 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*.



Let

$O1$ $O2$, $O3$ = three consecutive ordinates

d = common distance between the ordinates

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

Here,

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

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

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

So, the area between the first two divisions,

$\Delta_1 = \frac{O_1 + O_3}{2} \times 2d + \frac{2}{3}\left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$

$= \frac{d}{3}(O_1 + 4O_2 + O_3)$

Similarly, the area between next two divisions,

$\Delta_2 = \frac{d}{3}(O_3 + 4O_4 + O_5)$, and so on.

$\therefore$ Total area = $\frac{d}{3}(O_1 + 4O_2 + 2O_3 + 4O_4 + \cdots + O_n)$

$= \frac{d}{3}\{O_1 + O_n + 4(O_2 + O_4 + \ldots) + 2(O_3 + O_5 + \ldots)\}$ (7.4)

$= \dfrac{\text{common distance}}{3}$ {first ordinate + last ordinate)

+ 4 (sum of even ordinates)

+ 2 (sum of remaining odd ordinates)}

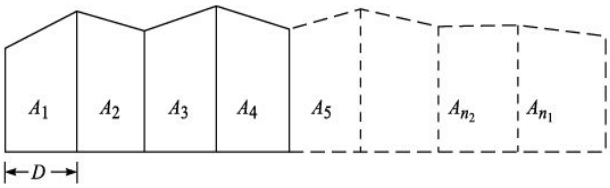
Thus, the role may be stated as follows.

To the sum of the first and the last ordinate, four times the sum of even ordinates and twice the sum of the remaining odd ordinates are added. This total sum is multiplied by the common distance. One-third of this product is the required area.

Trapezoidal Rule	Simpson's Rule
1. The boundary between the ordinates is considered straight.	1. The boundary between the ordinates is considered an arc of a parabola.
2. There is no limitation. It can be applied for any number of ordinates. That is, the number of divisions must be even.	2. To apply this rule, the number of ordinates must be odd.
3. It gives an approximate result.	3. It gives a more accurate result.

8.3 Calculation of Volumes by Prismoidal Formula & Trapezoidal Formula, Prismoidal Corrections, Curvature Correction for Volumes.

Formula for Calculation of Volume –



A. Trapezoidal Rule (Average-End-Area Rule)

Volume (cutting or filling), $V = \frac{D}{2}\{A_1 + A_n + 2(A_2 + A_3 + \ldots + A_{n-1})\}$

i.e. volume = $\frac{\text{common distance}}{2}$ {area of first section + area of last section + 2 (sum of area of other sections)}

B. Prismoidal Formula

Volume (cutting or filling), $V = \frac{D}{3}\{A_1 + A_n + 4(A_2 + A_4 + A_{n-1}) + 2(A_3 + A_5 + \ldots + A_{n-2})\}$

i.e., $V = \frac{\text{common distance}}{2}$ {area of first section + area of last section + 4 (sum of areas of even sections) + 2 (sum of areas of odd sections)}

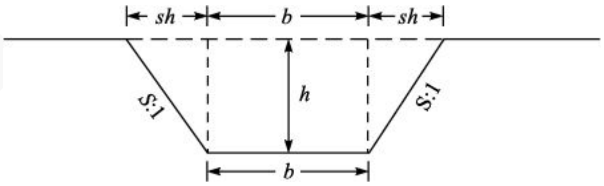
Formula For Calculation of Crosssectional Area –

- ***Level Section***

When the ground is level along the transverse direction:

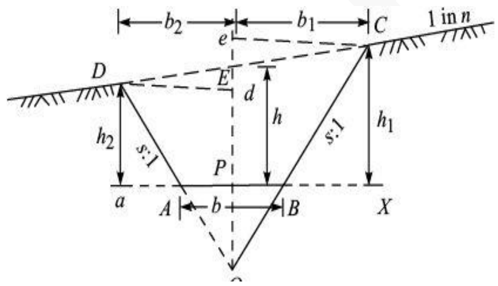
Cross-sectional area = $\frac{b + b + 2sh}{2} \times h$

= $(b + sh)h$



- ***Two-Level Section***

When the ground surface has a transverse slope:



Area = $\frac{1}{2}\left\{\left(\frac{b}{2s}+h\right)b_2+\frac{1}{2}\left(\frac{b}{2s}+h\right)b_1-\frac{1}{2}b\times\frac{b}{2s}\right\}$

= $\frac{1}{2}\left\{\left(\frac{b}{2s}+h\right)(b_1+b_2)-\frac{b^2}{2s}\right\}$

Prismoidal Correction for Trapezoidal or Average-End Area Rule

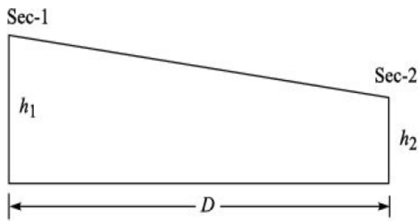


Fig. 8.7 Sample for Prismoidal Correction

1. Prismoidal correction for level section:

$C_p = \frac{D \times s}{6}(h_1 - h_2)^2$ (Considering, transverse slope = 1 in n side slope = s : 1)

2. Prismoidal correction for two-level section:

$$C_p = \frac{D \times s}{6} \times \left(\frac{n^2}{n^2 - s^2}\right) \times (h_1 - h_2)^2$$

3. Prismoidal correction for side hill two-level section:

(a) C_p (for cutting) = $\frac{D}{12(n - s_1)} \times n^2 (h_1 - h_2)^2$ (side slope = s_1 : 1)

(b) C_p (for filling) = $\frac{D}{12(n - s_2)} \times n^2 (h_1 - h_2)^2$ (side slope = s_2 : 1)

4. Prismoidal correction for three-level section:

$C_p = \frac{D}{12}(h_1 - h_2)$ (whole width of first section – whole width of second section)

THANK YOU