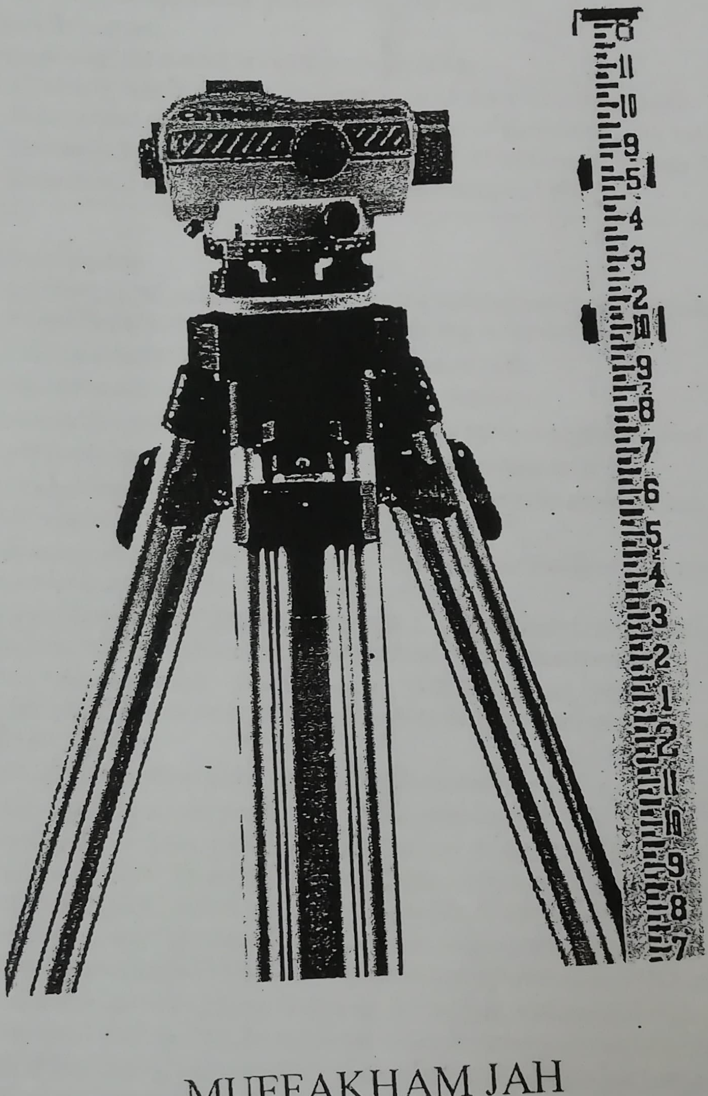
DEPARTMENT OF CIVIL ENGINEERING

SURVEYING LABORATORY

COURSE : SURVEY - LAB



MUFFAKHAM JAH
COLLEGE OF ENGINEERING AND TECHNOLOGY

ROAD NO.:3, BANJARA HILLS, HYDERABAD – 500 034

Course Code	Course Title						Core/Elective
PC252CE	**Surveying Lab**						**Core**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	-	-	-	2	25	50	1

Course Objectives

- ➢ To study and understand the different methods involved in survey field work
- ➢ To know the importance of theodolite, total station and their practical applications
- ➢ To study the basic concept of trigonometrical levelling, and field applications
- ➢ To analyse the curves for survey work related to Roads and Railways
- ➢ To study the applications of GPS for field work.

Course Outcomes

After completing the course, the students will able to

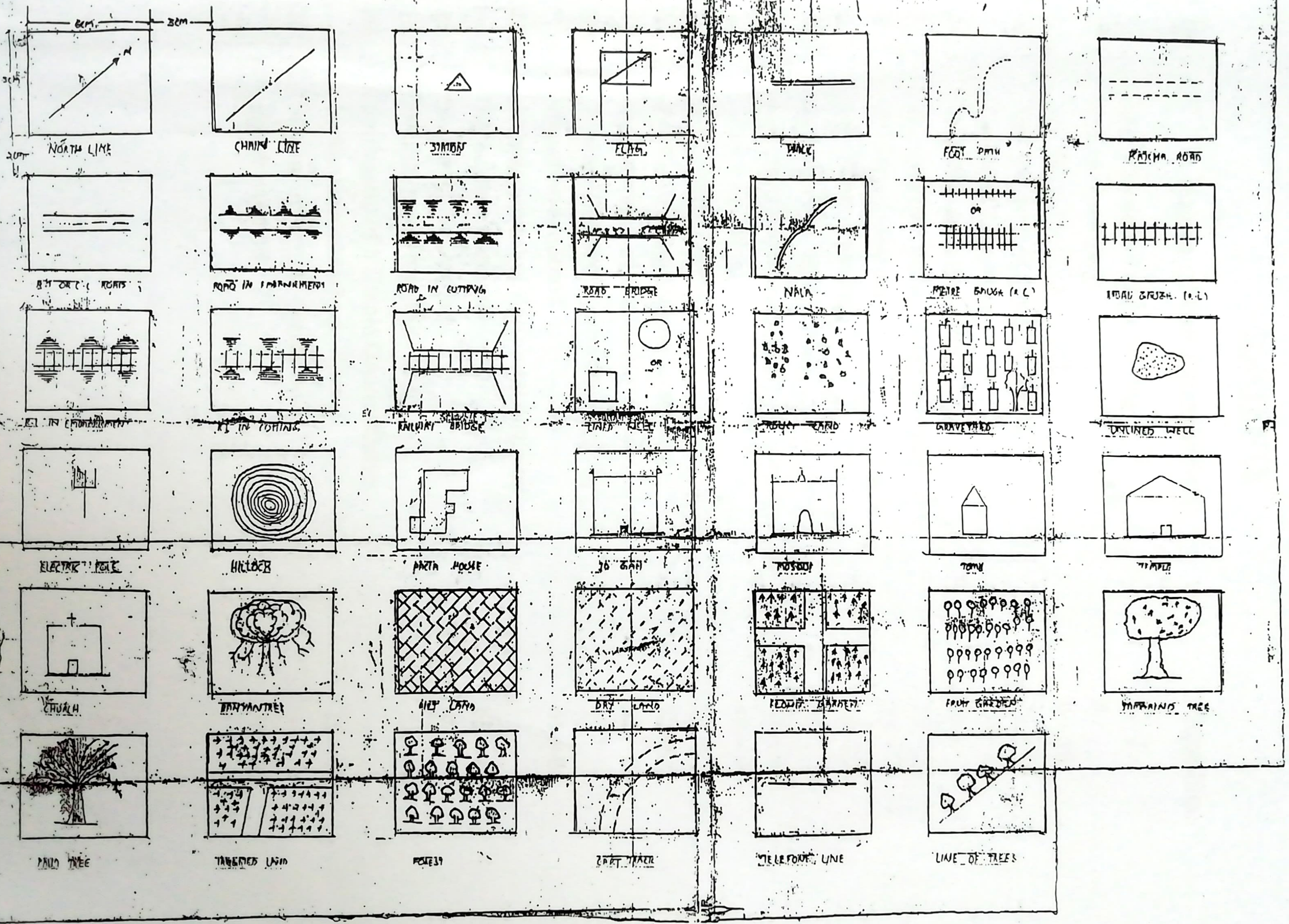
- ➢ Compute lengths, areas and bearings of the given field work
- ➢ Understand the basic working principles of theodolite and total station
- ➢ Compute setting out data for setting out of horizontal curves by various methods
- ➢ Understand and learn the basic concepts related to GPS

List of Experiments:

1. Applications of chain traversing to locate a building and field objects by taking perpendicular and oblique offsets and recording in the field book.
2. Study of prismatic compass and setting out a polygon
3. Plane table survey: Radiation & Intersection methods
4. Introduction to levelling: Differential levelling using dumpy/Auto level
5. Profile and cross-sectional levelling using Dumpy/Auto level
6. Measurement of horizontal angles by repetition and reiteration methods using Vernier Theodolite.
7. Measurement of vertical angle: Application to simple problems of height and distance by measuring angle of elevation and depression
8. Single plane method: Determination of R.L. of an elevated Object using two Instrument Stations which are placed in a same vertical plane- when base of the Object inaccessible.
9. Two plane method: Determination of R.L. of an elevated Object using two Instrument Stations which are not placed in the same vertical plane- when base of the Object inaccessible.
10. Setting out of a simple circular curve by linear method
11. Setting out of a simple circular curve by angular method
12. Introduction to Total station and applications: To determine difference in elevation of any two given points. The introduction includes, setting up of the Total station over a station, input values, field measurements, downloading of the data in to a computer.
13. Total station and applications: Application to simple problems of height and distance by measuring angle of elevation and depression and determination of R.L of the target object.
14. Total station and applications: Determination of area enclosed in a closed traverse having minimum 5 stations. Plot the measured values by using a software package.
15. Global Positioning System (GPS): Determination of Latitude and Longitude of any four stations and computation of the area.

Note: At least 10 experiments must be performed during the semester

CONVENTIONAL SIGNS



CONTENTS

LIST OF EXPERIMENTS

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
Surveying Laboratory

CHAIN SURVEYING

INTRODUCTION:

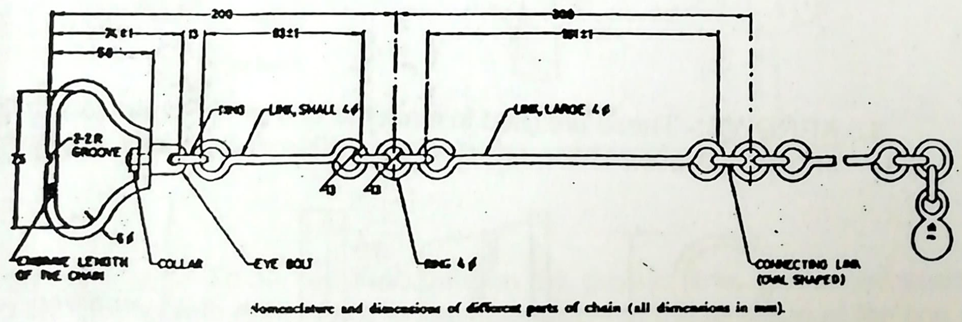
Chain surveying is the method of land surveying in which only linear measurements are made. No angular measurements are taken. This is the simplest type of surveying and consists of measuring the lengths of the lines marked out in the field. Chain surveying requires only simple instruments like chain, tape & few ranging rods but it is much time consuming. It is suitable only when the ground to be surveyed is flat and the area to be surveyed is small.

The process of measuring the horizontal distance between two terminal stations is known as chaining, which may be done either along a level ground or along a sloping ground. For measuring the lengths of the lines it is important that the chain should follow as far as possible straight line between the terminal points. If the line is long or if the terminal stations are not intervisible, the it is necessary to place ranging rods at intermediate points to maintain the direction. This operation of establishing intermediate points on a straight line between the terminal points is known as ranging.

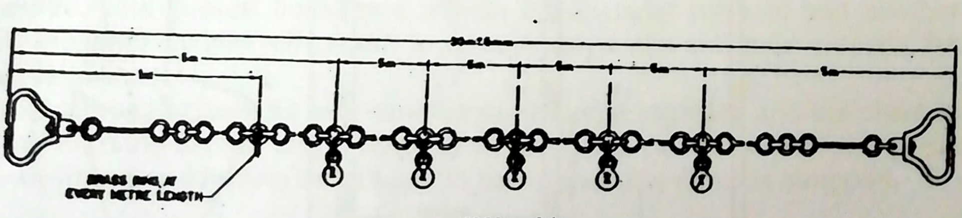
Instruments used in chain surveying:-

The following are some of the instruments used in chain surveying.

1. **CHAIN:-** Chains are used for linear measurements. Metric chains are generally available in 20m or 30m length. A chain is composed of links of gaivanised mild steel wire of 4mm diameter. Each metre length is divided into 5links, each of 20cm length measured from the centre to centre of links.



Nomenclature and dimensions of different parts of chain (all dimensions in mm).

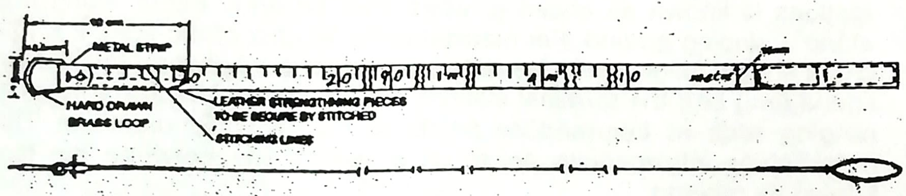


30 Meter chain.

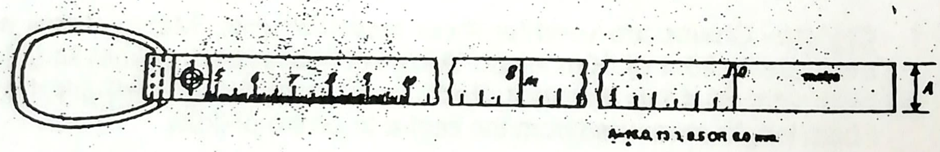
The following chains are used in countries where the unit of linear measurement is foot.

S.No.	Name	Length	No. of links
1.	Gunters chain	66ft	100
2.	Revenue chain	33ft	16
3.	Engineer's chain	100ft	100

2. **METALLIC TAPE**:- This is made of linen cloth reinforced with brass or copper wires to prevent undue stretching. The tape is 12mm wide, the zero being at the end of its brass terminal loop. The common lengths of tapes used are 15m, 20m or 30m and are coiled into a circular flat leather or plastic box by means of a brass handle which can be folded by a winding device.

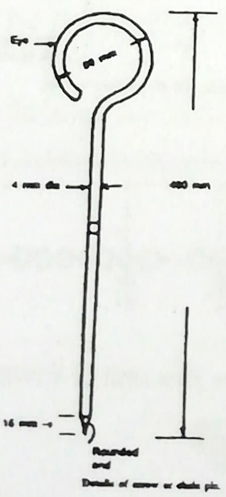


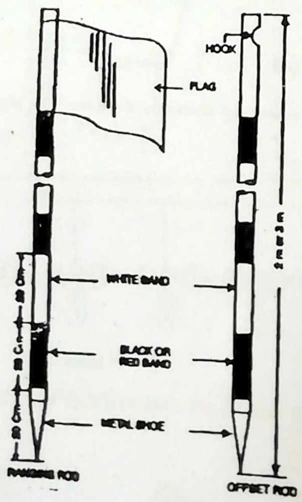
Metallic tape

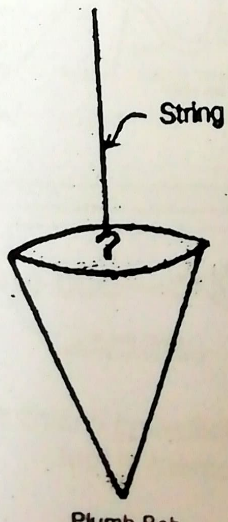


Steel tape

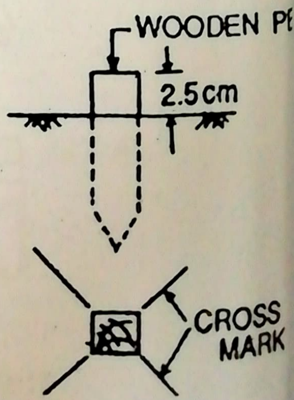
3. **ARROWS**:- These are used to mark the end of the chain length by inserting them into the ground. These are steel pins 400mm long and are pointed at one end.







Plumb Bob



They have a ring at the other end to facilitate in carrying them. A bunch of 10 arrows is always carried along with the chain.

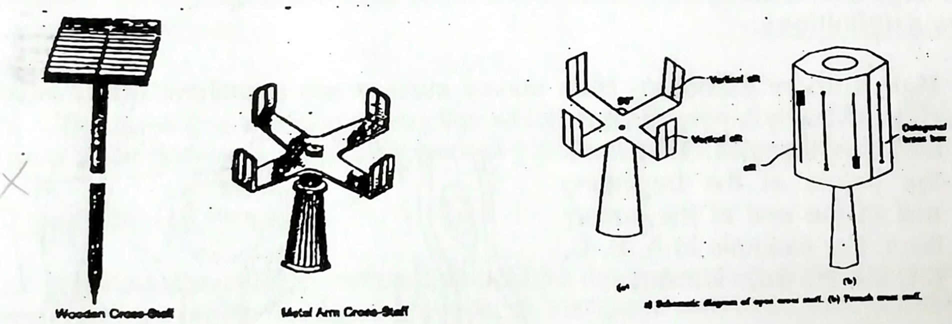
4. **PEGS**:- Pegs are made from hard timber and tapered at one end. They are usually 2.5cm square and 15cm long. These are driven into the ground to mark the positions of the stations.

5. **PLUMB BOB**:- It is required when measuring distances along slopes in a hilly country to transfer the points to the ground as in the method of stepping and also used for testing the verticality of the ranging poles.

6. **RANGING RODS**:- These are wooden or metal poles of 2m or 3m length with 30mm diameter. They are provided with iron shoes at their lower ends to facilitate easy driving into the ground. They are pointed in bands alternately black and white or red and white for better visibility. These are used to define a station point and also for ranging the line. For distant stations a coloured flag is inserted at the top for clear identification of a station. In such case they are also termed as flag poles.

7. **OFFSET RODS**:- It has two short narrow vertical slots passing through the centre of the section at right angles to one another and set at about the eye level.

8. **CROSS STAFF**:-The cross staff is the simplest instrument for setting out right anglesThe different types of cross staves are 1)Open cross staff 2)French cross staff.The French cross staff consists of a hallow octagonal brass box with sighting slits cut in the the middle of each face such that the lines between the centres of opposites slits make angles of 45 with each other.Therefore it is possible to set out angles of either 45 or 90 with this instrument.



Wooden Cross-Staff Metal Arm Cross-Staff (a) Schematic diagram of open cross staff. (b) French cross staff.

Method of using chain:- To spread the chain on the ground, it is unstrapped and hurled on to the ground with right hand, as far as possible in the direction of the line to be measured. One person holds one handle firmly under his foot and another person pulls the other handle with a jerk to remove any kinks and then spreads the chain in a straight line.

To fold a spread chain, its two handles are brought together and the chain is folded starting from the central tally collecting the two links on either side of it at the same distance from it and folding them back to back. Then the chain is strapped.

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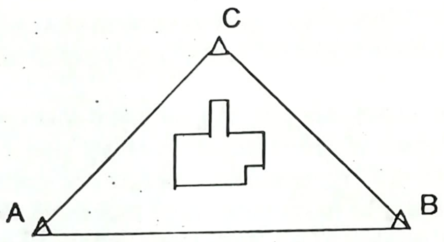
PRINCIPLES OF CHAIN SURVEYING

The principle of chain surveying is triangulation. The area to be surveyed is divided into a network of connected triangles as triangle is the only simple figure which can be plotted from the lengths of the three sides measured in the field, even if the angles are not known. Chain surveying is sometimes also called as chain triangulation.

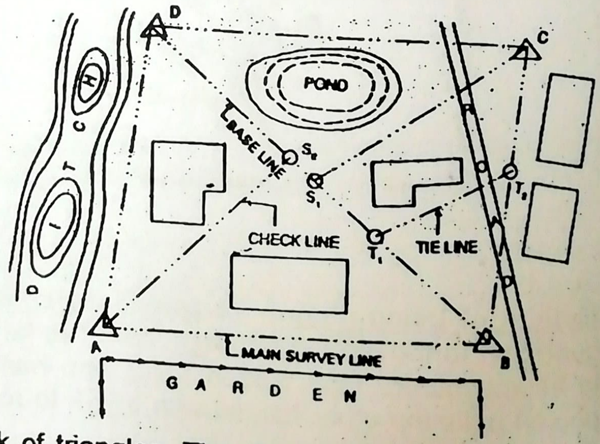
The simplest possible chain surveying consists of only one triangle. The three sides AB,BC & CA are measured in the field. The offsets are taken to locate the details. The plan of the area & the details are plotted in the office from the measurements taken in the field.



For large areas, the system consists of a frame work of triangles.

Basic definitions:-

1) **Main Survey stations:-** Main survey stations are prominent points which are connected by survey lines to form the triangles. These are the points at the beginning and at the end of the survey lines. For example in A, B, C, & D are the main stations.



2) **Main Survey Lines:-** The lines joining the main survey stations are called main survey lines or chain lines.

3) **Check lines:-** These are the lines which are run to check the accuracy of the frame work of triangles. The check line is not required for plotting the triangles. A check line is measured in the field during the surveying of the area. After plotting the plan from the survey lines, the length of the check line is scaled off from the drawing and compared with the measured length in the field. If there is no mistake in the measurement and plotting of the survey line, the length of the check line as plotted on the plan should agree with it's measured value. Check lines are also called proof lines.

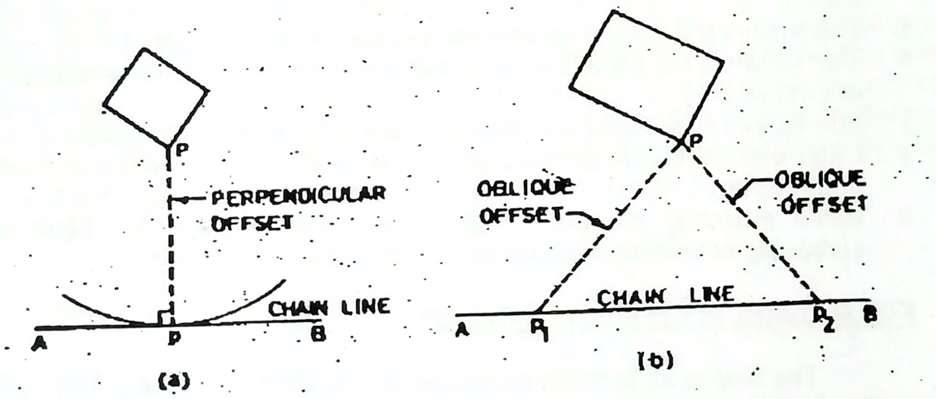
4) **Offsets:-**

Offsets are the lateral distances measured from the survey lines. Offsets are taken from the survey lines to determine the location of the details.

The offsets are of two types:

1) Perpendicular Offsets. 2) Oblique Offsets.

The perpendicular offset is perpendicular to the survey lines. The oblique offset is a short measurement inclined to the chain line.



5) **Tie lines:-**

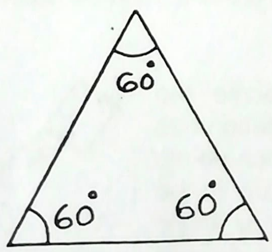
If the distance of the point of detail from the chain line is very large, long offsets have to be taken. The tie lines are the lines run to locate details to avoid long offsets.

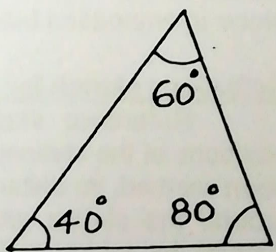
6) **Base lines:-**

The base line is a long survey line which runs through the middle of the area to be surveyed. The frame work of triangles is built up on the base line.

<u>**Well Conditioned Triangle**</u>

In chain surveying, an attempt should be made to select main survey stations so that they form well conditioned triangles. A triangle is said to be well conditioned if it can be plotted accurately by the intersection of arcs from the ends of the base line. An equilateral triangle is said to be an ideal well conditioned triangle. If equilateral triangle is not possible due to site conditions, an attempt should be made to form a triangle in which no angle is less than 30^0 nor more than 120^0. This will give a fairly good intersection when plotting the triangles.





SELECTION OF SURVEY STATIONS AND SURVEY LINES

For a good arrangement of survey lines, the following points should be kept in mind while selecting the main stations and survey lines.

1. The main stations should be mutually intervisible so that ranging can be done easily.
2. Survey lines should be as few as possible, so that the frame work of triangles can be plotted easily.
3. Survey lines should pass through a level open ground as far as possible so that chaining can be done easily.
4. The frame work should have atleast one long base line that runs in middle of the area.
5. The main survey line should form well conditioned triangles.
6. The survey lines should be selected such that there are no obstacles in chaining and ranging.
7. The survey lines should be closed to the detail to avoid long offsets.
8. Each triangle should have a check line to detect the mistake in measurements and plotting.
9. While selecting the main stations and survey lines, the basic principle of surveying of working from whole to part should be followed.

FIELD WORK IN CHAIN SURVEYING:

The field work in chain surveying can be divided into the following four stages.
1. Reconnaissance 2.Marking stations 3.Running survey lines 4.Taking offsets

1. Reconnaissance:

Reconnaissance is the preliminary inspection of the area to be survey to have some idea of the terrain and the principal features of the ground. In reconnaissance, the surveyor thoroughly examines the ground and then decides upon the best possible arrangements of triangles. Suitable positions of main survey stations and survey lines are then selected. The intervisibility of the selected stations are checked after fixing the ranging rods.

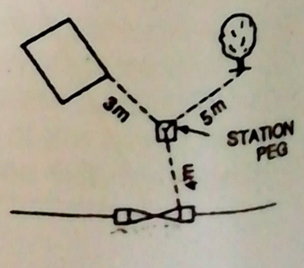
During reconnaissance, the surveyor generally makes an index sketch or the key plan to show the principal features, such as buildings, roads, boundaries etc.The positions of the stations and survey lines are also marked.

2. Marking Stations:

After completing the reconnaissance, the main stations are marked on the ground, so that the stations can be readily located afterwards if required. If the survey is extensive wooden pegs are driven to mark the station. The name of the station is also written on the peg. If stations are to be marked permanently a block stone is embedded below the ground surface and a cross is marked on its top.

Reference sketch for stations:

Reference sketches are required to relocate the positions of the stations at a future date. After the station has been marked, its distances from permanent reference points around the station are measured. The stations are to be located by taking suitable measurements from any three permanent points. The permanent points should be definite



and easily recognisable, such as the corner of the building, gate pillars, boundary stones, fence etc.

Although two measurements are sufficient to locate the stations from the reference point a third measurement to taken to serve as a check.

3. Running Survey Line:

Survey lines are run to measure the distance between main stations and locate the adjacent details by offsets. The chaining usually commences from the base line and is continued to other survey lines.

4. Taking Offsets:

The process of taking the offsets is also known as offsetting. The offsets are generally measured with a metallic tape in chain surveying. An offset rod can be also used for taking short offsets if the tape is not available. The offsets are generally termed short if they are less than 15 metres in length. The offsets are long offsets when they are more than 15 metres in length. The maximum length of the offsets is generally limited to 1 tape length, usually 30metres. When the length exceeds 30 metres, a tie line should be run to take the offsets. However the maximum length of offset depends on the scale of plot chosen for drawing.

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EXPERIMENT -

CHAIN TRAVERSING

AIM- To survey the given area by chain and tape.

INSTRUMENTS REQUIRED:- Chain, tape, and cross staff, etc.,

PROCEDURE:-

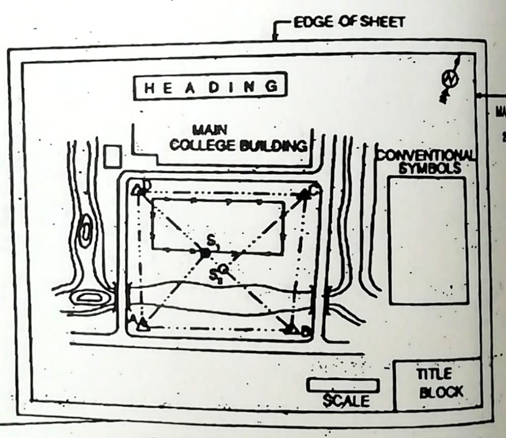
First go around the area to be surveyed. Prepare a rough sketch of the area to be surveyed showing the major features of the area.

Fix the control points or station points keeping in view the requirements for them along the boundaries of the area. Mark the stations as A,B,C,D and so on in the direction of progress.

Set the base line approximately in the middle of the area say AD. While chaining along the chain line take offsets to the nearby permanent features. After having completed the field work, the plan should be drawn to some scale.

Plotting of a Chain Surveying Work:

The main object of a Chain Survey is to produce plans and maps of the area surveyed. These plans and maps also indicate the various details of the area. Before plotting the plan, the scale is to be selected.

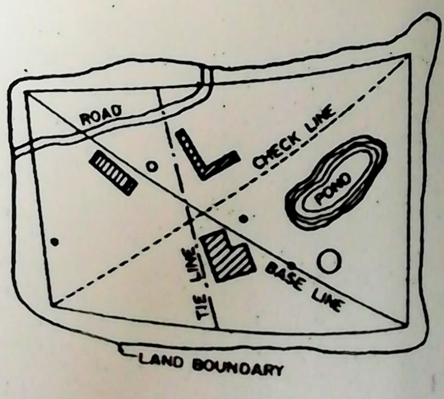


Sample Plotting of Map Showing Different Positions

The base line which is generally the longest line is plotted first in the middle of the drawing paper. The intermediate stations on the base line are then marked by scaling the corresponding chainages. The positions of the other main stations are located by drawing arcs from the ends of the base line to form triangles. The triangles are then checked by drawing the check lines measured in the field.

After finishing the frame work of triangles, offsets are plotted. After all the points have been plotted, the details are shown.

RESULT:-



1. Define surveying
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4. What is meant b
5. Briefly explain th
6. Give the names
7. Which instrumen
8. Give the names angles of depres
9. How will you de
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11. Define Represe
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48. What is a fie
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51. What are the
52. What is the

QUESTIONS FOR VIVA-VOCE

1. Define surveying.
2. Give the names of different types of surveying.
3. What do you understand by cadastral surveys?
4. What is meant by geodetic surveys?
5. Briefly explain the meaning of topographic surveys.
6. Give the names of some of the survey instruments in which telescope is attached.
7. Which instruments are used when horizontal angles are to taken?
8. Give the names of some instrument from which angles of elevation as well as angles of depression both can be read.
9. How will you define a scale?
10. In what ways a scale may be represented?
11. Define Representative Fraction.
12. What is the full form of R.F?

RF = Representative fraction

13. Differentiate between Scale and R.F.
14. What do you understand by Least Count in a scale?
15. How will you define least count in a vernier scale?
16. Why the chain and tape survey is so named?
17. What instruments are required for chain and tape survey?
18. Of what material is the chain made?
19. Name different parts of chain.
20. Of what material the arrows or pins, handles of the chain and the tags made?
21. Of what material are the links and the rings in the chain made of?
22. Why tags are generally made of brass?
23. What is the purpose of the tags in the chain?
24. What is the function of the arrows or pins?
25. Of what material the ranging rods are made?
26. What is the size of a ranging rod?
27. Why are the ranging rods alternately coloured?
28. How many types of chains do you know?
29. What is the name of the chain that you use in your surveys?
30. What is an Engineer's chain?
31. What is a metric chain?
32. What is the length of a metric chain?
33. How are the tags placed in a metric chain?
34. What is an offset?
35. What is an optical square?
36. What is a cross staff?
37. What is the best time of survey?
38. How to cross a narrow river in chain and tape survey?
39. How to avoid an obstacle in chaining?
40. How to turn a chain a t right angles wit the help of chain and tape?
41. Describe a Gunter's chain.
42. What are the advantages of a Gunter's chain?
43. Give the names of different types of tapes.
44. What is the name of the tape which you generally use in surveys?
45. What is an invar steel tape?
46. How to carry o chain and tape survey in a thick jungle?
47. How to measure the horizontal distances on a steep slope?
48. What is a field book?
49. What are probable errors in chain and tape surveying?
50. When is the chain and tape survey most suitable
51. What are the objects of surveying?
52. What is the principle of surveying?

53. Explain the methods of chaining along a sloping ground?
54. Explain how a chain is tested and adjusted?
55. Explain the following terms.
a)Chaining b) Ranging c) Compensating error d) Cumulative error e) Gunters chain f) Revenue chain g) Engineer's chain h) Well conditioned triangle I) Check line j) Reconnaissance k) Base line l) Reference sketch.
56. Give the list of corrections to be applied to measurements taken with steel tape?
57. What are the limits of errors under different conditions of surveying?
58. Name the instrument used for setting out right angles?
59. Give the conventional symbols for the following.
a)Pipe line b) Road c) Embankment d) Woods e) Boundaries f) Fence.
60. While chaining a line you come across a) River b) A Building. Describe how you would continue the line with the chain only.
61. Describe with sketches how you would overcome the following obstacles in carrying out a chain survey.
a) Those which obstruct ranging but not chaining.
b) Those which obstruct chaining and ranging.

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COMPASS SURVEY

INTRODUCTION:-

Surveying in which a compass is used to measure the direction of survey line in a traverse is known as compass survey. Compass surveying is suitable in the following situations.

a) When the surveying has to be done quickly and other types of surveying are considered difficult.
b) When the area is hilly & chaining is difficult.
c) When the surveying is to be done in dense forest.
d) When the area cannot be divided into triangles like in urban areas.
e) When the area to be surveyed is too long & narrow, eg = Road, Canal etc.
f) When the area is large with few details.

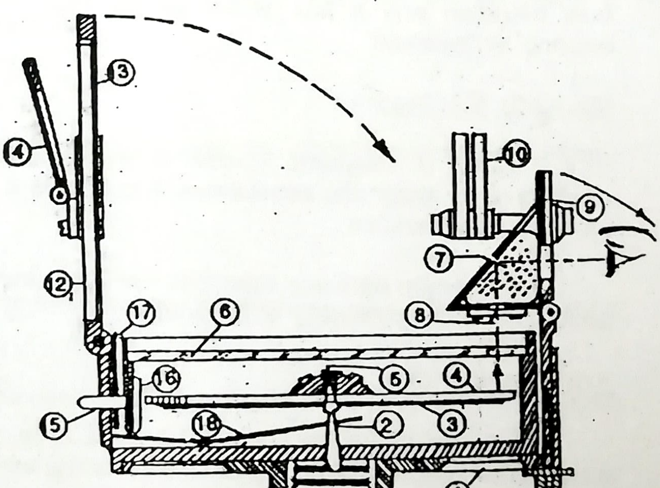
However compass survey is not suitable in area having magnetic rock, iron ore, power transmission lines etc, which will affect the magnet of the compass.

COMPASS:

The angles at stations are measured with the help of a compass. The prismatic compass is the one which is most commonly used by engineers.

PRISMATIC COMPASS

(1)At the centre of the metal box there is a pivot (2) It carries a magnetic needle (3) The needle is attached to an aluminum ring which is graduated to ½ degree (4) A light spring brake (16) Is attached to the inside of the box to damp the oscillations of the needle and bring it to rest before taking a reading. The spring is brought to rest by means of the inward brake pin (15) A reflecting prism (7) facilitates reading of the angles and is protected from moisture and dust etc., by a prism cap (8) A sighting slit (9) is provided through which the readings can be read. The



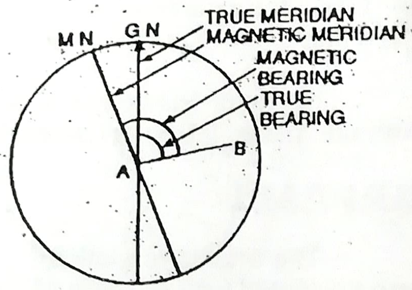
1. Compass box.
2. Pivot.
3. Magnetic needle.
4. Graduated ring.
5. Agate cap.
6. Glass cover.
7. Prism.
8. Prism cap.
9. Sighting slit.
10. Coloured glasses.
11. Focussing screw.
12. Object-vane.
13. Horse hair.
14. Reflecting mirror.
15. Brake pin.
16. Spring brake.
17. Lifting pin.
18. Lifting lever.

prism base and vertical faces are made convex which magnifies the reading. The focussing can be adjusted by means of the focussing screw (11) The object vane is located diametrically opposite to the prism (12) It is hinged to the side of the box and carries a horse hair (13) The object vane can be brought down on the face of the glass cover (6) When it is brought down, it presses against a lifting pin (17) This automatically lifts the pivot by the lifting lever (18) This reduces the undue wear and tear of the pivot. A tilted reflecting mirror (14) is provided on the side of the object vane to enable bearings of very high or low objects to be taken. A pair of coloured glasses (10) are provided between the slit and the object vane to enable sighting the sun or any luminous object. A metal cover is provided to enclose the compass and the object vane.

Bearing of a line:-

The bearing of a line is the horizontal angle made by the line with selected reference line. Magnetic meridian is taken as reference line in compass survey.

True Meridian:-



The line or plane passing through the geographical north pole, south pole and any convenient point on the surface of the earth is known as the true meridian. True meridian is constant at a station. The angle between the true meridian and a line is known as 'true bearing' or 'Azimuth'.

Magnetic Meridian:-

When a magnetic needle is suspended freely and balanced properly, unaffected by magnetic substances, it indicates a direction. This direction is known as 'magnetic meridian'.

The angle between magnetic meridian and a line is known as the 'magnetic bearing' or simply 'bearing' of the line.

Arbitrary Meridian:-

Sometimes for the survey of a small area, a convenient direction is assumed as meridian (especially in theodolite traversing) which is known as arbitrary meridian.

Whole Circle bearing (W.C.B):-

The magnetic bearing of a line measured in clock-wise from the north pole towards the line is known as the 'whole circle bearing', of that line. WCB may have any value between 0^0 to 360^0. The WCB of a line is obtained by prismatic compass.

Quadrantal Bearing (QB):-

The magnetic bearing of a line measured clockwise or counter clockwise from the North pole or South pole (whichever is nearer to the line) towards the east or west is known as quadrantal bearing like NE, SE, SW & NW. The value in this system lies between 0° & 90°, but quadrant should always be mentioned. QB are obtained by Surveyor's Compass.

Reduced Bearing (RB):

When the WCB of a line is converted into QB, it is termed as reduced bearing (RB).

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

Fore Bearing and Back Bearing:-

The bearing of the line measured in the direction of the progress of survey is known as fore bearing (FB) of the line.

The bearing of the line measured in the direction opposite to the survey is known as 'back bearing' (BB) of the line.

Magnetic Declination:

The horizontal angle between magnetic meridian and true meridian is know as 'magnetic declination'.

Isogonic and Agonic lines:-

Lines passing through the points of equal declination are known as 'Isogonic lines'.

The line passing through the points of zero declination is said to be 'Agonic line'.

Dip of the magnetic needle:-

If a needle is properly 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 knows as the dip of the 'magnetic needle'.
South end of the magnetic needle is deflected downwards in the southern hemisphere and North end is deflected in the northern hemisphere and needle is just horizontal at equator.

Local Attraction:-

When a magnetic needle comes near some magnetic substances, such as iron ore, steel structures, electric cables conveying current etc, it deflects from its true direction and does not show the true north. This disturbing influence of magnetic substances is known as 'local attraction'.

To detect the local attraction, the F.B & BB of a line should be taken. If the difference is exactly 180^0 then there is no local attraction.

To compensate the local attraction, the amount of error is found out and equally distributed between FB & B.B.

Principles of Compass Surveying:-

The principle of compass surveying is traversing, which involves a series of connected lines. The magnetic bearings of the lines are measured by prismatic compass & distance of the lines is measured by chain or tape. Such survey do not require formation of network of a triangles.

Traversing is of two types:

a) Closed traverse. b) Open traverse.

In traversing, FB & BB's of the traverse legs are measured by prismatic compass & sides of the traverse by chain or tape. Observed bearings are verified and necessary corrections for local attraction are applied. In this method, closing error may occur when plotted. This error is adjusted graphically by using 'Bowditch's Rule'.

CHECK ON CLOSED TRAVERSE:-

i) The sum of the measured interior angles should be equal to $(2N - 4)x90^0$ where N is the number of sides of the traverse.
ii) Sum of the measured exterior angles should be equal to $(2N + 4) \times 90^0$.
iii) The algebraic sum of the deflection angles should be equal to 360^0.

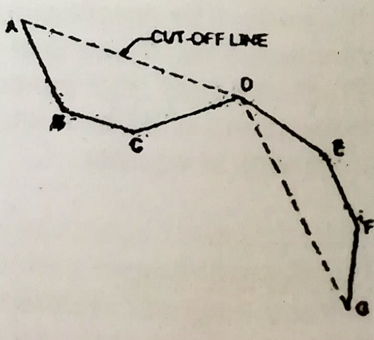
CHECK ON LINEAR MEASUREMENT:-

a) The lines should be measured once each on two different days (along opposite directions). Both measurements should tally.
b) Linear measurements should also be taken by the stadia method. The measurements by chaining and by the stadia method should tally.

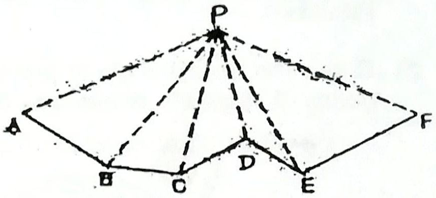
CHECK ON OPEN TRAVERSE:-

In open traverse, measurements cannot be checked in the field. But some field measurements can be taken to check the accuracy of the work. The following are the field measurements taken for check.

(1) **TIE LINE OR CUT-OFF LINE:-** Tie lines or Cut-off lines are taken between some intermediate stations of the open traverse. Suppose ABCDEFG represents an open traverse. Let AD and DG be the cut-off lines. The lengths and magnetic bearings of the cut-off lines are measured accurately. After plotting the traverse, the distances and bearings are noted from the map. If these distances and bearings tally with the field measurements, then the traverse is said to be correct.



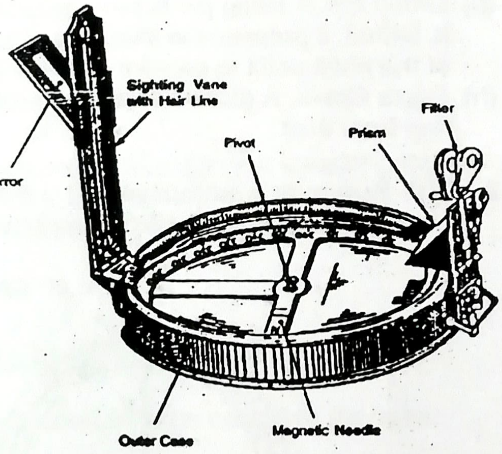
(2) AUXILARY POINT:- Let ABCDEF be an open traverse. A permanent point 'P' is selected on one side of it. The magnetic bearings of this point are taken from the traverse stations A,B,C,D,E & F. If the survey is carried out accurately & plotted correctly, then all the measured bearings of 'P' when plotted should meet at the point 'P'. The permanent point 'P' is known as an 'auxiliary point'.



TYPES OF COMPASS

There are two types of compass:
1. The prismatic compass,
2. The surveyor's compass.

1. **The Prismatic compass:-** In this compass, the readings are taken with the help of a prism. The following are the essential parts of this compass:



Prismatic compass, non-liquid.

(a) *Compass Box*: The compass box is a circular metallic box (the metal should be non-magnetic) of diameter 8 to 10cm. A pivot with a sharp point is provided at the centre of the box.

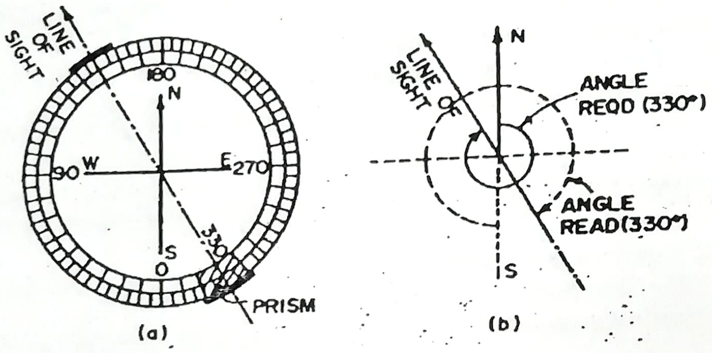
(b) *Magnetic Needle and Graduated Ring*: The magnetic needle is made of a broad, magnetised iron bar. The bar is pointed at both ends. The magnetic needle is attached to a graduated aluminium ring. The ring is graduated from 0^0 to 360^0 clockwise, and the graduations begin from the south end of the needle. Thus 0^0 is marked at the south, 90^0 at west, 180^0 at the north and 270^0 at the east. The degrees are again subdivided into half-degrees. The figures are written upside down. The arrangement of the needle and ring contains an agate cap pivoted on the central pivot point. A rider of brass or silver coil is provided with the needle to counterbalance its dip.

(c) *Sight Vane and Prism*: The sight vane and the reflecting prism are fixed diametrically opposite to the box. The sight vane is hinged with the metal box and consists of a horsehair at the centre. The prism consists of a sighting slit at the top and two small circular holes, one at the bottom of the prism and the other at the side of the observer's eye.

(d) *Dark Glasses*: Two dark glasses are provided with the prism. The red glass is meant for sighting luminous objects at night and the blue glass for reducing the strain on the observer's eye in bright daylight.

(e) *Adjustable Mirror*: A mirror is provided with the sight vane. The mirror can be lowered or raised, and can also be inclined. If any object is too low or too high with respect to the line of sight, the mirror can be adjusted to observe it through reflection.

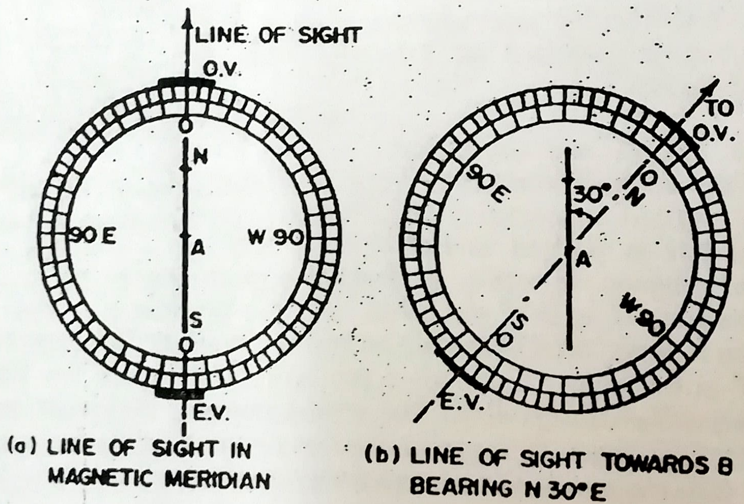
(f) *Brake Pin*: A brake pin is provided just at the base of the sight vane. If pressed gently, it stops the oscillations of the ring.



(g) *Lifting Pin*: A lifting pin is provided just below the sight vane. When the sight vane is folded, it presses the lifting pin. The lifting pin then lifts the magnetic needle out of the pivot point to prevent damage to the pivot head.

(h) *Glass Cover*: A glass cover is provided on top of the box to protect the aluminum ring from dust .

2. **The 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 directly with 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 0^0 to 90^0 in four quadrants. 0^0 is marked at the north and south, and 90^0 at the east and west. The letters E (east) and W (west) are interchanged from their true positions. The figures are written the right way up.
(f) No mirror is attached to the object vane.

SOURCES OF ERROR IN COMPASS

The following are the kinds of error which may occur while taking readings with a compass:

1. Instrumental errors

(a) The needle may not be perfectly straight and might not be balanced properly.
(b) The pivot point may be eccentric.
(c) The graduations of the ring may not be uniform.
(d) The ring may not rotate freely on account of the pivot point being blunt. This may occur due to the head of the pivot being broken because of careless handling.
(e) The sight vane may not be vertical.
(f) The horse hair may not be straight and vertical.

2. Personal errors

(a) The centering may not be done perfectly over the station.
(b) The graduated ring may not be levelled.
(c) The object might not be bisected properly.
(d) The readings may be taken or entered carelessly.
(e) The observer may be carrying magnetic substances.

3. Other sources of error

(a) There may be local attraction due to the presence of magnetic substances near the station.
(b) The magnetic field could vary on account of some natural causes.
(c) The magnetic declination might vary.

PRECAUTIONS TO BE TAKEN IN COMPASS SURVEYING

The following precautions should be taken while conducting a compass traverse:

1. The centering should be done perfectly.
2. To stop the rotation of the graduated ring, the brake pin should be pressed very gently and not suddenly.
3. Readings should be taken along the line of sight and not from any side.
4. When the compass has to be shifted from one station to other, the sight vane should be folded over the glass cover. This is done to lift the ring out of the pivot to avoid unnecessary wear of the pivot head.
5. The compass box should be tapped gently before taking the reading. This is done to find out whether the needle rotates freely.
6. The stations should not be selected near magnetic substances.
7. The observer should not carry magnetic substances.
8. The glass cover should not be dusted with a handkerchief, because the glass may be charged with electricity and the needle may be deflected from its true direction. The glass cover should be cleaned with a moist finger.

TEMPORARY ADJUSTMENT OF PRISMATIC COMPASS (FIELD PROCEDURE OF OBSERVING BEARING):

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. **Centering:** Normally, the compass is centered by dropping a piece of stone from the bottom of the compass box. Centering may also be done with the aid of a plumb bob held centrally below the compass box, if plumb-bob is available.

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 centering 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. At this time the graduated ring may rotate rapidly. The brake pin is pressed very gently to stop this rotation. When the ring comes to rest, the box is struck very lightly to verify the horizontality of the ring and the frictional effect on the pivot point. Then the reading is taken from the graduated ring through the hole in the prism. The reading will be the magnetic bearing of the line.

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EXPERIMENT -

COMPASS TRAVERSING

AIM:- To run a closed traverse survey by using prismatic compass & plotting the same.

INSTRUMENTS REQUIRED:- Prismatic compass with all its accessories, tape, plumb bob, ranging rods, pegs etc.

PROCEDURE:-

FIELD PROCEDURE OF COMPASS TRAVERSING

Prismatic compass traversing is conducted in accordance with the following steps:

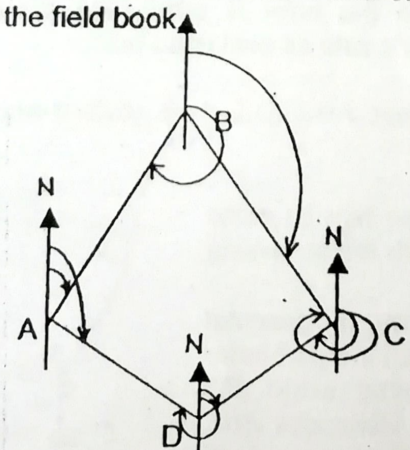
(a) *Reconnaissance:* The area to be surveyed is examined thoroughly to select the traverse stations. These stations should be intervisible and should cover the whole area. It should be ensured that there is no magnetic substance near the selected stations. The traverse legs should run along fairly level ground.

(b) *Preparation of index sketch:* After reconnaissance, an index sketch should be prepared showing the skeleton of the traverse.

(c) *Marking the station on the ground:* The traverse stations are marked on the ground by wooden pegs. The pegs should be fixed on the station points in such a way that a height of about 3cm is always exposed above the ground surface.

Reference sketches should be prepared for all the traverse stations by taking at least two measurements from some permanent points. This precaution is taken so that the stations can be located accurately even if the pegs have been removed by somebody.

(d) *Measurement of bearings of traverse legs:* The traverse stations may be selected clockwise or anticlockwise order. But the direction of the traverse should be indicated in the index sketch. Suppose four traverse stations A,B,C and D are selected to enclose an area. The prismatic compass is centered and levelled at the starting station A. The fore bearing of AB and back bearing of DA are taken from this station. The distance AB is measured and offsets are taken along the line AB and recorded in the field book.



Closed Traverse by Compass

The compass is then shifted and centred over station B. Then the FB of BC and BB of AB are taken. Here, the FB and BB of line AB should differ by exactly 180°. However, the error should not exceed the permissible limit. If it does, the bearings of the lines should be observed again. Now, the line BC is measured and offsets are taken and noted in the field book. Similarly, all the traverse legs are measured and noted in the field book.

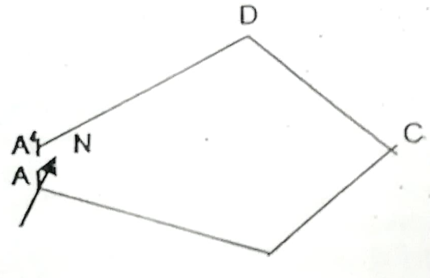
After completion of the work, the observations are tabulated and necessary corrections applied to eliminate the effect of local attraction.

PLOTTING OF COMPASS TRAVERSE

By considering included angles: The starting station A is suitably selected on the sheet. A line representing the north line is drawn through station A. The bearing of the line AB is plotted by protractor and the distance AB marked to a suitable scale. At station B the angle <B is plotted and the distance BC marked according to the previous scale. Angle <C is plotted at station C and the distance CD is marked.

This process is continued until all the lines have been plotted. In this case also, there may be a closing error which has to be adjusted graphically.

Closing error (AA')



Plotting of Closed Traverse by Compass

ADJUSTMENT OF CLOSING ERROR:-

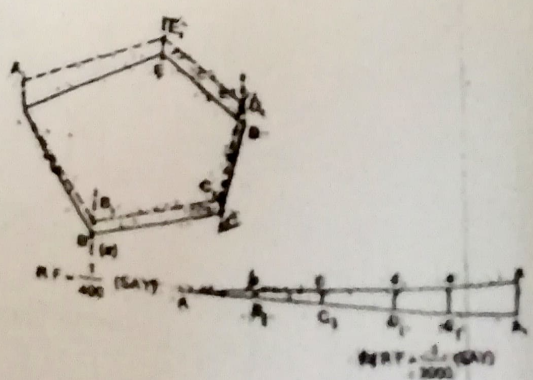
When a closed traverse is plotted, the finishing and starting points may not coincide. The distance by which the traverse fails to close is said to be the closing error. Such an error may occur due to mistakes made in the measurement of lengths and bearings of the lines, or because of an error in plotting.

If the closing error exceeds a certain permissible limit, the field work should be repeated. But when the error is within the permissible limit, it is adjusted graphically by **Bowditch's rule** as explained below.

Suppose a traverse $AB_1C_1D_1E_1A_1$ is plotted according to any suitable scale (RF = 1/400).

In this case, the traverse fails to close by a distance AA_1, which is the closing error.

To adjust this error, a horizontal AA_1 is drawn to represent the perimeter of the traverse to another scale (RF =1/2,000). On this line, distances AB_1, B_1C_1, C_1D_1, D_1E_1 and E_1A_1 are set off according to the corresponding measured lengths of the traverse legs.



A perpendicular A_1a is drawn equal to the amount of closing error, after which the line Aa is drawn. From the points B_1, C_1, D_1 and E_1, the lines B_1b, C_1c, D_1d and E_1e are drawn parallel to A_1a . These intercepts represent the amount by which the respective stations are to be shifted.

The lines are drawn parallel to the closing error through stations B_1, C_1, D_1 and E_1. Then the intercepts B_1b, C_1c, D_1d and E_1e are set off along the parallel lines drawn through the respective stations. In this manner, the adjusted traverse ABCDEA is obtained.

Limits of closing error:- The angular error of closure should not exceed $15' \sqrt{N}$ mins, where N is the number of sides of the traverse.

$$\text{Relative closing error} = \frac{\text{amount of closing error}}{\text{Perimeter of traverse}}$$

The value should not exceed 1/600.

QUESTIONS FOR VIVA-VOCE

1. What are the accessories for the plane table survey?
2. What precautions should be taken while selecting a base line?
3. What is meant by Radiation Method?
4. What is intersection Method?
5. What is Traverse Method?
6. What should be the length of base line?
7. What should be the height of the plane table?
8. If the base line is too long or too short, what will be its effect on the survey?
9. Why the trough compass should not be used for orientation at the second plane table station?
10. What will happen to the plan if the scale is large or small?
11. What do you understand by Two Point Problem?
12. What is Three Point Problem?
13. What are the different methods to carry on Three Point Problem?
14. What is meant by Resection?
15. What is setting?
16. What is orientation an how it is done?
17. What is the difference between setting and orientation?
18. What are Lehman's Rules?
19. What will happen if the table is not levelled?
20. What will happen if the table is not properly centered?
21. Name the instrument which is used for centering?
22. How is centering done by centering fork?
23. Describe a centering fork?
24. What is the greatest advantage of plane table survey?
25. What are the probable errors in plane table survey?
26. Why one of the Resection Methods is called Trial and Error Method?
27. What is meant by Triangle of Error Method?
28. What is meant by "Strength of Fix"?
29. What is the practical utility of the two and three point problem?

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PLANE TABLE SURVEYING

INTRODUCTION:-

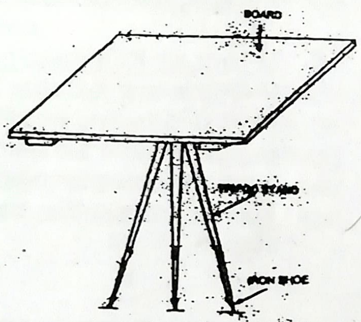
Plane Table survey is the simplest and best instrument of surveying. It is ideal for locating objects which are inaccessible like ponds, points across a river etc. It is a graphical method of surveying in which the field work and plotting are done simultaneously and such survey does not involve the use of a field book. Its is most suitable for filling in the details between the stations previously fixed by triangulation or theodolite traversing. It is particularly adopted for small scale mapping. But this survey is recommended for the work where great accuracy is not required, as the fitting & fixing arrangement of this instrument is not perfect.

Principle:- The principle of plane tabling is parallelism; meaning the rays drawn from stations to objects on the paper are parallel to the lines from the stations to the objects on the ground. The table is always placed at each of the successive stations parallel to the position it occupied at the starting station.

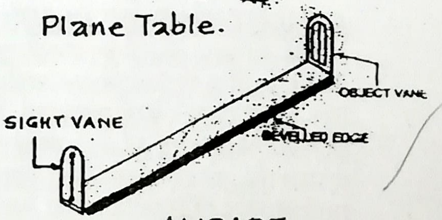
ACCESSORIES OF PLANE TABLE:-

1. **Plane Table:** The plane table is a drawing board of size 750mm x 600mm made of well-seasoned wood like teak, pine, etc. The top surface of the table is well levelled. 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.



Plane Table.

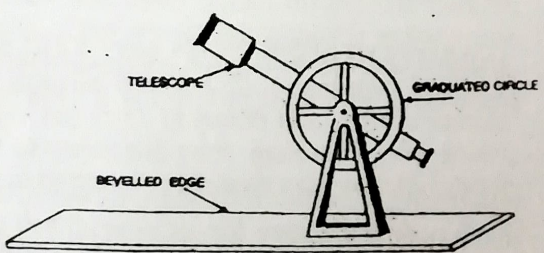


ALIDADE.

2. **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 50cm. One of its edges is bevelled, and is known as the fiducial edge. It consists of two vanes at both ends which are hinged with the ruler. One is known as the 'object vane' and carries a horse hair; the other is called the 'sight vane' and is provided with a narrow slit.

(b) ***Telescopic Alidade:*** The telescopic alidade consists of a telescope meant for inclined sight or sighting distant objects clearly. This alidade has no vanes at the



Telescopic Alidade.

ends, but is provided with fiducial edge.

The function of the alidade is to sight objects. The rays should be drawn along the fiducial edge .

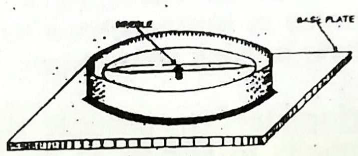
3. **<u>The Spirit Level</u>:** The spirit level is a small metal tube containing a small bubble of spirit. The bubble is visible on the top along a graduated glass tube.

The spirit level is meant for levelling the plane table.

4. **<u>The Compass</u>:** There are two kinds of compass – (a) the trough compass. 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.

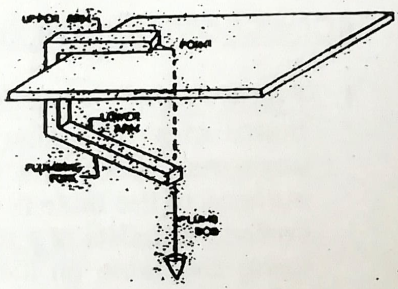
(b) ***The Circular Box Compass:*** It carries a pivoted magnetic needle at the centre. The circular box is fitted on a square base plate.



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.

5. **<u>U-fork or Plumbing fork with plumb bob</u>:** 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.



<u>ADVANTAGES OF PLANE TABLING</u>:- (i.) It is most suitable for preparing small-scale maps. (ii) It is most rapid. (iii) The field book is not necessary as plotting is done in the field concurrently with the field work, and hence the mistakes in booking the field notes are avoided. (iv) The surveyor can compare the plotted work with the actual features of the area surveyed and thus can ascertain if it represents them properly, and cannot, therefore, overlook any essential features. (v) There is no possibility of omitting the necessary measurements as the map is plotted in the field. (vi) Errors of measurment and plotting may be readily detected by check lines. (vii) Contours and irregular objects can be represented accurately, since the tract is in view. (viii) It is particularly advantageous in magnetic areas where compass survey is not reliable. (ix) It is less costly than a theodolite survey. (x) No great skill is required to prepare a satisfactory map. (xi) Inaccessible points can be easily located by intersection.

<u>DISADVANTAGES OF PLANE TABLING</u>:- (i.) The plane table is essentially a tropical instrument. (ii) It is not suitable for work in a wet climate. (iii) It is heavy, cumbersome, and dificult to carry.(iv) The number of accessories to be carried, are more and, therefore, they are likely to be lost. (v) It is not intended for accurate work.(vi) The map cannot be replotted to a different scale as there is no field book.

PROCEDURE OF SETTING UP PLANE TABLE OVER A STATION

The following steps have to be performed in order to set 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 wing nut at the bottom.

2. **Levelling the table:** The table is levelled by placing the spirit level at different corners and various positions on the table. The bubble is brought the centre of its run at every positions of the table by adjusting the legs.

3. **Centring 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 centring. The table is then clamped. Care should be taken not to disturb the levelling.
4. **Marking the north line:** The trough compass is placed on the right-hand top corner with it north end approximately towards the north. Then the compass is turned clockwise or anticlockwise so that the needle exactly coincides 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 magnetic needle or by the backsighting method. The back sighting process is always preferred, because it is reliable. During orientation, it should always be remembered that the requirements of centering, levelling, and orientation must be satisfied simultaneously.

ORIENTATION:- The operation of keeping the table at each of the successive stations parallel to the position which it occupied at the first station is known as orientation. It is necessary when the instrument has to be set up at more than one station. When the table is properly oriented, the lines on the paper are parallel to the lines on the ground, which they represent. There are two methods of orienting the table, (i.) By the use of the magnetic needle, and (ii) By backsighting. Orientation may also be effected by solving the two-point problem and three-point problem.

1. **Orientation by the Magnetic Needle:-** To orient the table at any subsequent station, the trough compass (or circular box compass) is placed along the line representing the magnetic meridain which has been drawn on the first station, and the board is then turned until the ends of the needle are oppostie to the zeros of the scale. The board is then clamped in position. This method is sufficiently accurate provided there is no local attraction. It is suitable for rough small-scale mapping.

2. **Orientation by Backsighting:-** This is the most accurate method of orientation and is always to be preferred. Suppose the table is set up over the station Q on the line PQ which has been previously drawn as pq from the station P. The

alidade is placed along the line qp. The board is then turned until the line of sight bisects the ranging rod at P. The board is then properly oriented and clamped in this position. Care should be taken to placed the table at each of the successive stations in such a position that the centering of the table is least altered when the table is turned in azimuth for orientation. To ensure this, the line (qp) joining the station (q) and the preceding one (p) plotted on the paper should be as nearly parallel as possible to the corresponding line (QP) on the ground.

ERRORS IN PLANE TABLING:- The following are the chief sources of errors:

1. The board not being horizontal.
2. The table not being accurately centered.
3. The table not being correctly oriented. To guard against this error, the orientation of the table should be checked at as many stations as possible by sighting to a distant and prominent object, which has been previously plotted.
4. The table rotating between sights due to insufficient clamping. The orientation should be checked after the observations at a station are completed.
5. The objects not being sighted accurately.
6. The alidade not being correctly centered on the station point on the paper.
7. The rays not being accurately drawn through the station point.
8. Inaccuracy in plotting.
9. The expansion and contraction of the paper.

NOTE:- The following are some of the important points to be noted down while surveying with the plane table.

(1) The small letters a,b,c, denote the points plotted on the sheet to represent the corresponding point A,B,C, etc., on the ground.
(2) The table remains clamped in position while the objects are sighted. It is the alidade that is moved on the table to bisect the objects.
(3) While the sights are being taken, the alidade must be centered or pivoted on (i.e. the fiducial edge of the alidade must be set to) the plotted station point on the sheet.
(4) The board is turned only when the table is to be oriented. After the table is properly oriented, the board must be clamped in position.

Plane table

EXPERIMENT -

RADIATION METHOD

AIM & THEORY:-

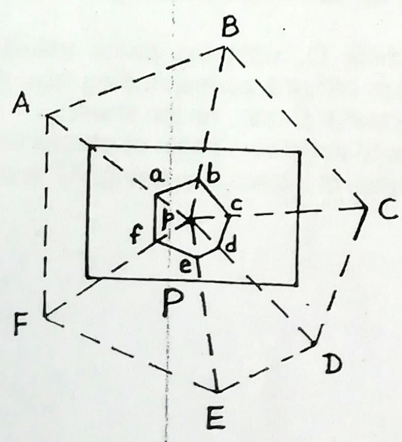
In this method the point is located on plan by drawing a ray from the plane table station to the point, and plotting to scale along the ray the distance measured from the station to the point. The method is suitable for the survey of the small areas which can be commanded from a single station. It is chiefly used for locating the details from stations, which have been previously established by other methods of surveying such as triangulation or transit-tape traversing.

INSTRUMENTS REQUIRED:- Plane table & it's accessories, ranging rods, tape etc.

PROCEDURE:-

1) Select a point P so that all points to be located are visible from it.
2) Set up the table at P and after levelling it, clamp the board.
3) Select a point P on the sheet so that it is exactly over the station P on the ground by the use of U frame. The point represents on the sheet the instrument station P on the ground.
4) Mark the direction of the magnetic meridian with the help of the compass (trough or circular) in the top corner of the sheet.
5) Centering the alidade on p, sight the various points A,B,C etc. and draw rays along the fiducial edge of the alidade lightly with a chisel-pointed pencil.
6) Measure the distances PA,PB,PC, etc., from P to the various points with the chain or tape, or by stadia and plot them to scale along the corresponding rays. Join the points a,b,c, etc., to give the outline of the survey.

Care must be taken to see that the alidade is touching the point p while the sights are being taken. To avoid confusion, the various rays should be referenced. The field work can be checked by measuring the distances AB, BC, CD, etc., and comparing them with their plotted lengths ab, bc, cd, etc.



RESULT:- The area enclosed by the given stations ABCDEF =______ Sq. metres.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING DEPARTMENT

Surveying Laboratory

EXPERIMENT -

INTERSECTION METHOD

AIM:- To fix a point on the plan by the intersection of the rays drawn from the two instrument stations.

INSTRUMENTS REQUIRED:- Plane table & its accessories, ranging rods, pegs, tape etc.

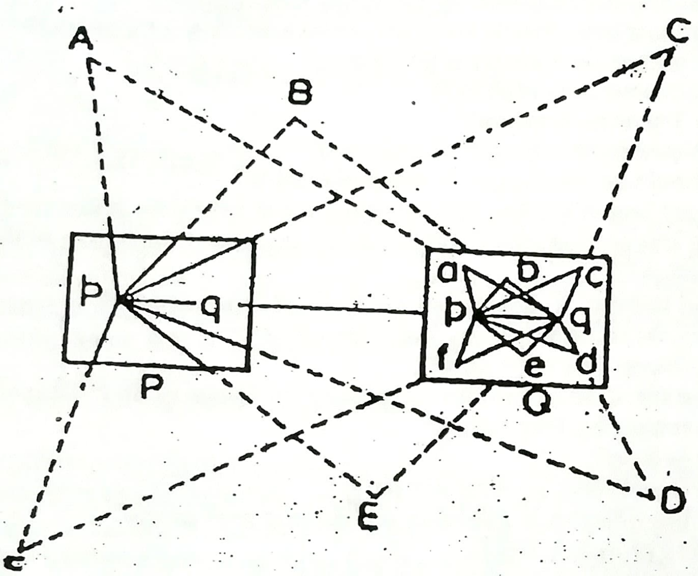
THEORY:- In this method the point is fixed on plan by the intersection of the rays drawn from the two instrument stations. The line joining these stations is called the base line. In this method only the base line is measured.

The method is commonly employed for locating (I) the details pertaining to the broken boundaries(ii) the distant and inaccessible points. (iii) the rivers, lakes etc., (iv) the points which may be used subsequently as the instrument stations. It is suitable when it is difficult or impossible to measure distances as in the case of the survey of a hilly terrain. It is also used for checking distant objects.

PROCEDURE:-

1) Select two points P and Q in a commanding position so that all points to be plotted are visible from both P and Q. The line joining the stations P and Q is known as the base line.
2) With the table set up and levelled at P, select a suitable point p on the paper so that it is over the instrument station P on the ground, and mark the direction of the magnetic meridian by means of the compass.
3) With the alidade pivoted on the point P, sight the station Q and other objects A,B,C, etc., to be located and draw rays along the fiducial edge of the alidade towards Q,A,B,C, etc.
4) Measure the distance from P to Q, accurately with the steel tape and set it of to scale along the ray drawn to Q thus fixing the position of q on the sheet.
5) Shift the table and set it up at Q. Centre the table so that the point Q is directly above the point Q on the ground and level it.
6) Place the alidade along QP, and after orienting the table by backsighting on P, clamp it.
7) With the alidade touching Q, sight the same objects and draw rays. The intersections of these rays with the corresponding rays drawn from P determine the positions of the objects A,B,C, etc., on the sheet.

   Care should be taken to avoid very acute or obtuse intersections, the extreme limits for the angles of intersection being 30^0 and 120^0.



RESULT:- Map of the field is plotted to a suitable scale, furnishing all the details such as scale, location, names of the survey party etc & is submitted as 'Result'.

QUESTIONS FOR VIVA-VOCE

1. What are the accessories for the plane table survey?
2. What precautions should be taken while selecting a base line?
3. What is meant by Radiation Method?
4. What is intersection Method?
5. What is Traverse Method?
6. What should be the length of base line?
7. What should be the height of the plane table?
8. If the base line is too long or too short, what will be its effect on the survey?
9. Why the trough compass should not be used for orientation at the second plane table station?
10. What will happen to the plan if the scale is large or small?
11. What do you understand by Two Point Problem?
12. What is Three Point Problem?
13. What are the different methods to carry on Three Point Problem?
14. What is meant by Resection?
15. What is setting?
16. What is orientation an how it is done?
17. What is the difference between setting and orientation?
18. What are Lehman's Rules?
19. What will happen if the table is not levelled?
20. What will happen if the table is not properly centered?
21. Name the instrument which is used for centering?
22. How is centering done by centering fork?
23. Describe a centering fork?
24. What is the greatest advantage of plane table survey?
25. What are the probable errors in plane table survey?
26. Why one of the Resection Methods is called Trial and Error Method?
27. What is meant by Triangle of Error Method?
28. What is meant by "Strength of Fix"?
29. What is the practical utility of the two and three point problem?

LEVELLING - INTRODUCTION

OBJECT AND USE OF LEVELLING

Object:- The AIM of levelling 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. The elevation of a point is its vertical distance above or below a reference level, called datum. The most commonly used datum is the mean sea level (M.S.L.). The levelling deals with distances in a vertical plane.

Uses:- Levelling 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 ad 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.

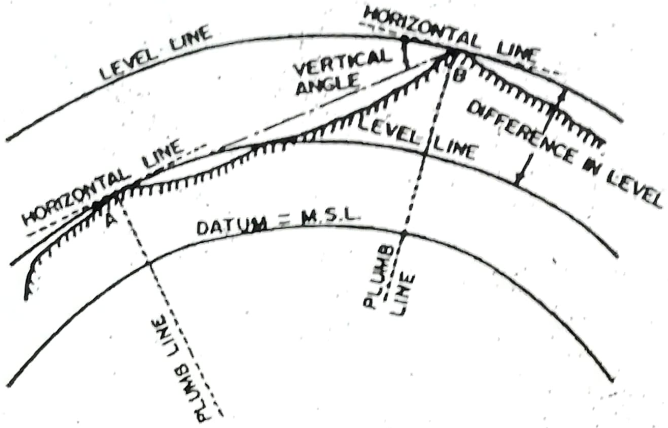
Levelling is an important method of surveying for many engineering works and construction projects. Levelling is required to determine the undulations of the earth's surface for topographic mapping. Levelling is needed for the design of highways, railways, canals, sewers, etc., and for locating the gradient lines. Levelling is essential for the layout of construction projects, for locating the excavation levels, and for the control of various elevations in buildings, bridges, dams, etc,

The drainage characteristics of the area can be obtained by leveling. The results of the levelling can be used to determine the catchment area, volume of the reservoir and the area submerged by a reservoir. The results of levelling can also be used to determine the volume of earthwork for roads, railways, etc.

Levelling is required in almost all engineering work of importance in one form or the other.

DEFINITIONS

1. **Levelling:** The art of determining the relative heights of different points on or below the surface of the earth is known as levelling. Thus, levelling deals with measurements in the vertical plane.
2. **Level surface:** Any surface parallel to the mean spheroidal 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 to be 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. **Vertical Angle:** It is the angle measured in a vertical plane. The vertical angle is usually measured with respect to a horizontal line at that point.

   The vertical angle is the angle of elevation if measured above the horizontal line, and the angle of depression if measured below the horizontal line.
9. **Datum surface or line:** It is an imaginary level surface which is taken as a reference surface for the determination of elevations of various points (above or below this line). The datum most commonly used is the mean sea level (M.S.L).
10. **Mean Sea Level:** The water level in a sea also represents a level surface if it is not affected by tides. The mean sea level at a location is obtained by averaging the height of the surface of the sea for all stages of the tides for a long period, usually 19 years. The mean sea level is commonly taken as the reference level surface.
11. **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.
12. **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***.
13. **Axis of the telescope:** This axis is an imaginary line passing through the optical center of the object glass and the optical centre of the eye-piece.
14. **Axis of bubble tube:** It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.
15. **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 levelling operations in projects involving roads, railways, etc.

BENCH MARKS (B.M.)

Bench marks established by important agencies are usually in the form of metal discs, generally bronze discs, set in concrete, large rock, footpath or kerbs, etc. A triangle is generally cut or painted around the bench mark to indicate the location.

The following types of bench marks are established and used, depending upon the permanency and precision.

1. **G.T.S. Bench Marks:** The great trigonometrical survey (G.T.S.) bench marks are established by the Survey of India throughout the country. The elevations of the bench marks are correct to two decimal places of a metre. The levels of the G.T.S. bench marks are determined very accurately with respect to the mean sea level at Bombay port. Formerly, these referred to main sea level at Karachi (now in Pakistan).

   The G.T.S. bench marks are depicted on topo sheets published by the Survey of India. These are also published in leveling pamphlets for each belt of 1° latitude and 1° longitude over the entire country.

3. **Permanent Bench Marks:** The permanent bench marks are established at a closer interval between widely spaced G.T.S. bench marks. These bench marks are established by the Survey of India or some other government agency such as P.W.D. The permanent bench marks are usually established on relatively permanent natural or artificial points, such as isolated rocks, culverts, gate pillars of public buildings. The elevations of the permanent bench marks are generally less accurate than those of G.T.S. bench marks.

4. **Temporary Bench Marks:** These are the bench marks established temporarily whenever required. These are generally the points at which a day's work is closed and from which next day's work is started.

   The temporary bench marks should be carefully established on relatively permanent or stable points, such as boundary walls, gate pillars, roots of old trees, etc. The correct descriptions of all the temporary bench marks so established should be invariably given in the level field book.

5. **Arbitrary Bench Marks:** These are the bench marks whose elevations are arbitrary assumed for leveling of a small area. The elevations assumed do not refer to any fixed datum such as M.S.L.

16. **Height of Instrument (HI):** When the leveling instrument is properly leveled, the RL of the line of collation is with reference to the datum 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. Height of Instrument is not the height of the L.O.S above the ground where the leveling instrument is set up.

17. **Focussing:** The operation of setting the eye-piece and the object glass a proper distance apart for clear vision of the object is known as focussing. This is done by turning the focussing screw clockwise or anti-clockwise.

    The function of the object glass is to bring, the object into focus on the diaphragm, and that of the eye-piece is to magnify the cross-hairs and object.

    Focussing is done in two steps as follows.

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

(b) Focussing the object glass: The telescope is directed to the object and the focussing screws turned clockwise or anti clockwise until the image is clear and sharp.

18. **Parallax:** The apparent movement of the image relative to the cross-hairs is known as parallax. This occurs due to imperfect focussing, 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 focussing is not correct, the image moves up and down relative to the cross-hairs. If the focussing is perfect, the image appears fixed to the cross-hairs. The parallax may be eliminated by properly focussing the telescope.

19. **Backsight reading (BS):** It is the reading taken on a staff held at a point of known elevation or at the point whose elevation has already been determined, to ascertain the amount by which the line of sight is above the point & thus to obtain the height of instrument.

The back sight is usually the first reading taken after setting up the instrument. The back sight is taken on a B.M. for the first setting of the instrument and on a turning point (T.P.) for the subsequent settings because the level of turning point can be determined before the shifting of the instrument.

The back sight is used to determine the height of the instrument (H.I.).

Height of instrument = known elevation + Back sight

The back sight is also known as the *plus sight.*

20. **Fore sight (FS):** It is the reading taken on the staff either held at the last point whose elevation is required or held at the turning point just before shifting the instrument, to ascertain the amount by which the point is below the line of sight.

The fore sight is used to determine the elevation of the staff station.

Elevation = Height of instrument – Foresight.

The foresight is also known as the minus sight. It is usually the last reading before shifting the instrument.

21. **Turning Point (T.P) or Change point (C.P):** For levelling over a long distance, the instrument has to be set up a number of times. A turning point should be selected on the route before shifting the instrument. The turning point should be selected on a firm ground or rock. The turning point is also called a change point (C.P.).

The staff is kept on the turning point and a foresight (F.S.) is taken before shifting the instrument. The staff should not be moved when the instrument is being shifted. After the instrument has been shifted and set up at the new location, a back sight (B.S.) is taken on the staff still held at the turning point. Thus it is a point on which both foresight & backsight are taken.

22. **Intermediate Sight (I.S.):** It is the reading taken on a staff held at a point whose elevations is required, but which is not a turning point or the last point. The intermediate sight is also known as the intermediate fore sight (I.F.S). The intermediate sights are taken at the intermediate stations.

The difference between an intermediate sight and a fore sight is both the readings are taken to determine the elevation of a point. But the foresight is taken on a point which is the turning point or the last point, whereas the intermediate sight is taken at any other point. All the readings taken between a back sight(B.S.) and fore sight (F.S.) are intermediate sights. However, the reading taken at the staff held at the last point is always a fore sight.

The intermediate sights are taken at points of less importance. These sights do not play any part in the continuity of the level line, whereas B.S. and F.S. play a vital part.

23. **Balancing of Sights:** To reduce the effect of instrumental and other errors, the distance of the point where a back sight is taken and the distance of the point where a fore sight is taken, as measured from the instrument station, should be approximately equal. This is known as balancing of sights.

DIFFERENT METHODS OF LEVELLING

The following methods are used to determine the difference of elevations of various points.

1. **Direct Levelling:** This is the most common method of levelling. In this method, a spirit level fixed to the telescope of a levelling instrument is used to make the line of sight horizontal. Vertical distances are measured with respect to this horizontal line of sight. These vertical distances are used to compute the difference in elevations of various points.The direct levelling is also known as spirit levelling.

2. **Trigonometric Levelling:** This is the method of levelling in which the difference of elevations is determined indirectly from the horizontal distance and the vertical angle. As trigonometrical relations are used to determine the elevations, the method is known as trigonometrical levelling.

Trigonometric levelling is generally used when direct levelling becomes difficult. For example, the elevations of inaccessible points, such as mountain peaks, top of towers, etc. can be determined by trigonometric levelling.

$$H = D \tan\theta$$

Where H is the height of the top of tower above the horizontal line of sight, D is the horizontal distance and θ is the vertical line.

3. **Barometric Levelling:** Barometric levelling is another type of indirect levelling in which the elevations are determined indirectly from the changes in the atmospheric pressure. the atmospheric pressure decreases with an increase in elevation. Generally, an aneroid barometer is used for determining the changes in atmospheric pressure. These barometers are known as altimeters. The aneroid barometer is quite light, sturdy and convenient as compared with the mercury barometer which is fragile and cumbersome. However, the aneroid barometer is not as accurate as the mercury barometer.

The altimeters are used for reconnaissance and preliminary surveys. The elevations obtained by an altimeter may be accurate to the nearest 1m or 2m.

however, with careful procedures and large-size barometers, better accuracy can be achieved.

Barometric levelling is a quick method of levelling. The altimeter is also commonly used to determine the altitude of an aeroplane.

4. **Hypsometric Leveling:** Hypsometric leveling is another method of indirect leveling. In this method, the difference of elevations is determined by noting down the temperature at which water starts boiling. As the latitude of the place increases, the boiling point of water decreases.

Hypsometric leveling is very rough method of levelling. The heights of mountains can be determined approximately from the boiling temperature of water. However, the method is rarely used by a surveyor.

TYPES OF LEVELLING OPERATION

The direct levelling can be further classified into the following methods.

1. **Simple Levelling:** This is the easiest type of direct levelling. In this method, only one setting of the instrument is done. The method is used for determining the difference of elevations of two points which are visible from a single position of the instrument.
   There are two steps in levelling: (a) To find by how much amount the line of sight is above the bench mark, and (b) to ascertain by how much amount the next point is below or above the line of sight.

   It is to be noted that if a back sight is taken on a bench mark located on the roof of a tunnel or on the ceiling of a room with the instrument at a lower elevation, the back sight must be subtracted from the elevation to get the height of the instrument. Similarly, if a foresight is taken on a point higher than the instrument, the foresight must be added to the height of the instrument, to get the elevation of the point.

2. **Differential levelling:** Differential levelling is adopted when:(i.) the points are a great distance apart,(ii) the difference of elevation between the points is large, (iii) there are obstacles between the points.

   This method is also known as compound levelling or continuos levelling. In this method the level is set up at several suitable positions and staff readings are taken at all of these. The differential levelling is also required in profile levelling, cross sectioning, contouring and various other levelling operations. In fact the levelling means the differential levelling, because in practice a number of setting of the instrument are generally required.

   Knowing the RL of A, that of B can be calculated.

3. **Fly levelling:** When differential levelling is done in order to connect a benchmark to the starting point of the alignment of any project, it is called fly levelling. Fly levelling is also done to connect the BM to any intermediate point of the alignment for checking the accuracy of the work. In such leveling, only the back sight, and fore-sight readings are taken at every set up of the level and no distances are measured along the direction of leveling. The level should be set

just midway between the BS and the FS. The fly levelling is done rapidly, but precision is low.

4. **Longitudinal or Profile levelling:** This is a type of differential levelling done for the purpose of determine he elevations of the ground surface along a fixed line. The operation of taking levels along the center line of any alignment (road, canal, railway line, sewer line etc) at regular intervals is known as longitudinal levelling. In this operation, the back sight, intermediate sight and foresight readings are taken at regular intervals, at every set up of the instrument. The chainages of the points are noted in the level book. This operation is undertaken in order to determine the undulations of the ground surface along the profile line. The levels obtained in profile leveling are used for plotting the longitudinal section which is required for various purposes such as fixing the gradients, determine the earth work quantities.

5. **Cross-section Levelling:** This type of differential levelling is done to determine the difference of elevations of the ground surface along the lines perpendicular to the center line of the proposed road, canal, etc. generally, the profile levelling and cross-section levelling are done simultaneously.

   The cross-section levelling is required to determine the configuration across the alignment. The information obtained is used for plotting the cross-sections. The cross-sections are taken at regular intervals (such as 20m, 40m, 50m, etc.) along the alignment. Cross-sectional levelling is done in order to know the nature of the ground across the center line of any alignment.

6. **Check levelling:** It is a type of differential levelling done for the purpose of checking of elevations which have already been obtained. The fly levelling done at the end of day's work to connect the finishing point with the starting point on that particular day is known as check levelling. It is undertaken in order to check the accuracy of the day's work. Some times, the day's work in checked by connecting the last station to a point of known elevation or to a B.M.

7. **Reciprocal Levelling:** It is a method of levelling used for the determination of the difference of elevations of the two points which are situated quite apart, and it is not possible to set up the instrument midway between the points. For example, if the two points are located on the opposite banks of a river, it would not be possible to set up the instrument in the river bed. The difference of elevations between the two points is determined by reciprocal levelling by first setting up the instrument at one bank and holding the staff at the other bank and then interchanging the positions of the staff and the instrument.

8. **Precise Levelling:** This is a very accurate method of differential levelling used when high precision is required. The instruments and methods used are such that a very high degree of accuracy is achieved. It is a specialized form of levelling.

   As the cost of the levelling increase rapidly with an increase in accuracy, the precise levelling is used only when a high degree of precision is essential.

DIFFERENT TYPES OF LEVELS

The following are the different types of level.

1. **The Dumpy level:** The dumpy level is originally designed by Gravatt.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 permanent adjustment for a long time. This instrument is commonly used.

2. **The Wye level (Y-level):** The telescope is held in two 'Y' support. 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.

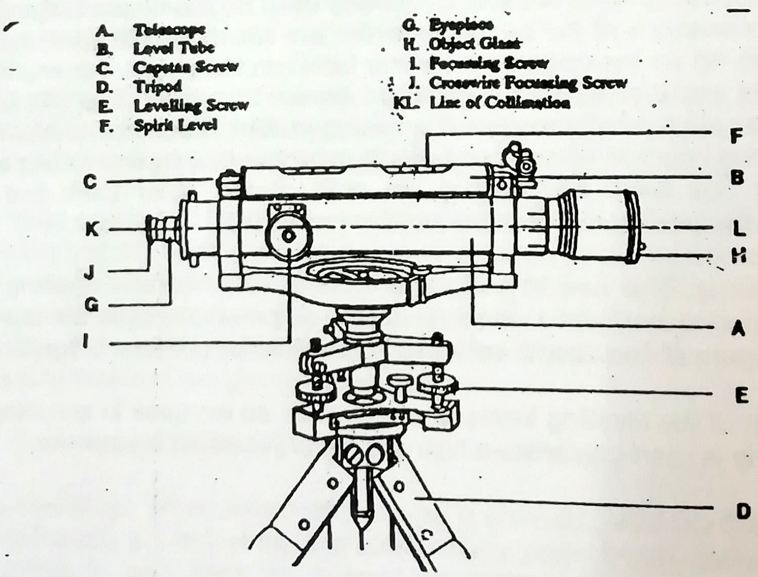
3. **Cooke's reversible level:** This is a combination of the dumpy level and the Y-level. It is supported by two rigid sockets. The telescope can be rotated about its longitudinal axis, withdrawn from the socket and replaced from one end of the telescope to the other end.

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. **The 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. The line of sight can be tilted slightly without tilting the vertical axes. Thus the LOS and the Vertical axis need not be exactly perpendicular to each other. It helps in quick levelling.

6. **The Automatic level:** This is also known as the self-aligning level. In an automatic level , the L.O.S. is automatically made perpendicular to the vertical axis by an optical system called compensator. This instrument is levelled automatically within a certain tilt range by means of a compensating device (the tilt compensator). The image is erect and bright. It has a high contrast for accurate staff readings.

Description of Dumpy Level



1. **Tripod stand:** The tripod stand consist 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. **Levelling head:** The levelling 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 eye-piece on opposite ends. A diaphragm is fixed with the telescope just in front of the eye-piece. The diaphragm carries cross-hairs. The telescope is focussed by means of the focussing screw and may have either external focussing, or internal focussing.

   In the external focussing telescope, the diaphragm is fixed to the outer tube and the objective to the inner tube. By turning the focussing screw the distance between the objective and diaphragm is altered to form a real image on the plane of cross-hairs.

   In the internal focussing telescope, the objective and eye-piece do not move when the focussing screw is turned. Here, a double concave lens is fitted with track and pinion arrangement between the eye-piece and the objective. This lens moves to and from when the focussing screw is turned and a real image is formed on the plane of cross-hairs.

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 spit it bubble. The bubble is brought to the center 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 compass, indicates a reading of 0^0 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.

TEMPRORAY ADJUSTMENT OF LEVEL

The adjustments made at every set up of the level before the staff readings are taken are known as temporary adjustment. The following are the different steps to be followed in temporary adjustment.

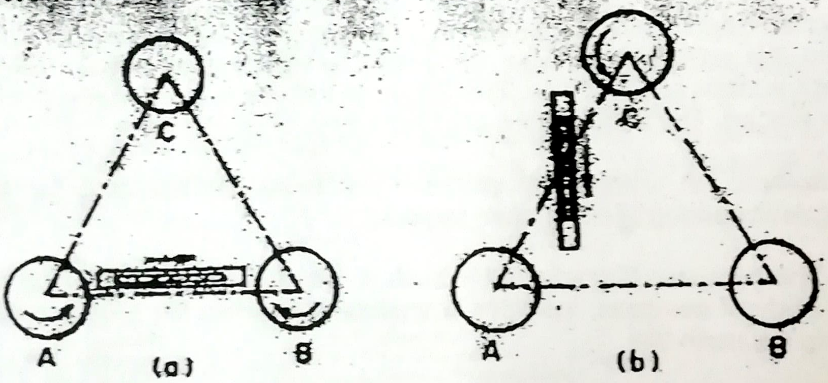
1. **Selection of suitable position:** A suitable position is selected for setting the level. From this position, it should be possible to take the greatest number of observations without any difficulty. The ground should be fairly level and firm.

2. **Fixing level with tripod stand:** The tripod stand is placed at the required position with its legs well apart, and pressed firmly to the ground.

The level is fixed on the top of the tripod stand according to the fixing arrangement provided for that particular level. It should be remembered that the level is not to be set at any station or point along the alignment.

3. **Approximate levelling by legs of tripod stand:** The foot screw are brought to the centre of their run. Two legs of the tripod stand are firmly fixed into the ground. Then the third leg is moved to the leg is moved to the left or right, in or out until the bubble is approximately at the centre of its run.

4. **Perfect levelling by foot screws:** As the longitudinal bubble is on the top of the telescope, the latter is placed parallel to any pair of foot screws (i.e. first position) and the bubble is brought to the center by turning the foot screws equally either both inwards or both outwards. The telescope is then turned through 90^0 (i.e. second position) and brought over the third foot screws, and bubble is brought to the centre by turning this foot screw clockwise or anticlockwise. The telescope is again brought to tits original position (the first position) and the bubble is brought to the centre. The process is repeated several times until the bubble remains in the central position in the first as well as the second position. Then the telescope is turned through 180^0. If the bubble still remains in the central position, the temporary adjustment is perfect and so is the permanent adjustment. But if the bubble is deflected from its central position, the permanent adjustment is not perfect and needs to be modified.



LEVELLING-UP WITH THREE FOOT SCREWS

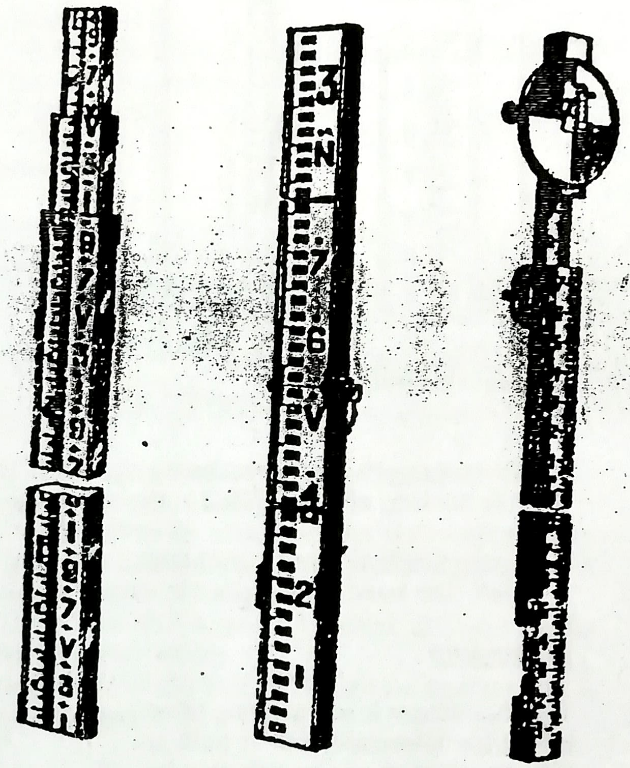
5. **Focussing the eye-piece:** A piece of white paper is held in front of the object glass and the eye-piece is moved in or out by turning it clockwise or anticlockwise until the cross-hairs can be seen clearly.

6. **Focussing the object glass:** The telescope is directed towards the levelling staff. Looking through the eye-piece, the focussing screw is turned clockwise or anticlockwise until the graduation of the staff is distinctly visible and the parallax is eliminated. To eliminate the parallax, the eye is moved up and down to verify whether the graduation of the staff remains fixed relative to the cross-hairs.
7. **Taking the staff readings:** Finally, the levelling of the instrument is verified by turning the telescope in any direction. When the bubbles (the longitudinal bubble and cross bubbles) remain in the central position for any direction of the telescope, the staff readings are taken.

Le lling Staff

The levelling staff is a gradu: wooden rod used for measuring the vertical dis ces between the points on th ground and the line of collimation. Levelling sta s are classified into two groups the target staff, and (II) the self-reading staff

1. arget staff: The target staff co ts of a movable target. The target is provided th a vernier which is adjusted he staff man, according to directions from the vel man, so that the target cc ides with the collimation hair. After this, the ading is taken by either the sta en or the level man. This staff is used for long ghtings.

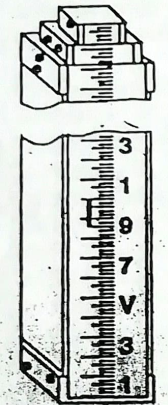


2. **Self-reading staff:** The following are the different types of self-reading staffs:

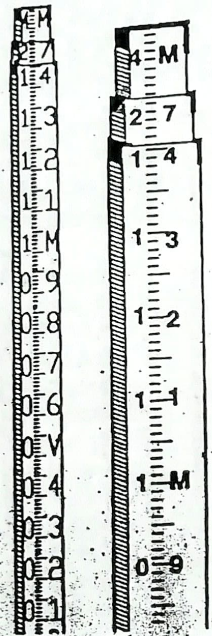
(a) ***Sop-with Telescopic Staff:*** Such a staff is arranged in three lengths placed one into the other. It can be extended to its full length by pulling. The top portion is solid and of length 1.25m, the central box portion is hollow and of length 1.25m, and the bottom box portion is hollow and 1.5m long. The total length of the staff is 4m. the top portions are held in the vertical position by a brass spring catcher.

The staff is graduated in such a way that smallest division is of 5mm(0.005m). The values in metres are marked in red on the left and those in decimetres are marked in black on the right.

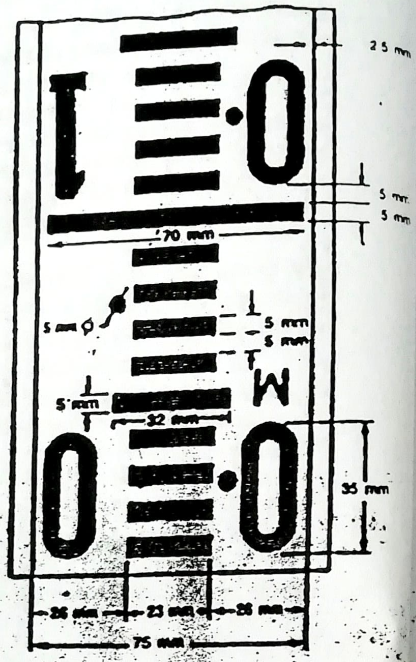
(b) ***Folding Metric Staff:*** This staff is made of well-seasoned timber, and is of width 75mm, thickness 18mm, and length 4m. it is divided into two parts of length 2m having a locking arrangement. It can be folded or detached when required. It is graduated like the telescopic staff.



Sopwith Telescope Staff (in three pieces)



Aluminium Telescopic Staff 4m



Typical Details of Graduations on Staff

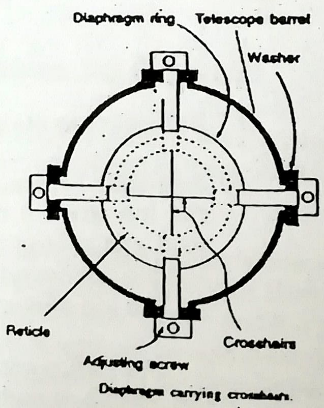
(c) One –Length Staff: The one-length staff, is solid and made of seasoned timber. It is 3m long and graduated in the same way as the telescopic staff.

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

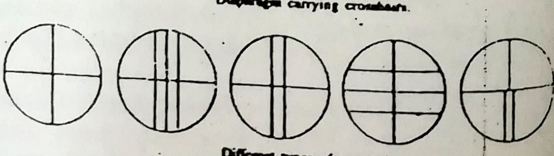
Diaphragm

The diaphragm is a brass ring fitted inside the telescope, just in front of the eye-piece. It can be adjusted by four screws. The ring carries the cross-hairs, which get magnified when viewed through the eye-piece. 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.



Diaphragm carrying crosshairs.



Different types of crosshairs.

The cross-hair consists of the following lines:

1. Two vertical hairs meant for maintaining the verticality of the staff.
2. Middle horizontal hair representing the line of collimation.
3. Upper stadia hair and lower stadia hair, both horizontal and short in length. The stadia hairs are meant for determining the horizontal distance between the position of level and that of the staff.

Points to be Remembered by Staffman

1. The staff should be made vertical by holding it with both arms while standing behind it.
2. The staff should be held on firm ground.
3. When the telescopic staff is to be extended, care should be taken so that it is perfectly stretched and properly fixed on the spring catcher.
4. The bottom of the staff should be kept clean.

Points to be Remembered by Level Man

1. The levelling instrument should be placed at a position suitable for the greatest number of observations to be taken.
2. The instrument should not be too high or too low.
3. The levelling should be done perfectly.
4. The levelling instrument should not be placed on the profile line (i.e. the center line of the project).
5. The eye-piece should be focussed by holding a sheet of white paper in front of the telescope.
6. The objective should be focussed by pointing the telescope towards the staff.
7. The parallax should be eliminated.
8. The verticality of the staff should be verified by observing the two vertical hairs and by noting the minimum reading on the staff when it is moved along the line of sight.
9. When looked at through the telescope, the staff appears inverted. So, the reading should be taken carefully from the top down wards.
10. After taking the staff reading, the position of the bubble should be verified. If it is disturbed, the reading should be taken again.

PRECAUTIONS IN LEVELLING

The following precautions should be taken while levelling.

1. The staff should be held vertical when the reading is taken. the staffman should stand behind the staff and hold the staff between the palms of the hands. The bottom of the staff should be held between the toes. To ensure the verticality, the staff is first waved slightly towards the instrument and then slightly away from the instrument. The process is known as rocking of the staff. The instrument man should take the smallest reading so obtained. This ensures the verticality in the forward and backward direction. The verticality can be also be checked with a circular level, if attached to the staff.

2. When using a folding staff, always ensure that each section of the staff is drawn out to its full extent when extended and the spring clips are secured.

3. When taking readings, always make sure that the bubble of the level tube is central. If not, centre it by using the foot screw which is most nearly in line with the telescope in the case of a dumpy level. Centre it using the tilting screw in the case of a tilting level.
4. When the graduations on the staff are erect, the reading obtained is inverted. It should be read in the downward direction in which direction the graduations increase.

   However, in some staves the graduations are inverted and when viewed through a telescope, they appear erect. The staff should be read upward in such a case.

   The basic principle is to read in the direction in which the graduations increase.

5. If the diaphragm has two vertical hairs, bring the image of the staff between the two vertical hairs and check the verticality of the staff. Always use the portion of the horizontal cross hair between the vertical hairs for taking the staff reading because the horizontal hair may be slightly inclined.

6. If the diaphragm has two stadia hairs in addition to the central horizontal hair, they can be used to check whether the staff is out of plumb forward or backward. The intercept of the staff between the upper stadia hair and the central hair should be equal to the intercept between the central hair and the lower stadia hair.

7. To reduce the effect of the instrumental errors, the distance of the station A from the instrument station should approximately be equal to the distance of the station B. In other words, the length of B.S. and the F.S. should be nearly equal.

   However, it is not necessary that the instrument station should be on the line. It can be set up at any convenient point away from the line.

8. The instrument should be securely clamped to the tripod. The tripod should be firmly set up on the ground.

9. The instrument man should not grip the tripod or rest his hands on it while taking readings. He should not straddle the legs of the tripod.

   When moving round the instrument, he should keep his feet clear of the tripod legs.

10. Use a base plate below the foot of the staff for turning points (or change points) when the ground is soft.

11. Do no drag the staff on the ground. The metal base should not strike a hard surface.
12. Read the staff correctly. There should be no parallax. The staff reading can be estimated to the nearest mm, even when the graduations are at 5mm. Avoid very long sights.
13. Avoid error in booking a reading. To ensure that the reading is booked correctly, the normal practice is to read back the recorded observation.

14. Avoid the mistake of reading the meter and decimeters incorrectly. If necessary, ask the staffman to slightly raise the staff to note the meter or decimeter mark.

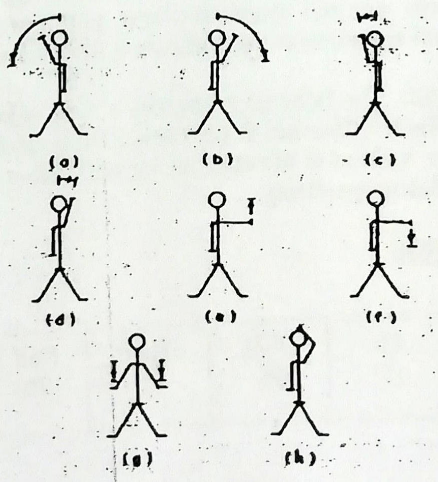
15. To avoid unequal heating of the various parts of the instrument, the instrument should be shaded.

16. Very intense sun shine causes the air close to the ground to shimmer. Avoid readings less than 0.5m.

HAND SIGNALS DURING OBSERVATIONS

When levelling is done at construction site located in busy, noisy areas, it becomes difficult for the instrument man to give instructions to the man holding the staff at the other end, through vocal sounds. In that case, the following hand signals are found to be useful.

Hand Signals	Message
a) Movement of left over 90^0	Move to my left
b) Movement of right arm over 90^0	Move to my right
c) Movement of left arm over 30^0	Move top of staff to my left
d) Movement of right arm over 30^0	Move top of staff to my right
e) Extension of arm horizontals and moving hand upwards	Raise height peg or staff
f) Extension of arm horizontally and moving hand downwards	Lower height peg or staff
g) Extension of both arms and slightly and thrusting downwards	Establish the position
h) Extension of arms and placements of hand on top of head.	Return to me



LEVEL FIELD BOOK

A level field book or a level book is used for booking and reducing the levels of various points. There are two methods for reducing the levels:
(1) Height of Instrument method, (2) Rise and Fall methods.

1. **Height of Instrument Method:** The table given below shows a page of the level book for the height of instrument method. There can seven columns. The first column indicates the station at which the staff is placed. The second column is for the back sight (B.S.).

HEIGHT OF INSTRUMENT METHOD

Station (1)	B.S (2)	I.S (3)	F.S (4)	H.I (5)	R.L (6)	Remark (7)

Arithmetic Check: The arithmetic calculations made in the computations of the height of instrument (H.I.) and the reduced levels (R.L.) can be checked by applying the following simple arithmetic check.

$$\sum B.S. - \sum F.S. = \text{Last R.L.} - \text{First R.L.}$$

It may be noted that if $\sum$ B.S. is greater than $\sum$ F.S., the last point is higher than the first point, and if it is smaller, the last point is lower.

It may be noted that the above check is only on the arithmetic calculations and not on the field work. If the staff readings are to correctly taken and entered, the reduced levels will be wrong even if the arithmetic check is satisfied. Such errors in the field work can be detected only be relevelling.

In the arithmetic check, the computations, involved in the reduced levels of the intermediate points are not checked even arithmetically. If the R.L. of the intermediate stations have been wrongly computed, these would not be detected.

2. **Rise and Fall Method:** The table given below shows a page of the level book for the rise and fall method. There are 8 columns. The first four columns are exactly the same as in Table. Instead of the column for H.I., there are two columns (5) and (6) marked rise and fall respectively.

RISE AND FALL METHOD

Station (1)	B.S (2)	I.S (3)	F.S (4)	Rise (5)	Fall (6)	R.L (7)	Remarks (8)

Arithmetic Check: The computations are checked by applying the following arithmetic check.

$$\Sigma \text{B.S.} - \Sigma \text{F.S.} = \Sigma \text{Rise} - \Sigma \text{Fall} = \text{Last R.L.} - \text{First R.L.}$$

It may be noted that as the computations of the rise and falls also involve the I.S., the R.L., of the intermediate stations are also checked in the rise and fall method.

Comparison of the two methods of reduction.

1. The height of instrument method is simpler, less tedious and quicker than the rise and fall method.
2. In the height of instrument method, the mistake in the computation of R.L. of an intermediate station goes undetected, whereas in the rise and fall method, the R.L. of the intermediate station is also checked.
3. The rise and fall method gives a visual picture of the topography.
4. When there are a number of important intermediate stations, the rise and fall method should be used.
5. The rise and fall method should be used for a long run of differential levelling for important works.
6. The height of instrument method can be used when there are no intermediate sights.

The height of instrument method is, however, more convenient if a large number of intermediate sights are to be taken such as in profile levelling and in the setting out.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING DEPARTMENT

Surveying Laboratory

EXPERIMENT -

SIMPLE LEVELLING

AIM:-To find out elevation (i.e. Reduced levels) of different points shown on the ground w.r.t. given arbitrary B.M.

INSTRUMENTS REQUIRED:- Dumpy level, levelling staff etc.

Theory and Significance:

It is simplest form of levelling, where in the elevation of different points can be found out with a single set up of the instrument. The elevation or R.L. of the line of sight is established first by taking B.S. on a B.M. Once the elevation of line of collimation is known, the elevations of other points can be determined just by determining the amount by which the given point is lying above or below the line of sight with the help of a levelling staff so that

R.L. of the point = Height of collimation $\pm$ staff reading

Use – when the point is lying below the line of sight and

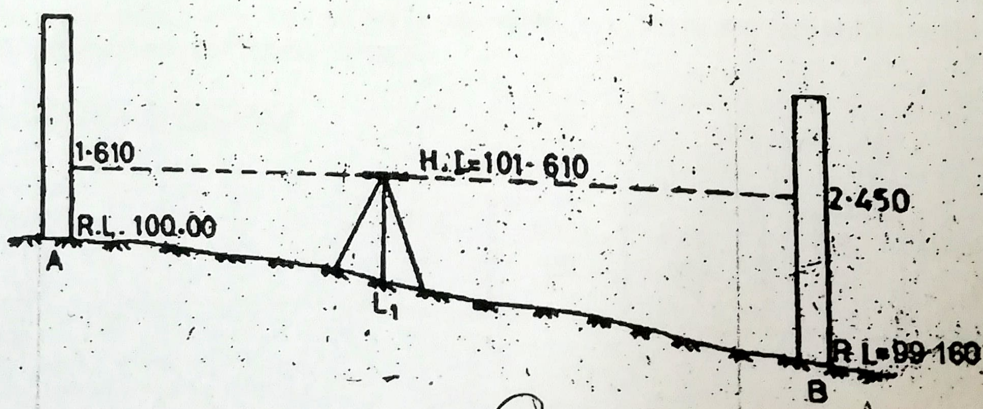
Use + when the point is lying above the line of sight.

The method adopted to find out the R.L.'s of points is known as "height of collimation" method, where in we the elevation of line of sight is established first and later determining by how much distance the given point is lying above or below this line of collimation. The normal check adopted to determine accuracy of the work in Height of collimation method is.

Σ.F.S. - Σ.B.S. = last RL – First RL

From the above, it is clear that no check is available for intermediate sights.

This is the simplest form of levelling and is a preliminary step in understanding the principle involved in levelling.

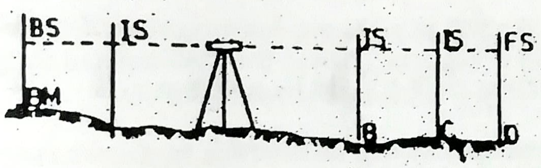


PROCEDURE:-

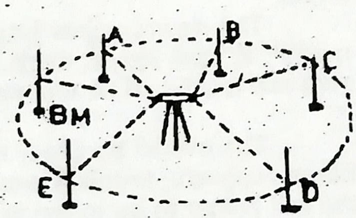
1. Set up the instrument at a convenient point so that all the points and B.M. are visible property.
2. Do the temporary adjustments properly and make the line of sight exctly horizontal.
3. First take a back sight by focussing the telescope towards the staff held on the bench mark, the R.L. of which can be assumed suitably (50.00m/100.00m) and enter staff readings in the B.S. column of level book.
4. Calculate elevation of the line of sight as H.I. or H.C. = R.L. of B.M + B.S.
5. Now focus the telescope towards the staff held on different points on the ground and note down their corresponding readings and enter them in the I.S. columns of the level book. The R.L.'s of these points can be calculated as

R.L. of the given point = H.I. – I.S.

The last reading should be entered in the foresight (F.S.) column so as to have a proper check on the accuracy or work. However R.L. is calculated in a similar manner.



(a)



(b)

RESULT:-

Reduced levels of given points w.r.t. assumed arbitrary B.M. of R.L. of 100.00m .

B.M. OF R.L. = ...

Point 1 = ...

Point 2 = ...

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EXPERIMENT -

DIFFERENTIAL LEVELLING

AIM:- To find out the difference of elevation between two points shown which are too far apart with respect to a given bench mark and checking the accuracy of the work by Fly back.

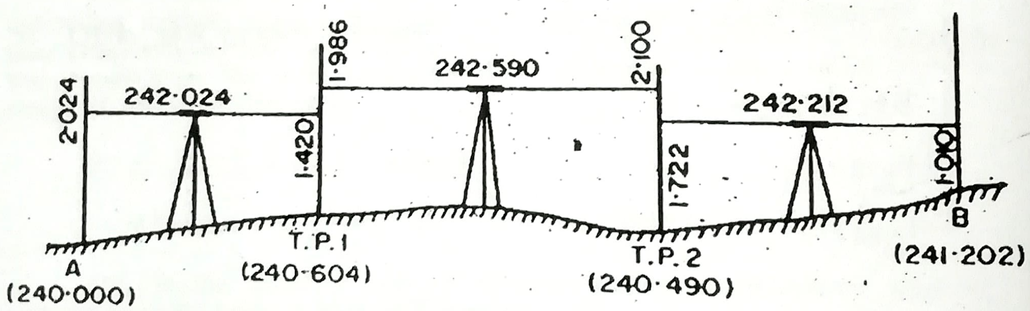
INSTRUMENTS REQUIRED:- Dumpy level, levelling staff.

Theory and Significance:

Differential levelling is the operation of levelling to determine the elevations of points some distance apart or to establish bechmarks. It is also known as taking fly levels.

The datum points lying above the line of sight are know as "inverted bench marks". In such cases, the B.S. reading is taken by holding the staff inverted so that zero end touches B.M. and the staff reading (i.e.B.S.) will be negative.

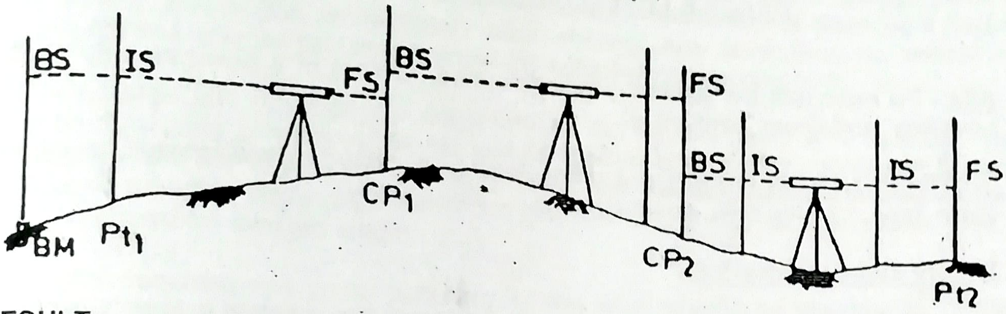
The overall accuracy of any levelling work can be checked by flyback. As the name suggests, levelling work is carried out in the reverse direction after reaching the last points so as to reach the B.M. at the end. The F.S. taken on the last point will be the B.S. for fly back levelling.



PROCEDURE:-

1. Set up the instrument near the B.M. and do the temporary adjustments.
2. Take B.S. on Bench mark. If the B.M. is inverted, the staff should be held reverse so that zero end touches the B.M. and B.S. reading should be entered with negative sign.
3. Take a series of I.S.'s on near by objects including first point before taking F.S. on first turning point (T.P.)
4. Continue levelling by taking F.S.'s and B.S.'s on T.P.'s until the last point is reached. Calculate R.L.'s of all the points.

5. Now the levelling process is repeated in the reverse direction known as fly back to check the accuracy. For this the F.S. taken on last point will be B.S. so that last point can be treated as B.M.
6. Now calculate the R.L.s of I.S. which are required in the fly back. For the work to be accurate, the R.L of B.M. thus determined should confirm suitably with the R.L. that is assumed at the beginning of the work within experimental limits. Calculate the R.L.'s and apply the checks suitably.



RESULT:-

1. The difference of elevation between two show points = ...m (rise or fall)
2. R.L. of bench mark after fly back = ...m.
3. Percentage of error = $\frac{100\text{ (Assumed R.L- R.L. afterflyback)}}{\text{Assumed R.L.}}$ = ± ....%

TABLE:-

S.No.	B.S	I.S	F.S	H.I	R.L	Remarks

CONCLUSION:- A conclusion can be made about the relative elevation of different ground points. In addition, the accuracy of work can also be checked.

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EXPERIMENT -

PROFILE LEVELLING & CROSS SECTIONING

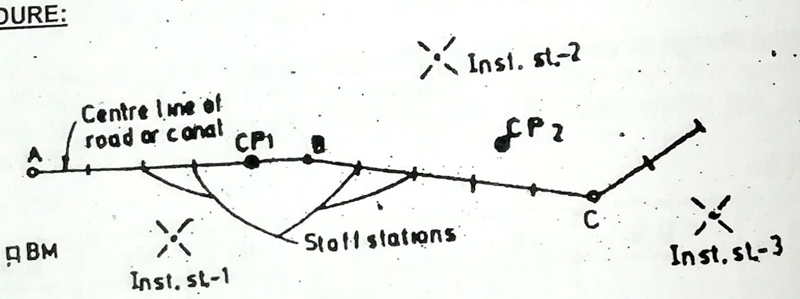
AIM:- To represent the general profile (slopping nature) of a given area by "Profile Levelling" and Cross Sectioning".

INSTRUMENTS REQUIRED:- Dumpy level with tripod, levelling staff, compass, chain, tape, ranging rods, cross-staff etc.

Theory and Significance:-

Profile levelling is the type of leveling wherein the purpose is to determine the elevation of points at known distances apart along a given line and thus outline of the ground surface or undulations can be represented graphically.

PROCEDURE:



1. To begin with, the line along which section is to be taken is marked by ranging rods and fore bearings is taken. Let AB be this centre line.

2. The level is set up on firm ground at some suitable position either to the left or right of centre line, so as to command a large number of points on the line and temporary adjustments are done properly.

3. A back sight is taken on B.M. to determine H.I.

4. Having stretched the chain from A in line with AB, staff readings are taken at point A, and at the representative point i.e., the points at which the slope of the ground surface changes appreciably are taken and entered in the I.S. column.

   Generally staff readings are taken at equal intervals along the chain line beside the points where the slope changes appreciably and their distances should also be noted down in the 'Remarks' column.

5. Cross-sections are taken by setting out perpendicular lines to section lines on either side. The staff is held at each 10m point and other points of appreciable change in slope along these perpendicular cross-section lines. All these are entered in I.S. column only. The distances along the chain line where the cross-

section is taken and the distances of staff points along the cross-section lines measured with tape, left and right of centre station are noted.

Cross staffs may be used for setting cross-sectional lines.

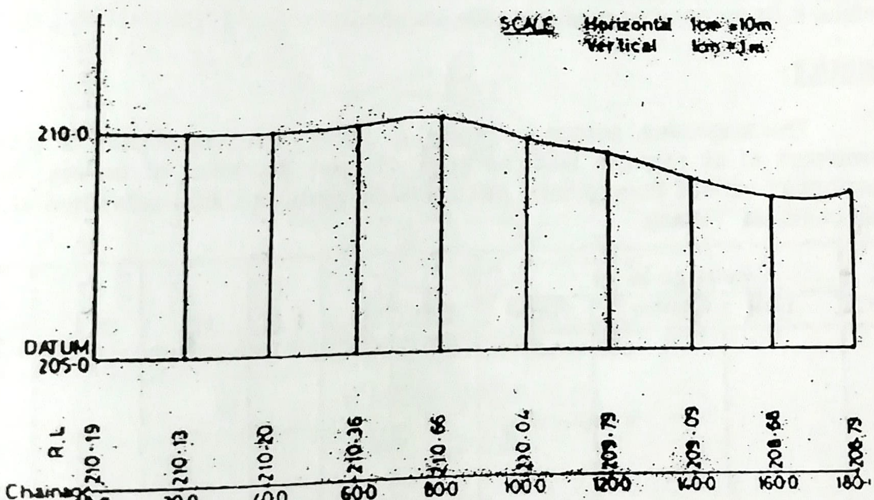
6. When it is found necessary to shift the instrument, a suitable change point is selected on a firm ground or permanent object and a F.S. is taken on it before shifting and a B.S. immediately after shifting. Any point lying on section or centreline or cross sectional line can be selected as change point.

7. Chainage and readings are continued as before until point B is reached. The back bearing of section line AB and fore bearing of a new centre line BC are taken and the operations of taking down staff readings and noting down their corresponding distances either along centre line or along cross sectional lines is continued for required length.

8. After reaching end point, accuracy of the work should be checked by "Flying back" until reaching the B.M. established at the beginning of work.

Then the general profile of the ground and cross-sectional slope are plotted as described below.

Plotting the Profile:



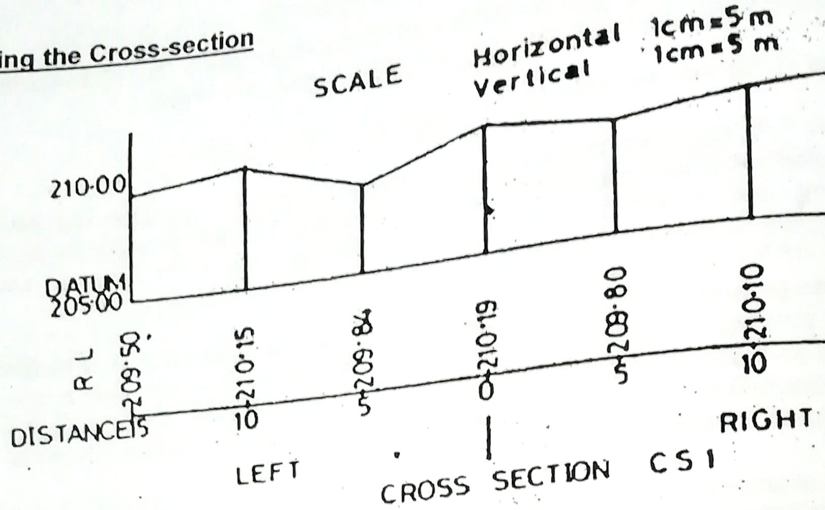
LONGITUDINAL SECTION

A horizontal line is first drawn as a datum as a datum and the chainages of staff-points taken along section or centre lines are marked to convenient scale. Perpendicular lines are then drawn at each plotted chainage and on these lines, the respective levels are set off.

The elevation of datum line should be so assumed that the lengths of ordinates would be between 4cm to 15 cm. Suppose if the R.L.'s of different points varies between 208m and 211m, the elevation (i.e. R.L) of datum line can be assumed as 205m.

The vertical scale used in plotting exaggerated i.e. larger than horizontal; usually ten times.

Plotting the Cross-section



It is plotted in the same manner as profile levelling except that the scale used for horizontal and vertical are same. The elevations of datum line may be different for cross sections to keep the ordinates fairly short. The datum and ground lines are drawn in black ink and the ordinates shown as thin blue lines. The datum level should be written above the datum line. The chainages and the reduced level of the points should be written against the ordinates and the description of prominent objects written in its appropriate position on the section.

RESULT:

The longitudinal section (i.e.profile) and cross sections should be plotted and completed in all respects such as scale chosen. Location of survey, details of bearings of various lines, details, about survey party etc. and submitted along with field books as "Results"

Sl. No.	Chainage in m			B.S.	I.S.	F.S.	H.I.	R.L.	Remark
	Left	Centre	Right						
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING DEPARTMENT

Surveying Laboratory

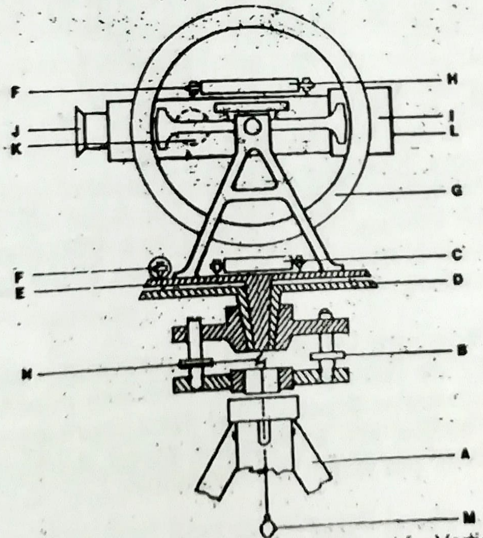
THEODOLITE SURVEY

Theodolite is supposed to be the most sophisticated instrument for measuring the horizontal and vertical angles i.e. angles in horizontal and vertical planes. It is therefore used where great accuracy is required specially for finding out minor difference in elevation, laying horizontal angles etc. As far as their function is concerned, there are two broad types of theodolites:

(i) Transit theodolites in which the telescope can be rotated through 360^0 in vertical plane.

(ii) Non-Transit theodolites in which the telescope cannot be rotated through 360^0 in vertical plane.

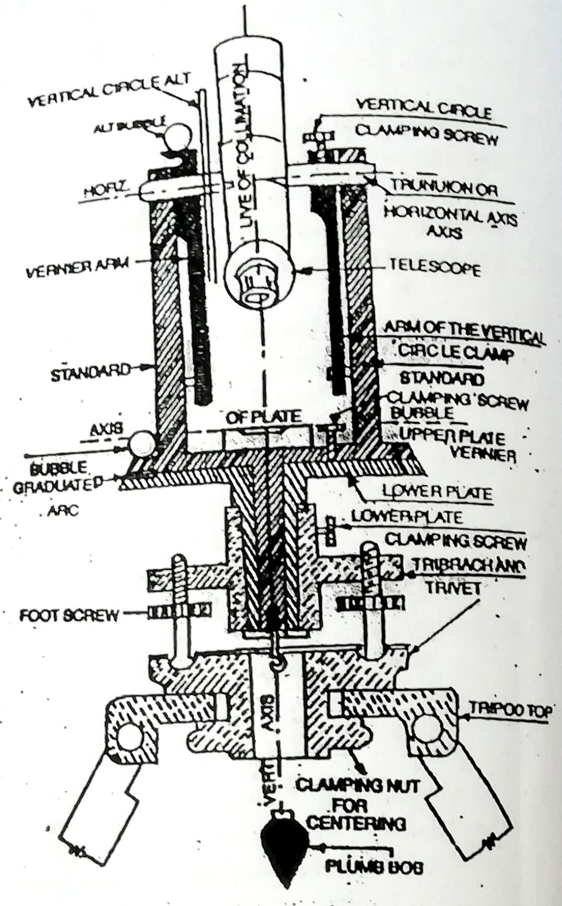
The size of the theodolites is pronounced against the size of the horizontal circle e.g. if it has a diameter of 12 centimetres, the theodolite will be named 12 cm. theodolite. Depending upon the type of survey to be performed, there are various sizes e.g. 8 to 12 cm theodolites which are used where great precision is not required i.e. for general survey work and 12 to 25 cm, theodolites are used where great precision is required e.g. in triangulation work.



A. Tripod
B. Levelling
C. Spirit Level
D. Lower Horizontal Plate
E. Upper Horizontal Plate
F. Capstan Screw
G. Vertical Circle
H. Spirit Level for Vertical Angle
I. Telescope
J. Eyepiece
K. Focussing Screw
L. Object Glass
M. Plumb Bob
N. Plumbing Hook

Parts of Theodolite

Tripod: Starting from the bottom upwards , one of the most important part is tripod. It is made up of highly seasoned hardwood. It has three firm legs with pointed metallic shoes to hold the theodolite firmly. At the top of the tripod is another metallic part firmly fitted in the tripod with a threaded opening in which the theodolite is fitted. The three legs of the tripod are joined to one another at the top usually by wing nut screw.



Transit Vernier Theodolite (Sectional Elevation)

Plumbing Hook : Just at the bottom of the theodolite there is a hook from which the Plumb Bob is suspended with the help of which the instrument is centered over the station.

Centering Plate: This plate is threaded to the main instrument. By unscrewing it, the entire instrument can be slided on the base sideways for the purpose of finer centering. When the plumb bob is exactly over the station point, the centering plate is tightened.

Levelling Screws or Foot Screws: Earlier there used to be four levelling screws but now-a-days there are three levelling screw. The function of these screws is to bring the instrument in a perfect horizontal plane. They are attached to a Spirit Level. The bubble in which has to be brought in the center of its run to bring the instrument in level position.

Lower Horizontal Plate : Above the levelling screws are two circular horizontal plates covered in a box with two openings at 180° from one another, This plate is graduated from 0° to 360° in a clockwise direction. The least count on this plate is of 20 minutes. (each degree being divided into three equal parts). Upon the size of this plate, the theodolite is named as 12 cm, 25 cm. etc. theodolite.

Clamp Screw for the Lower Plate : Just below the lower horizontal plate is a screw which when tightened will not allow the lower plate to move.

Tangent Screw for the Lower Plate: This screw is also called finer adjustment screw. It functions only when the clamp screw has been tightened. With the help of this screw, the lower horizontal plate can be moved very slowly and the object can be sighted very accurately.

Upper Horizontal Plate : This circular plate which is also inside a covered box moves on the lower horizontal plate. On this plate are graduations to read minutes and 20 seconds. It has 20 big divisions each divided into three equal parts. It helps in taking accurate readings by vernier arrangement. On one of the openings is written A i.e. Vernier A whereas on the other opening , 180° apart B i.e. vernier B. When the lower plate is clamped, the upper plate can move independently. If the lower plate is unclamped and the upper plate clamped, both the plates move simultaneously. Just like the lower plate, it is also provided with clamp and tangent screws, there function being the same is that of the lower plate. If the lower plate is clamped and the upper plate unclamped, then the upper plates will move independently.

Magnifying Glass : At both the openings there are magnifying glasses, one for vernier A and one for vernier B. Since the graduations are very fine, they help in enlarging the graduations so that they can be read easily.

Spirit Level : On the outer covering of the two horizontal plates a spirit level has been placed with alcohol or spirit as liquid forming the bubble. It is used for putting the instrument in a level position. Like all other instruments which have spirit level, in theodolite also the bubble has been provided with Capstan Screws and the capstan screw is associated with the permanent adjustment of the instrument.

Vertical Circle: Just like the horizontal plate there are two circular vertical plates, inside the box, sliding over the other. To the inner vertical plate a graduated a vernier is fixed and over which the outer vertical plate slides. There are two openings on one C is written whereas on the other D is written. They are also provided with magnifying glasses. The outer vernier plate is attached to the telescope and therefore it moves with it. The graduations on the outer vertical plate are as shown.

Spirit Level for Vertical Angles : At right angles to the spirit level attached to the horizontal plate, there is another spirit level attached to the outer cover of the vertical circle. While taking angles of elevations or depression, the bubble in this spirit level has also to be brought in the center along with the one attached to the horizontal plate. With the help of a levelling screw for this spirit level, the bubble can be brought in the center and thus leveled.

Telescope: One of the most important part of the theodolite is the telescope. Its purpose is to sight the object clearly. Inside the telescope lenses are arranged and the sighting power of the instrument depends on this arrangement.

The main parts of the telescope are

i) *Eyepiece* : Through the eyepiece the object is sighted and focussed.

ii) *Crosswire Focussing Screw:* To the eyepiece is attached a screw known as focussing screw. By turning the screw the crosswire is sharply focussed.

iii) *Focussing Screw* : Just after the eyepiece and in some instruments on the right hand side of the telescope, there is another screw type arrangement called the focussing screw. With the help of this screw the object is sharply focussed. When the crosswire is focussed, the object becomes out of focus. But in two or three attempts, both of them will be sharply focussed and there will be no displacement of the object with respect to the crosswire by sideway or up and down movement of the head and the parallax error will be said to have been removed.

iv) *Object Glass* : The far end of the telescope, opposite to the eye piece through which the ray enters the telescope is called the object glass.

v) *Sighting Pin and Sighting Hole :* They are actually not a part of the telescope but they have been provided on the outer cover of the telescope, They Since looking through the telescope only a small portion of the area can be sighted, therefore to facilitate quick sighting, a small hole called the sighting hole has been provided towards to eyepiece side of the telescope and a small pin provided towards the object glass end of the telescope. Before sighting the object directly through the telescope, it should be first of all brought in line with the top of the sighting pin and the sighting hole. When it has been done, the object will now appear in the telescope as well after which it can be focussed and brought on the cross wire very easily.

vi) *Clamp screw for the telescope*: On the right hand side of the telescope there is a screw which when tightened stops the movement of the telescope. Since the telescope is clamped by this screw, it has been named Clamp Screw.

vii) *Tangent Screw for the telescope:* When the camp screw for the telescope has been tightened, just below it is another screw called tangent screw with the help of which the telescope moves very slowly. This screw is also called Finer Adjustment Screw.

For all the Clamp Screws there are tangent screws but they will function only when the clamp screw has been tightened.

Prismatic Compass: With the help of this Prismatic Compass, bearings of the points which are sighted can to be taken.

Adjustments: In the theodolite there are two types of adjustments-Temporary and Permanent.

Temporary Adjustments: The adjustments done at each of the instrument stations are called Temporary adjustment. They involve

i) Setting the instrument at the station and centering it. It has to be done very accurately. The instrument is centered with the help of a plump bob suspended from the centering hook at the bottom of the theodolite.

ii) Levelling:

iii) Focussing: The object and the cross wires should be focussed in such a way that by moving the head side ways or up and down, there is no relative displacement of the crosswire and the object. When such a situation is arrived at, the parallax error is supposed to have been removed

Permanent Adjustments: The adjustments done in the instrument by the manufactures are called permanent adjustments. Some of them which must be checked prior to starting the actual survey work are as follows:

1) The horizontal axis or trunion axis of the instrument should be at right angles to the Vertical Axis
2) The axis of the horizontal circle should be at right angles to the vertical axis
3) The vertical crosswire should lie in a plane at right angles to the horizontal axis.
4) The line of Collimation should be at right angles to the Horizontal axis or trunion Axis.

5) The axis of the telescope should be parallel to the Line of Collimation.
6) The vertical circle should read zero when the bubbles in the spirit level of the telescope is in the centre of its run.
7) The graduations in the vertical or horizontal plate and in the verniers attached to them are perfect or not.
8) The Centering or the Plumbing Hook is exactly in the centre of the theodolite or not.

Some technical terms used in Theodolite survey:

Centering : It is the method of setting the theodolite in such a way that the center of the theodolite which is taken as the plumbing hook at the bottom of the theodolite is exactly over the station point on the ground.

Levelling: It is the art of adjusting the level of the instrument in such a way that in any position of the theodolite the bubble in the spirit level which is attached to the Horizontal Plate is always in the center of its run.

Horizontal Axis: It is the axis about which the instrument can be rotated in a vertical plane. It is called trunion Axis

Vertical Axis: It is the axis about which instrument can be rotated in a horizontal plane

Transiting: When the telescope is capable of marking a complete revolution the vertical, plane, the movement is called transiting.

Line of Collimation or Line of Sight: It is an imaginary line passing through the optical centre of the object glass, and plane passing through the centre of the eye piece and entering the eye.

Setting: When the theodolite has been levelled and centered perfectly at the instrument station the process is called setting i.e. the instrument is now ready for use.

Face Left: When looking through the telescope and sighting and object, the vertical Circle is on the left hand side of the telescope and the observer the theodolite is said to be in Face Left position.

Face Right: In the same way while sighting an object, if the vertical circle, is on the right hand side of the telescope observer, the theodolite is said to be in Face right position and observer.

Swing Right: While taking horizontal angles, the telescope is rotated clockwise the telescope is said to have been swung right.

Swing Left: In the same way if it has been rotated anti-clockwise, it is said to have been swung left.

Normal Position: While surveying with the theodolite, the normal position of the instrument is Face Left, Swing Right and zero or 360° of the main scale or the lower horizontal plate is exactly coinciding with zero of vernier scale or the upper horizontal plate at Vernier A.

Least Count: In any measuring instrument, the least count is defined as the minimum reading power of the instrument i,e what is the least reading that can be taken by an instrument,.

In the theodolite, the horizontal circle or the main scale is divided clockwise from 0° to 360° each degree further being subdivide to three equal parts of 20 minutes each. The arrangement is such that 60 secondary division of the vernier scale coincide with 59 secondary divisions of the main scale.

The least count will be calculated thus:

60 vernier scale division are = 59 main scale

$$1 \text{ vernier scale division} = \frac{59}{60} \text{ main scale divisions}$$

$$= \frac{59}{60} \times 20 \text{ minutes.}$$

$$= \frac{59}{3} \text{ minutes}$$

$$\text{Least Count} = 1 \text{ M. S.D} - 1 \text{ V. S.D}$$

$$= (20 - 59/3) \text{ minutes.}$$

$$= \frac{60 - 59}{3} \text{ minutes}$$

$$= 1/3 \text{ minutes.}$$

$$= \frac{1}{3} \times 60 \text{ seconds.}$$

least count = 20 seconds.

i.e. the least count of the theodolite in which I M.S.D. is equal to 20' and 59 main scale divisions are equal to 60 vernier scale divisions will be 20 seconds.

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EXPERIMENT -

MEASUREMENT OF HORIZONTAL ANGLE BY METHOD OF REPETITION

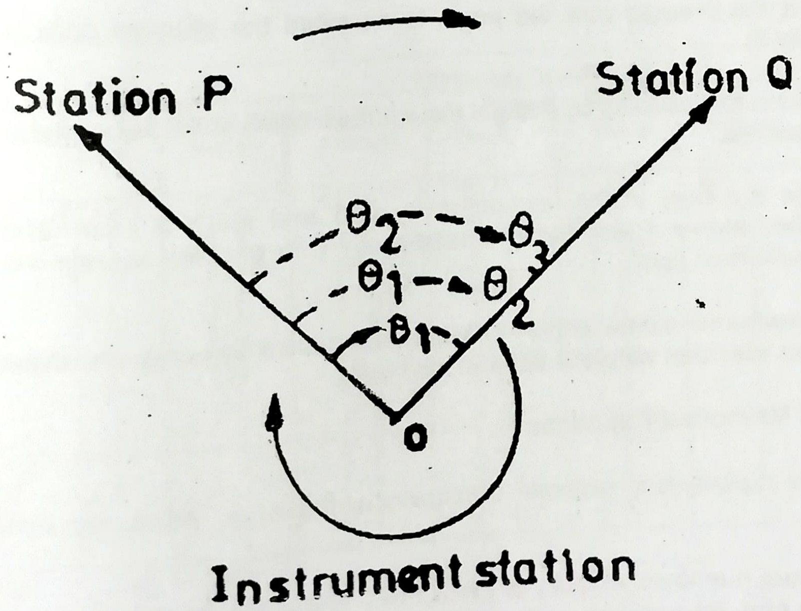
AIM:- To determine the horizontal angle POQ with respect to the station O and the object P and Q shown, by the method of repetition.

INSTRUMENTS REQUIRED:- Theodolite, ranging rods etc.

THEORY:- The method of repetition is used to measure a horizontal angle to a finer degree of accuracy than that obtained with the least count of vernier. In this method, an angle is measured two or more times by allowing the vernier to remain clamped each time at the end of each measurement instead of setting it back to zero when sighting at the previous station

In the method, the angle is added several times mechanically. The value of average horizontal angle in then obtained by dividing the final accumulated reading by the number of repetitions. This method of repetition consists in measuring the angle clockwise any desired number of time (usually 6.), half of which are made with the telescope normal and the other half with the telescope inverted.

PROCEDURE :-



(i) Set the instrument at the station O and level it accurately. (The face of the instrument should be left and the telescope in the normal position) and set ranging rods at P and Q.

(ii) Release the upper and lower clamp screws. Set the vernier A to 0^0 . Tighten the upper clamp. Bring it exactly to 0^0 by means of upper tangent screw. Also take the reading of vernier B.

(iii) Turn the telescope in the horizontal plane and point it at the station P (represent by a ranging rod) which is on the left side. Tighten the lower clamp. Bisect the ranging rod at Q exactly by using the lower tangent screw.(Sight at bottom or nearest to the bottom of ranging rods)

Check that the vernier readings have not changed.

(iv) Loosen the upper clamp screw. Turn the telescope clockwise until the line of sight is set on the station Q (represented by another ranging rod). Tighten the upper clamp. Bisect the ranging rod at P exactly by using the lower tangent screw.

(v) Read both the verniers. Determine the means value of the angle POQ.

(vi) Unclamp the lower plate and turn the telescope clockwise to sight the ranging rod at P again. Tighten the lower clamp. Use the lower tangent screw for exact bisection.

Check that the vernier readings have not changed.

(vii) Release the upper clamp and turn the telescope clockwise to sight the ranging rod at Q. Tighten the upper clamp. Bisect the ranging rod at Q exactly by using the upper tangent screw.

(viii) Repeat the process until the angle is repeated the required number of times (usually 3)

(ix) Divide the final reading by 3 to get the average value of the horizontal angle POQ with face left.

(x) Change the face of the instrument to right and make 3 more repetitions as described above. Divide the final reading by 3 to get the average value of the angle with face right .

(xi) The average horizontal angle POQ is then obtained by taking the average of the 2 angles obtained with face left and face right.

Advantage of Method of Repetition :

The method of repetition is accurate because the following errors are eliminated or minimised:

(i) The errors due to eccentricity of the centres and of the verniers are eliminated by reading both the verniers and averaging the readings.

(ii) The errors due to imperfect adjustment of the line of collimation and the horizontal axis of the telescope are eliminated by taking both face left and face right observations.

(iii) The error due to inaccurate graduations on the main scale are minimized by measuring the angle on different parts of the circle.

Limitations of Method of Repetition:

(i) When sight distance are relatively short, say less than 100m, there is little advantage in using the method of repetition. In that case, the errors in pointing the telescope correctly and setting up the instrument over the station exactly are more significant than the increased precision achieved in the method of repetition.

(ii) The error due to slip, the displacement of signals and the non-verticality of the vertical axes when the bubble is out of centre cannot be eliminated even by repetition.

OBSERVATIONS:-

I[st] observation (θ_1 - 0^0) =

2[nd] observation (θ_2 - θ_1) =

3[rd] observation (θ_3 - θ_2) =

Average horizontal angle POQ =

OBSERVATION TABLE:-

Inst at	Sight to	Horizontal Angle							Remarks
		Face left observations			Face right observations				
		Ver. A	Ver. B	Average	Ver.A	Ver. B	Average	Ave. Hori. Angle	
		0 ' "	0 ' "	0 ' "	0 ' "	0 ' "	0 ' "	0 ' "	
0	P Q								1st Repetition
0	P Q								2nd Repetition
0	P Q								3rd Repetition

RESULT:-

The average horizontal angle POQ =
(Average of Face left and Face Right)

Number of repetitions (n) =3

∴ Correct observed angles =

PRECAUTIONS : -

(1) Centering & levelling should be done accurately

(2) Clamps should be tightened properly.

(3) Bisect the ranging / Stations accurately .

(4) Reading should be taken without any parallax error.

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CIVIL ENGINEERING DEPARTMENT

Surveying Laboratory

EXPERIMENT -

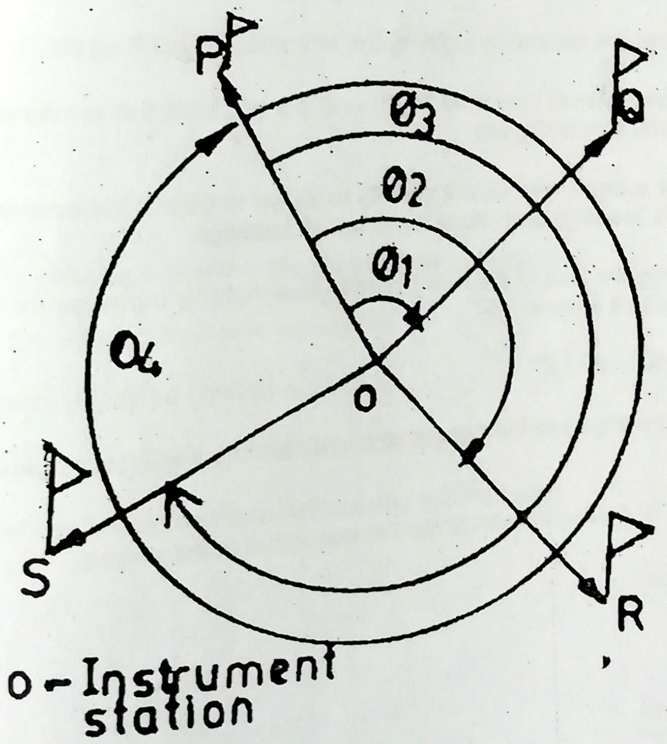
MEASUREMENT OF HORIZONTAL ANGLE BY METHOD OF REITERATION

AIM:- To measure the horizontal included angles between the objects P.Q.R.S etc. shown with respect to the station O. To Measure the horizontal angles POQ, QOP,ROS, SOP, etc. by the method of reiteration.

INSTRUMENTS REQUIRED:- Theodolite, ranging rods etc.

THEORY:- The method of reiteration or direction method or method of series is generally used when several angles are to be measured at the same station. All the angles are measured successively starting from the initial. station. The angle between the last station and the initial station is also measured and thus the horizon is closed. (closing the horizon is the process of measuring the angles at an instrument station round the point to obtain a check on their sum, which should equal 360°). The final reading of the vernier should be the same as its initial reading. If not, the discrepancy is equally distributed among all the angles measured.

PROCEDURE :-



(i) Set the instrument at the station O and level it accurately. Release both the upper and lower clamps.

Set the vernier A to 0^0. Tight in the upper clamp screw. Bring the vernier A exactly to 0^0 using the upper tangent screw.

(ii) Direct the telescope to the ranging rod at. P. Tighten the lower clamp screw. Bisect P using the lower tangent screw. (Generally the object at P is called 'reference object ').Read both the verniers.

(iii) Loosen the upper clamp screw and turn the telescope clockwise until the ranging rod at Q is bisected. Tighten the upper clamp. Use the upper tangent screw for exact bisection.

Read both the verniers. The mean of the vernier readings gives the horizontal angle POQ. (θ_1)

(iv) Loosen the upper clamp screw and turn the telescope clockwise until the station R is bisected. Tighten the upper clamp screw. Use the upper tangent screw for exact bisection.

Read both the verniers, the angle QOR is obtained by taking the difference between the readings on R and Q, $(\theta_2 - \theta_1) = \angle QOR$.

(v) Determine the angle ROS similarly. $(\theta_3 - \theta_2) = \angle ROS$

(vi) Finally close the horizon by sighting the reference object P again.

The vernier A should now read 360^0 (or 0^0). If not, note the vernier readings and find the error due to slip etc.

(vii) If the error is small, distribute it equally to all the angles. If the error is large, discard the readings and take a fresh set of readings.

(viii) Now change the face of the instrument to face right by transiting the telescope and swinging it through 180^0.

Set the vernier A ot 0^0.

(ix) Measure the angles in the same manner by turning the telescope in the clockwise direction.

(x) The mean of the two results gives the true value of the angles.

<u>CALCULATIONS:-</u>

$\angle POQ = \theta_1 =$

$\angle QOR = (\theta_2 - \theta_1) =$

$\angle ROS = (\theta_3 - \theta_2) =$

$\angle SOP = (\theta_4 - \theta_3) =$

OBSERVATION TABLE:

Inst at	Sight to	Horizontal Angle						
		Face left			Face Right			
		Ver. A	Ver. B	Average	Ver.A	Ver. B	Average	Ave. Hori. Angle
		0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''

RESULT:-

The values of the horizontal angles

∠POQ =

∠QOR =

∠ROS =

∠SOP =

PRECAUTIONS:- (1) Centering & leveling Should be done accurately .

(2) Set the Vernier 'A' to zero accurately.

(3) Clamps should be tightened properly .

(4) Bisect the ranging rods / stations accurately.

(5) Readings should be taken without any parallax error.

OBSERVATION TABLE:

Inst at	Sight to	Horizontal Angle						
		Face left			Face Right			Ave. Hori. Angle
		Ver. A	Ver. B	Average	Ver.A	Ver. B	Average	
		0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''	0 ' ''

RESULT:-

The values of the horizontal angles

∠POQ =

∠QOR =

∠ROS =

∠SOP =

PRECAUTIONS:-

(1) Centering & leveling Should be done accurately .

(2) Set the Vernier 'A' to zero accurately.

(3) Clamps should be tightened properly .

(4) Bisect the ranging rods / stations accurately.

(5) Readings should be taken without any parallax error.

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Surveying Laboratory

TRIGONOMETRIC LEVELLLING (HEIGHTS & DISTANCES)

EXPERIMENT -

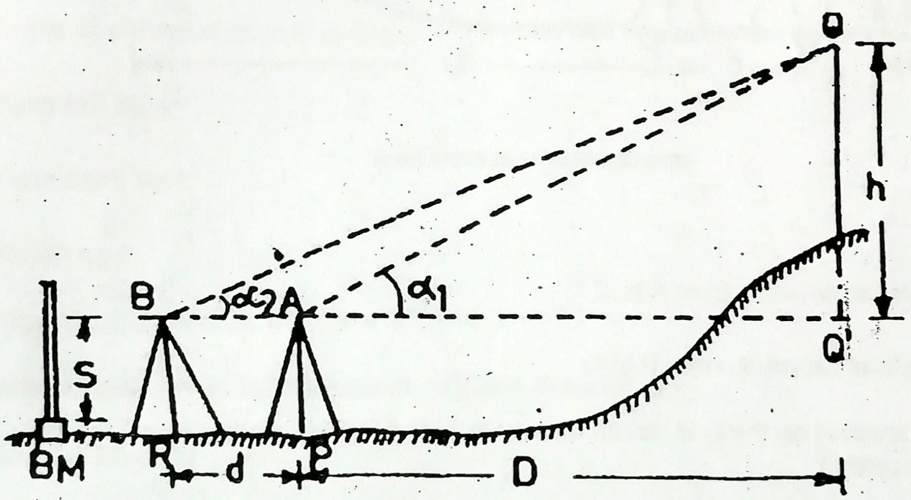
TO FIND THE R.L. WHEN BASE OF THE OBJECT IS INACCESSIBLE

(SINGLE PLANE METHOD)

AIM:- To find the reduced level of the top of an object when the base is inaccessible, given the R.L. of the B.M. by Single Plane method.

INSTRUMENTS REQUIRED:- Theodolite, levelling staff, steel tape, ranging rod , pegs etc.

PRINCIPLE:- When the horizontal distance between the object and the instrument cannot be measured due to obstacles etc, two instrument stations are used so that they are in the same vertical plane as the elevated objected .The instruments axis can be at the same level or at different levels.



PROCEDURE :-

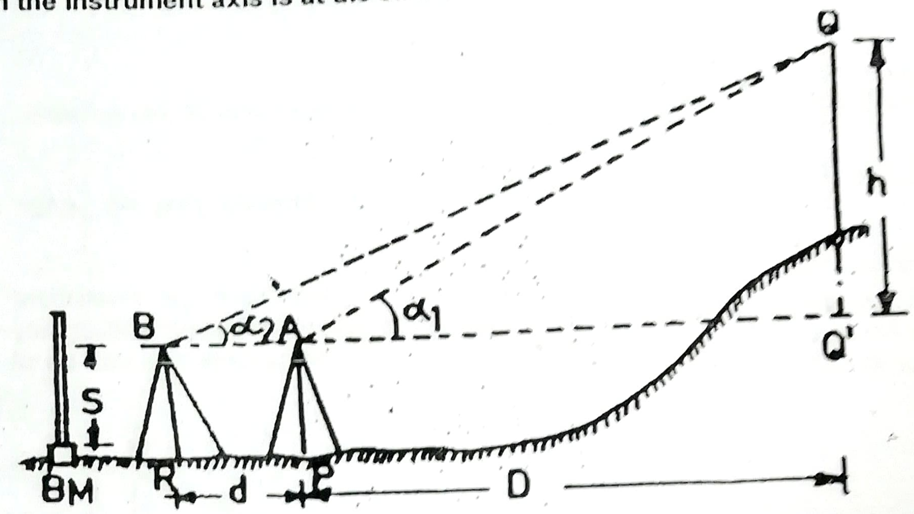
1. Set up the theodolite at P and level it accurately with respect to the altitude bubble.
2. Direct the telescope towards Q and bisect it accurately. Clamp both the plates. Read the vertical angle α_1.
3. Transit the telescope so that the line of sight is reversed. Mark the second instrument station R on the ground. Measure the distance RP (d) accurately.
4. Repeat steps (2) and (3) for both face observations. The mean value should be adopted.

5. With the vertical vernier set to zero reading, and the altitude bubble in the centre of its run, take the reading on the staff kept at nearby B.M.

6. Shift the instrument to 'R' and set up the theodolite there. Measure the vertical angle α_2 to Q with both face observations.

7. With the vertical vernier set to zero reading, and the altitude bubble in the centre of its run, take the reading on the staff kept at the nearby B.M.

(a) **When the instrument axis is at the same level on both the stations :**



Instrument axes at same level

h = QQ'

α_1 = angle of elevation from A to Q

α_2 = angle of elevation from B to Q

S = Staff reading on the B.M. taken from both A and B (the reading being the same in both cases)

d = horizontal distance between the instrument stations i.e, R and P

D = horizontal distance between P and Q

From ΔAQQ^1, $h = D \tan \alpha_1$ —— (1)

From ΔBQQ^1, $h = (D+d) \tan \alpha_2$ —— (2)

Equating (1) and (2) , we get

$D \tan \alpha_1 = (D + d) \tan \alpha_2$

$= D \tan \alpha_2 + d \tan \alpha_2$

$\therefore D(\tan\alpha_1 - \tan\alpha_2) = d\tan\alpha_2$

$$\therefore D = \frac{d\tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$$

Substituting the value of D in equation . (1).

$$h = D\tan\alpha 1 = \frac{d\tan\alpha_1\tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)}$$

$\therefore$ R.L. of Q = R.L. of B.M. + S + h

OBSERVATIONS:-

1. Angle of elevation from A to Q (α_1) :

   Face left α_1 =

   Face right α_1 =

   Mean value of $\alpha 1$ =

2. Angle of elevation from B to Q (α_2) :

   Face left α_2 =

   Face right α_2 =

   Mean α_2 =

3. Staff reading at B.M. from A or B , S =

4. Distance between the instrument Station R and P, d =

CALCULATIONS:-

$$D = \frac{d\tan\alpha_2}{(\tan\alpha_1 - \tan\alpha_2)} =$$

$$h = D\tan\alpha_1 =$$

R.L of Q = R.L. of B.M. + S + h

RESULT :-

EXPERIMENT -

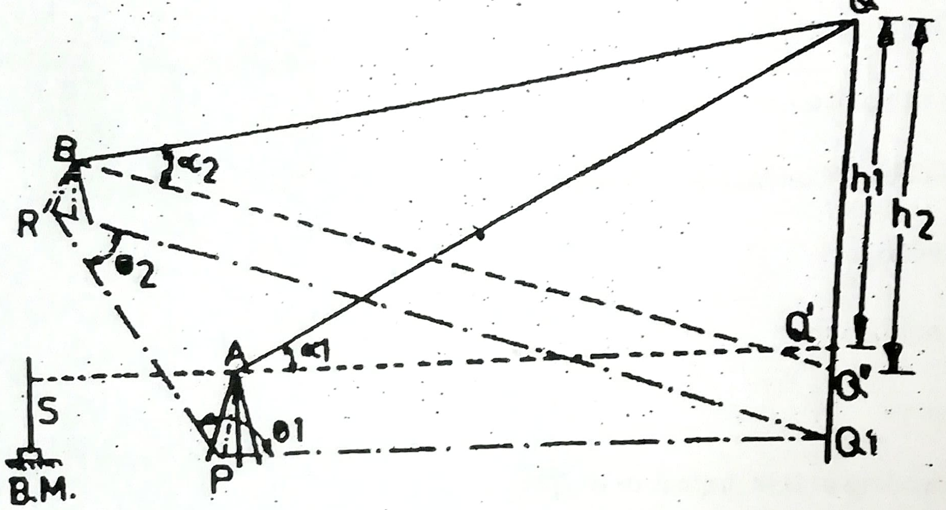
BASE OF THE OBJECT INACCESSIBLE

(DOUBLE PLANE METHOD)

AIM:- To find the R.L. of the top of an object when the base is inaccessible using theodolite by Double Plane method, given the R.L. of the B.M. as 100.000 m

INSTRUMENTS REQUIRED:- Theodolite, levelling staff, steel tape, ranging rod, pegs, etc.

PROCEDURE :-



Instrument and object are not in the same vertical plane

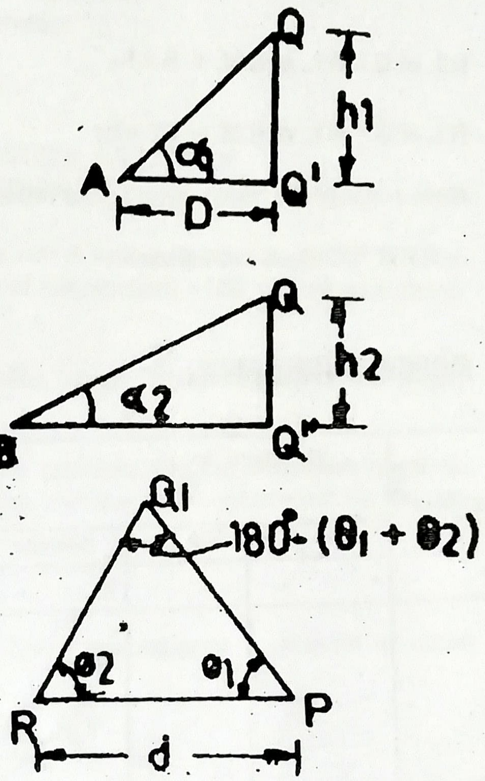
Let P and R be the two instrument station not in the same vertical plane as that of Q. P and R are so selected that the ΔPQR is a well conditioned triangle.

1. Set up the instrument at P and level it accurately with respect to the altitude bubble. Measure the angle of elevation α_1 to Q.
2. Sight the point R with the reading on the horizontal circle zero and measure the angle RPQ,. I.e. horizontal angle θ_1 at P.
3. Take the back sight S on the staff kept at B.M.
4. Shift the instrument to R and measure α_2 and θ_2 there.
5. Measure the distance between the two instrument stations R and P.

Instrument and object are not in the same vertical plane:-

From $\Delta AQQ'$

$$h_1 = D \tan \alpha_1 \text{ ———— } (1)$$



From ΔPRQ,

$\angle RQ_1P = 180^0 - (\theta_1 + \theta_2)$

Applying sine rule

$$\frac{PQ_1}{\sin\theta_2} = \frac{RQ_1}{\sin\theta_1} = \frac{RP}{\sin[180 - (\theta_1+\theta_2)]}$$

$$PQ_1 = D = \frac{d \sin \theta_2}{\sin(\theta_1+\theta_2)}$$

$$RQ_1 = \frac{d \sin \theta_1}{\sin(\theta_1+\theta_2)}$$

Substituting the value of D in (1), we get

$$h_1 = D \tan \alpha_1,$$

$$h_1 = \frac{d \sin\theta_1 \tan \alpha_1}{\sin(\theta_1 + \theta_2)}$$

R.L of Q = R.L of B.M. + S (from A) + h_1

OR

$$h_2 = RQ_1 \tan \alpha_2 = \frac{d \sin \theta_1 \tan\alpha_2}{\sin(\theta_1 + \theta_2)}$$

i.e. R.L of Q = R.L of B.M. + S (from B) + h_2

OBSERVATIONS:-

1. Angle of elevation α_1 from A to Q =
2. Angle of elevation α_2 from B to Q =
3. Horizontal angle Q_1PR (θ_1) =
4. Horizontal angle Q_1RP (θ_2)=
5. Staff reading on the B.M. from station P =
6. Distance between stations R and P, d =

CALCULATIONS:- $D = \dfrac{d \tan \theta_2}{\sin(\theta_1 + \theta_2)}$; $h_1 = D \tan \alpha_1$

R.L of Q = R.L. of B.M. + $S + h_1$

R.L of Q = R.L. of B.M. + $S2 + h_2$

Note :- *Adopt the mean value as the reduced level of Q)*

$\therefore$ R.L of 'Q' = -------------- .metres

OBSERVATION TABLE:-

Inst at	Sight to	Horizontal Angle			Vertical Angle			Remarks
		Ver. A	Ver. B	Average	Ver.C	Ver. D	Average	
		° ' "	' "	° ' "	° ' "	' "	° ' "	

RESULT :-

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING DEPARTMENT

Surveying Laboratory

EXPERIMENT -

SETTING OF A SIMPLE CIRCULAR CURVE
(RANKINE'S METHOD)

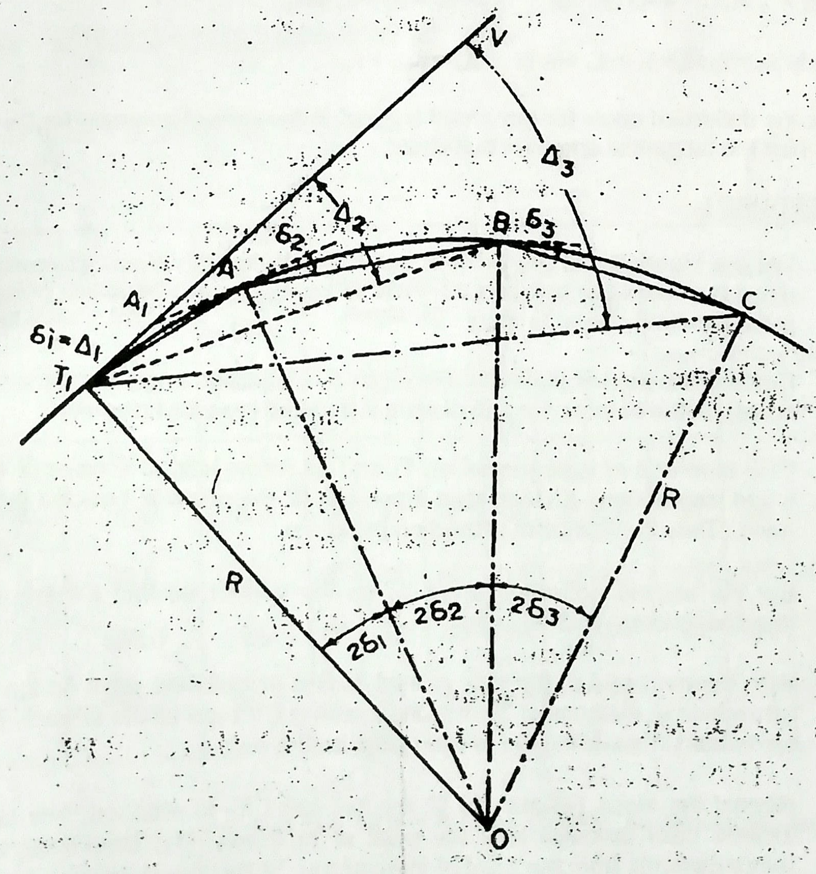
AIM:- To lay out a simple circular curve of radius 100 m and deflection angle 52° 30° by Rankine's method. Given the chainage of (point of intersection) =100 m & normal chord length = 30 m.

INSTRUMENTS REQUIRED:- Transit theodolite, chain, tape, ranging rods, pegs, arrows, flags etc.

PRINCIPLE:- Rankine's method is based on the principle that the deflection angle to any point on a circular curve is measured by one half the angle subtended by the arc from point of curve (P.C) to that point .

THEORY:-

Expression for the Tangential Angles:- Let T_1V = rear tangent T_1 = point of curve (P.C)



Setting of Simple Curve by Tangential Angle method

$\delta_1, \delta_2, \delta_3$ = the tangential angles or the angles which each of the successive chords T_1A, AB, BC etc makes with the respective tangents to the curve at T_1, A, B etc.

$\Delta_1, \Delta_2, \Delta_3$ = Total tangential or the deflection angles to the points A,B,C etc.

C_1, C_2, C_3 = Length of the chord T_1A, AB, BC......

A_1A = Tangent to the curve at A

From the property of a circle, $\angle VT_1A = \frac{1}{2} \angle T_1OA$

$\angle T_1OA = 2\angle VT_1A = 2\delta_1$; Now $\frac{\angle T_1OA}{C_1} = \frac{180}{\Pi R}$

Or $\angle T_1OA = 2\delta_1 = \frac{180^\circ C_1}{\Pi R} \Rightarrow \delta_1 = \frac{90C_1}{\Pi R}$ degrees $\Rightarrow \frac{90 \times 60 C_1}{\Pi R} = \frac{1718.9C_1}{R}$, Minutes

Similarly $\delta_2 = \frac{1718.9C_2}{R}$; $\delta_3 = \frac{1718.9C_3}{R}$ ....etc.

In general $\delta = \frac{1718.9C}{R}$ minutes, where 'C' is the length of the chord

For the first chord T_1A, the deflection angle = its tangential angle i.e., $\Delta_1 = \delta_1$

For the second point B, let the deflection angle = Δ_2.

$\angle VT_1B = \angle A_1T_1A + AT_1B$ or $\Delta_2 = \delta_1 + \delta_2 = \Delta_1 + \delta_2$

similarly $\Delta_3 = \delta_1 + \delta_2 + \delta_3 = \Delta_2 + \delta_3$ or $\Delta_n = \Delta_{n-1} + \delta_n$

Hence the deflection angle for any chord is equal to the deflection angle for the previous chord plus the tangential angle for that chord.

PROCEDURE :-

1. Set the theodolite at the point of curve T_1. With both plates clamped to zero, direct the theodolite to bisect the Point of intersection(V). The line of sight in this is the direction of rear tangent.

2. Release the vernier plate and set angle Δ_1 (deflection angle for first point on the curve) on the vernier, the line of sight is directed towards first point.

3. With zero end of tape pinned on T_1 and an arrow held at a distance of 1st sub chord length along it swing tape around T_1 till the arrow is bisected by the cross hairs. Thus the first point is fixed on the curve.

4. Set the second deflection angle Δ_2 on the vernier so that the line of sight is directed towards second point.

5. With the zero end of the tape pinned at first established point on the curve and arrow held at distance of 30 m along it, swing the tape till the arrow is bisected by cross-hairs, thus fixing the second point on the cure.

6. Repeat the steps (4) and (5) till the last point T_2 is reached. The last point so located must coincide with the point of tangency (T_2) fixed independently by measurements from the point of intersection. If the discrepancy is small, last few pegs may be adjusted. If it is more the whole curve should be reset.

CALCULATIONS:- For R = 100 m & deflection angle = 52° 30'

The following are the calculations.

1. Tangent length = $R \tan \frac{\Delta}{2}$ = 100 tan 52° 30' = 49.3 m (T_1V)
2. A length of the curve 'l' = $\frac{\Pi R.\Delta}{180} = \frac{\Pi x\ 100 \times 52^0\ 30'}{180}$ = 91.6m
3. Chainage of T_1 = Ch of P.I – Tangent length = 100-49.3 = 50.7m
4. Chainage T_2 = Ch of T_1 + length of the curve = 50.7 + 91.6 = 142.3m
5. Chainage of point 'A' = 60m. Therefore length of initial chord length (C_1) = 60 – 50.7 = 9.30m.
6. Second & third chord length = 30 m each (normal chords)
   ∴Chainage of second point on the curve (C_2) = 60+30 = 90m and
   Chainage of third point on the curve =the curve = 90+30 =120 m.
7. Chainage of final sub-chord = 142.3 – 120 =22.3m length of final sub-chord (C_4) 22.3m.
8. Tangential angle $\Delta_1 = \delta_1 = \frac{1718.9xC_1}{R} = \frac{1718.9x\ 9.3}{R}$ = 2° 40' 0"

   $\delta_2 = \delta_3 = \frac{1718.9xC}{R} = \frac{1718.9x30}{R}$ = 8° 35' 40"

   $\delta_4 = \frac{1718.C_4}{R} = \frac{1718.9x22.3}{R}$ = 6° 23' 40"

TABLE:-

Inst at	Sighted to	Chainage (m)	Chord length (m)	Tangential Angle (δ)			Deflection Angle (Δ)			Actual Theodolite Reading (on Vernier 'A')			Remarks
				o	'	"	o	'	"	o	'	"	
T1	V	50.7	-	-	-	-	-	-	-	-	-	-	
	A	60.0	9.3	2°	40'	0"	2°	40	0	2°	40'	0"	
	B	90.0	30	8°	35'	40"	11°	15'	40"	11°	15'	40"	
	C	120.0	30	8°	35'	40"	19°	51'	20"	19°	51'	20"	
	T2	142.3	22.3	6°	23'	40"	26°	14'	40"	26°	14'	40"	

RESULT:- A simple curve is laid out with the help of data as tabulated above by Rankine's method.

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EXPERIMENT - 1

SETTING OUT OF SIMPLE CURVES

(BY LINEAR METHODS)

AIM:- To set out a simple curve of radius 100 metres for two roads which meet at an angle of 142° by linear methods.

INSTRUMENTS REQUIRED:- Chain, tape, pegs, arrows etc.

THEORY:- There are two methods for setting and curves depending upon the instruments used.

1) **Linear Methods:-** In this methods, only a chain or tape is used. Linear methods are used when a high degree of accuracy is not required & when the curve is short.

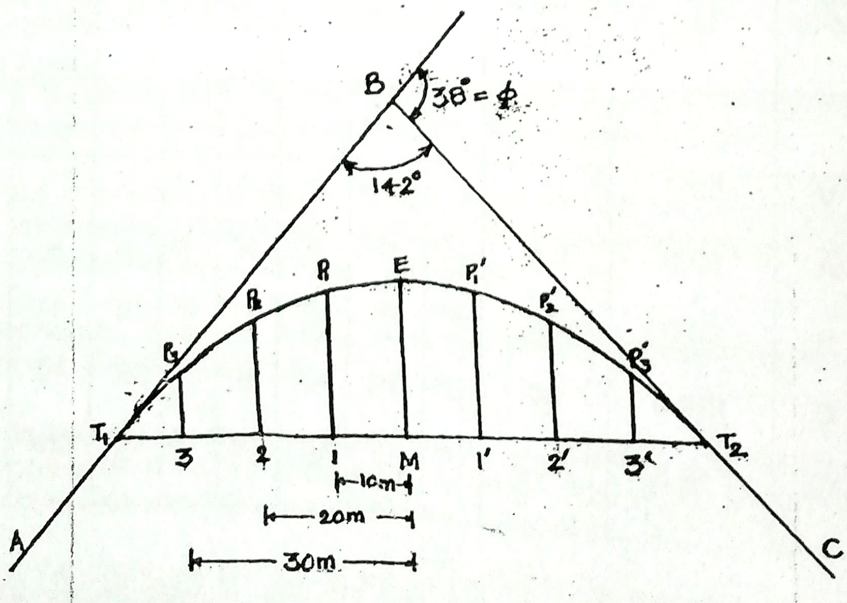
2) **Angular Methods:-** In angular method, an instrument such as theodolite is used with or without a chain (or tape).

Some of the linear methods for setting out simple curves are

1) By ordinates or offsets, from the long chord.
2) By successive bisection of arcs.
3) By offsets from the tangents.
4) By offsets, from chords produced (or by deflection distances).

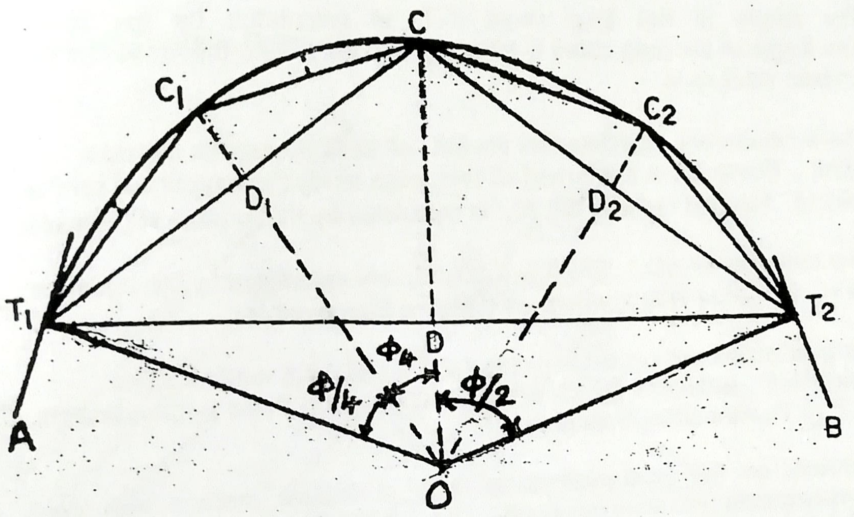
PROCEDURE :-

1) **By ordinates from the long chord:-**



Setting out of Simple Curve by Ordinates from the Long Chord

(2) By successive bisection of arcs:-



Setting out of Simple Curve by Successive bisection of Arcs

PROCEDURE :-

1) Join the tangent points T_1T_2 and bisect it at D. Erect a perpendicular DC (O_o) which is equal to the versed sine of the curve

$$O_o = DC = R\,(1\text{-}\cos\phi/2)$$

2) Again the lengths T_1C & T_2C will serve as long chords for the curves between T_1 and C, and T_2 and C. Joint T_1 C and T_2C, measure and bisect them at D_1 & D_2 respectively.

3) AT D_1 & D_2, set out perpendicular offsets $C_1D_1 = C_2D_2 = R(1 - \cos\phi/4)$ to get points C_1 & C_2 on the curve .

4) By the successive bisection of these chords, more points are obtained and the process is continued until the bisection of chords is not practically possible.

5) Then the points on the curve are joined by rope to show the shape of the curve.

CALCULATIONS:- (1) $O_o = R\left(1 - \cos\frac{\phi}{2}\right) = 100\left(1\text{-}\cos\frac{38^o}{2}\right) = 5.4\text{m}.$

(2) $C_1D_1 = C_2D_2 = R\left(1\text{-}\cos\frac{\phi}{4}\right) = 100\left(1\text{-}\cos\frac{38^o}{4}\right) = 1.37\text{m}$

(3) Similarly for next two bisections the ordinates will be

$R\left(1 - \cos\frac{\phi}{8}\right) = 100\left(1\text{-}\cos\frac{38^o}{8}\right) = 0.34\text{m}$, and

$R\left(1 - \cos\frac{\phi}{16}\right) = 100\left(1 - \cos\frac{38^o}{16}\right) = 0.08\text{ m}$

1) Let AB & BC be two tangents meeting at a point B, with deflection angle, ϕ (38°)

2) The tangent lengths are calculated by the formula R tan $\phi/2$ and points T_1 & T_2 are marked on the ground with pegs.

3) The length of the long chord T_1T_2 is calculated by the formula $2R\sin\phi/2$ The length of the long chord is bisected at point M and the curve will be symmetrical on both sides of M.

4) The ordinates are calculated for the left half at some regular intervals (10m). Points 1,2 & 3 are marked with pegs along the long chord on the left side of point M. The mid ordinate ME (0_o) is calculated by the formula R (1-cos$\phi/2$).

5) The ordinates IP_1 (O_1), $2P_2$ (O_2) & $3P_3$(O_3) are calculated by the equation $Ox = \sqrt{R^2-x^2} - (R-O_o)$, where x = distance from point M.

6) Perpendiculars are set out at points 1,2 & 3 (by 3,4,5 method). The calculated ordinates O_1, O_2 & O_3 identified along these perpendiculars and points P_1,P_2 & P_3 are marked with pegs.

7) Similarly on the right half, points 1^1,2^1 & 3^1 are marked with pegs and the corresponding ordinates (obtained for the left half) are set out to mark the points P_1^1, P_2^1 & P_3^1.

8) All these points P_1,P_2,P_3,E , P_1^1,P_2^1 & P_3^1. are on the curve. These points are joined by rope or thread to show the shape of the curve along the alignment (centre line) of the road.

CALCULATIONS:- Given ϕ= 38° ; R=100m

1) Tangent length , R tan $\phi/2$ = 100 tan 38°/2 = 34.43m

2) Curve length $= \frac{\Pi R \phi}{180} = \frac{3.14 \times 100 \times 38}{180}$ = 66.32 m.

3) Length of long chord (L) = 2 R sin$\phi/2$ = 2x 100 x sin 38/2 = 65.10m

4) The long chord (T_1T_2) is divided into two halves, so each half = 0.5 x 65.10m = 32.55m

5) Mid ordinates ME (O_o) = R (1-cos $\phi/2$) = 100 (1- Cos 38° /2)= 5.4m

6) The ordinate are calculated at 10m intervals starting from the center (M) towards T_1 for the left half

$$O_{10} = \sqrt{R^2 - x^2} - (R-O_o) = \sqrt{100^2 - 10^2} - (100 - 5.4) = 4.9m$$

Similarly $O_{20} = \sqrt{100^2 - 20^2}$ - (100..5.4) = 3.4m

$$O_{30} = \sqrt{100^2 - 30^2} - (100 - 5.4) = 0.9m$$

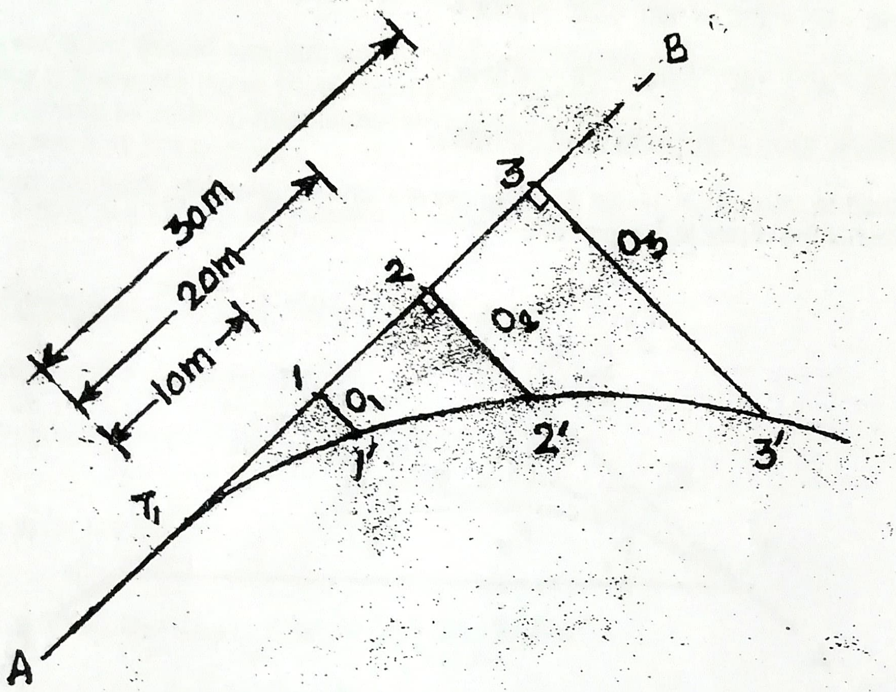
$$O_{32.55} = \sqrt{100^2 - 32.55^2} - (100 - 5.4) = 0 \text{ (checked)}$$

7) the ordinates for the right half are similar to those for the left half.

3) **By offsets from the tangents:-** There are two types of offsets from the tangents

1 Perpendicular offsets
2 Radial offsets

Procedure for perpendicular offsets from tangents:-



Setting out Simple Curve by Perpendicular offsets from Tangents

1. Let AB & BC be the two tangents meeting at a point B. Lay the chain arbitarily on the ground and assumed it to be in the direction of the rear tangent AB.

2. Mark T_1 (PC) at the starting of the chain by driving a peg at the zero meter remark.

3. Similarly drive pegs at points 1,2 & 3 at a distance of 10m , 20m & 30m respectively from point T_1.

4. Calculate the perpendicular offsets; O_1, O_2 & O_3 at points 1,2 & 3 by the formula $O_x = R - \sqrt{(R^2 - X^2)}$, where R = Radius of the curve & 'X' = the distance measured along the read tangent AB from T_1

5. Perpendiculars are set out at points 1,2 & 3 (by 3.4.5, method) and the calculated ordinates O_1, O_2 & O_3 are identified along these perpendiculars and points 1^1, 2^1 & 3^1 are marked with pegs.

6. The points $1^1, 2^1$ & 3^1 are on the curve & the points T^1 , 2^1 & 3^1 are joined by rope to show the shape of the curve (Partly).

CALCULATIONS:-

For R = 100m; & x_1, x_2 & x_3 = 10m, 20m & 30m respectively, the perpendicular offsets are

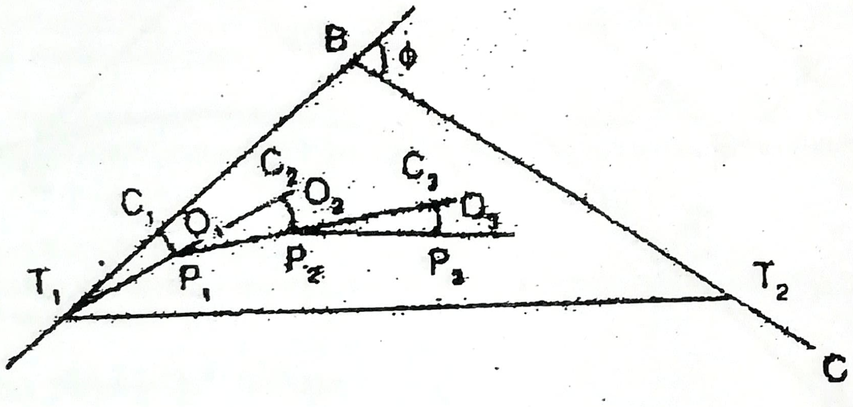
1) $O_{10} = (1-1^1) = R - \sqrt{R^2 - X^2} = 100 - \sqrt{100^2 - 10^2} = 0.51m.$

2) $O_{20} = (2 - 2^1) = 100 - \sqrt{100^2 - 20^2} = 2.02m$

3) $O_{30} = (3 - 3^1) = 100 - \sqrt{100^2 - 30^2} = 4.61m.$

(4) By offsets from chord produced method:-

This method is very much useful for long curves and is generally used on highway curves when a theodolite is not available.



Setting out of Simple Curve by Offsets from Chord Produced Method

PROCEDURE :-

1) Let AB and BC be the tangents and 'B' is the point of intersection

2) Calculate the length of the tangents & points T_1 & T_2 are marked on the ground with pegs.

3) The curve length is calculated & chainages of T_1 & T_2 are determined

4) The lengths of the initial and final sub chords & the number of full chords are determined.

5) The offsets for the initial sub chord, full chord and final sub chord are calculated.

6) The distance T_1C_1 is marked along the rear tangent AB so that T_1C_1 is equal to the initial sub chord.

7) With zero mark at T_1, spread the chain (or tape) along the rear tangent & mark point C_1 such that T_1C_1 = length of the initial sub-chord. From C_1 set off a distance C_1P_1 equal to first offset O_1. Mark the point P_1 on the curve.

8) Spread the chain along T_1P_1 & pull it straight in this direction to point C_2, such that the zero of the chain (or tape) is at P_1 and the distance P_1C_2 is equal to the length of second chord.

9) With the zero end of chain (or tape) at P_1 & P_1C_2 as radius swing the chain (or tape) to a point P_2 such that $C_2P_2 = O_2$ = length of second offset. Fix the point P_2 on the curve.

10) The process is continued until the second tangent point T_2 is reached.

11) The last point should coincide with T_2. If it does not the amount of error is found out. If the error is large, the curve should be reset If the error is less, it should be distributed to all the points by moving them sideways by an amount proportional to the square of their distance from the point T_1.

12) The points T_1, P_1, P_2, P_3 are joined to get the shape of the curve.

CALCULATIONS:- Given R =100 m, ϕ =38°

1 Tangent length = $R \tan \frac{\phi}{2}$ = 34.43m

2 Length of the curve 'l' = $\frac{\Pi R \phi}{180} = \frac{\Pi x\ 100\ x 38}{180}$ = 66.32 m

3 First offset $O_1 = \frac{b_1^2}{2R} = \frac{10^2}{2x100}$ = 0.5 m

4 Second offset, $O_2 = \frac{b_2 (b_1 + b_2)}{2R} = \frac{10\ (10 + 10)}{2x100}$ 1m

5 Third offset, $O_3 = \frac{b_3 (b_2 + b_3)}{2R} = \frac{10\ (10 + 10)}{2x100}$ 1m & so on

In above equations b_1, b_2, b_3, are the lengths of the first, second and third chords respectively.