

UNIT - III

Surya

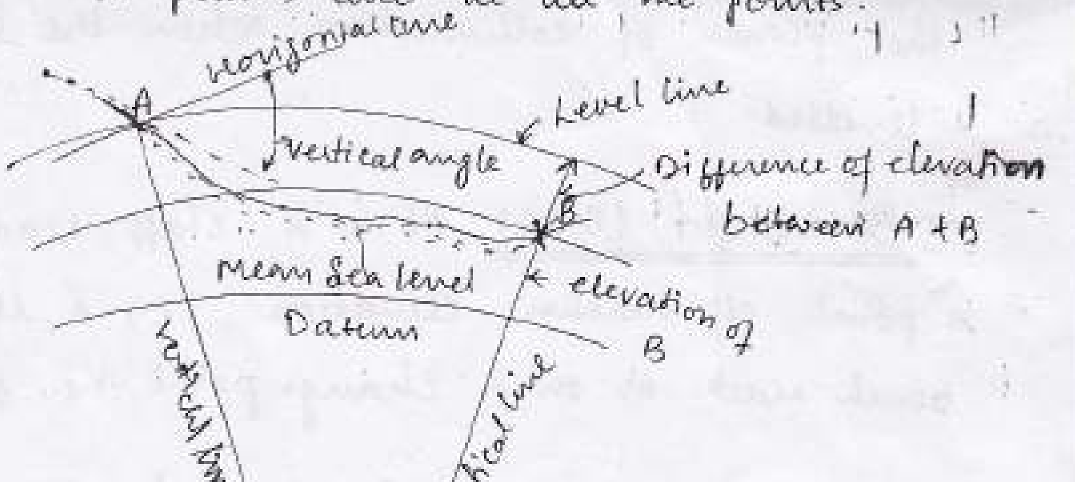
LEVELLING AND CONTOURING

→ **LEVELING:** The operation of determining the difference of elevation of points with respect to each other on the surface of the earth is called levelling.

→ **LEVEL SURFACE:** A surface parallel to the mean spheroidal surface of the earth is called level surface.

→ **VERTICAL LINE:** It is a line from any point on the earth's surface to the centre of the earth and is commonly considered to be the line defined by a plumb line.

→ **LEVEL LINE:** It is a line lying on a level surface and normal to plumb line at all the points.



→ **HORIZONTAL PLANE:** It is a plane tangential to the level surface at the point under consideration and perpendicular to plumb line.

→ **HORIZONTAL LINE:** It is a line lying in the horizontal plane. It is a straight line tangential to level line

→ **ELEVATION:** It is a vertical distance above or below the datum. It is also known as reduced level (R.L)

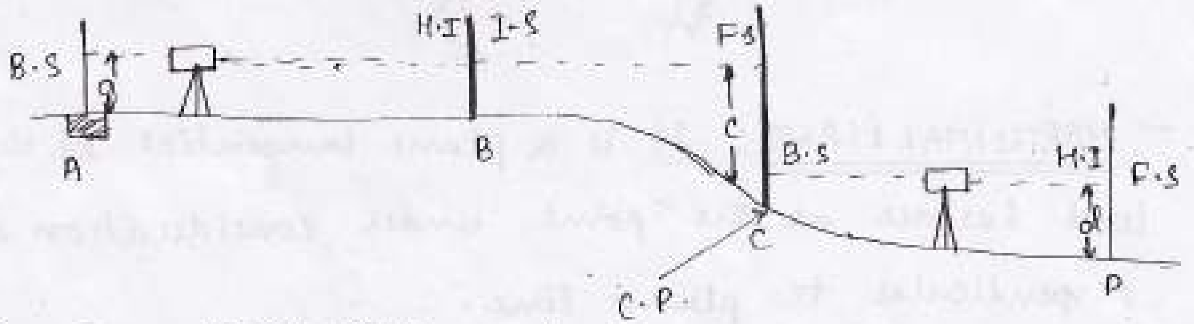
→ **AXIS OF TELESCOPE:** It is a line joining the optical centre of the objective to the centre of the eyepiece

→ **LINE OF SIGHT (or) LINE OF COLLIMATION:** It is a line joining the intersection of the cross-hairs to the centre of the objective and its continuation.

→ **AXIS OF LEVEL TUBE or BUBBLE TUBE:** It is an imaginary line tangential to the longitudinal curve of the tube at its mid-point.

→ **HEIGHT OF INSTRUMENT (H.I):** It is the elevation of the plane of collimation when the instrument is levelled.

→ **BACKSIGHT (B.S):** It is a staff reading taken on a point of known elevation i.e., a sight on a bench mark or on a change point i.e., station 'C' in (fig.)



→ **FORE SIGHT (F.S):** It is a staff reading taken on a point whose elevation is to be determined, eg. a sight on a change point, i.e. station C & D in (fig.(1))

→ **INTERMEDIATE SIGHT (I.S)**: It is a staff reading taken on a point of unknown elevation between backsight and foresight, e.g. a sight on Station B in fig (1).

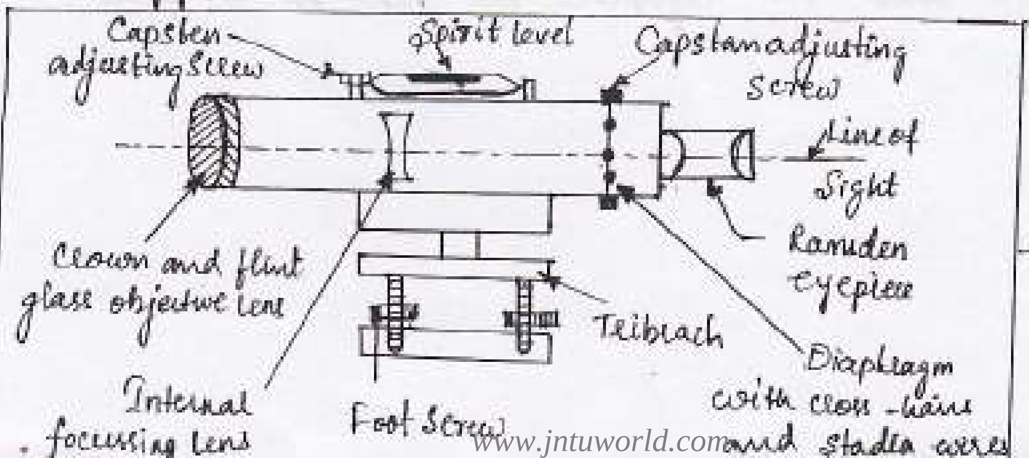
→ **CHANGE POINT (C.P) OR TURNING POINT (T.P)**: It is a point denoting the shifting of the level. Both F.S. and B.S. are taken on this point. eg. Station C in fig. 1.

→ **STATION**: A point whose elevation is to be determined is called station. The shaft is kept at this point, e.g. A, B and C in fig. 1

→ **PARALLAX**: It is the apparent movement of the image relative to the cross-hairs when the image formed by the objective doesnot fall in the plane of the diaphragm.

→ **BENCH MARK (B.M.)**: It is a fixed reference point of known elevation.

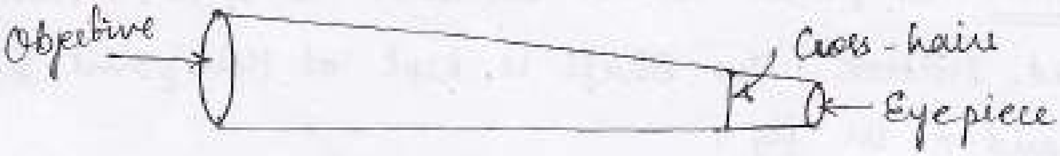
→ **LEVEL**: The instrument which is used to determine the vertical distance of points is known as level. A level consists of a telescope to provide the line of sight, a level tube to make the line of sight horizontal, a levelling head to bring the bubble of level tube at the centre, and a tripod to support the level.



→ Sketch of Dumpy level

TELESCOPE:

- A telescope consists of a diaphragm ring and two convex lenses. The lens near the eye is called eyepiece and that towards object is called objective.
- The diaphragm ring consists of cross-hairs near the eye piece.



- Focussing screw is provided to give lateral movement of telescope.
- Adjusting screw is provided to give small movement of telescope about vertical axis.

External Focussing Telescope:-

- Focussing is achieved by the external movement of objective tube.
- The movement is done with the help of a focussing screw.

Internal Focussing Telescope:-

- Focussing is done internally with a negative lens by moving the negative lens with a focussing screw.
- The objective and the eyepiece are kept at a fixed distance.

Advantages of internal focussing telescope:-

- Short in length and compact
- Difficult for dust or moisture to enter the telescope barrel.
- The error, tending to cause the movement of internal lens to become non-axial, will be much less than that resulting from a change in the position the line of sight of an external focussing telescope when the objective or eyepiece slide becomes loose.

Disadvantages of internal focussing telescope:-

- Reduction in brilliancy of the image resulting from the passage of light rays through the additional internal lens.
- Tends to be more expensive.

LEVELLING HEAD:-

- It is generally a conical socket attached with a triangular base called tribrach, over which level tube is provided. It is having three or four levelling screws.
- The bubble in the level tube is brought to its centre by adjusting the level screws.

LEVEL TUBE:

- It is a glass tube filled with a sensitive liquid such as alcohol or ether leaving enough space to form a bubble.

- The tube is provided with uniform graduations (generally of 2mm length) to show the exact positions of bubble.
- The bubble is made to come at the centre of level by levelling screws in all directions so that the instrument is horizontal.

SENSITIVENESS OF LEVEL TUBE:-

Measurement of Sensitivity:

(i) Fix two points at a known distance apart, say 100 m.

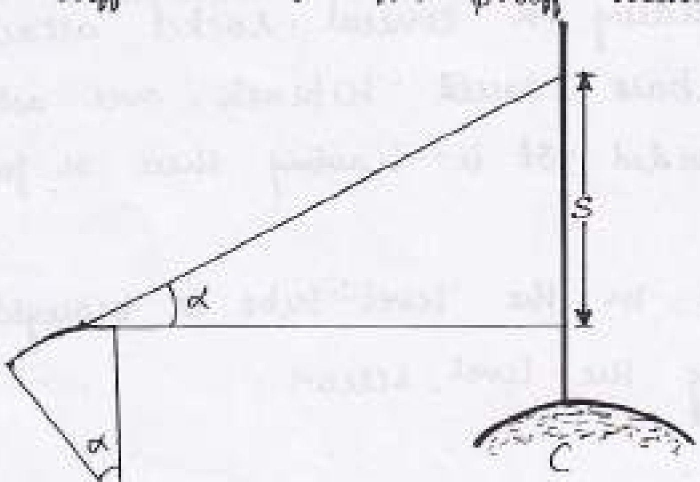
(ii) Set up and level the instrument at 'O'.

(iii) Take the reading on staff held vertical at C.

(iv) By turning the foot screw, move the bubble to n divisions.

(v) Read the staff again.

(vi) Find the difference in two staff readings.



$$\alpha = S/D = n \times (l/R) \rightarrow (1)$$

The term l/R is called sensitivity of bubble tube and equal to α'

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From $\alpha' = l/R = S/nD$ (in radians)

$\therefore \alpha' = l/R = S/nD \times 206265$ (in seconds)

where α = angle between the line of sights in radians

D = distance of the instrument from staff.

n = number of divisions through which the bubble is moved.

R = Radius of curvature of tube.

S = Staff intercept

l = length of one division of bubble tube (usually 2mm)

TYPES OF LEVELS:-

DUMPY LEVEL:

- Most widely used level and its telescope is rigidly fixed to its support. The telescope can neither be rotated about its longitudinal axis nor it can be removed from its support.

WYE - LEVEL:

- Similar to dumpy level except that the telescope is supported by two Y-sloped uprights, so that the telescope can be lifted clear of the Y-supports.

COOKE'S REVERSIBLE LEVEL

- It combines good features of both dumpy and wye-levels. It may be rotated about its line of sight giving a bubble left and bubble right reading. Thus, the collimation error is eliminated.

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CUSHING'S LEVEL:

- The telescope can neither be revolved about its longitudinal axis nor can it be removed from its socket. However, the object glass and the eye piece along with the diaphragm are reversible and can be interchanged.

AUTOMATIC (or) AUTO (or) ADJUSTING LEVEL

- It is similar to dumpy level with its telescope fixed to the tribrach.
- For approximate levelling, a circular spirit bubble is attached to the side of telescope.
- For accurate levelling, a stabilizer or compensator is fitted inside the telescope, which automatically levels the instrument.

TILTING LEVEL:

- The telescope can be rotated about horizontal axis by adjusting tilting screw.
- It enables surveyor to quickly centre the bubble and thus bring line of sight into the horizontal plane.

DIGITAL LEVEL:

- Has the advantage of being able to measure and record electronically.

HAND LEVEL:

- It is held in the hand while in use and is adjusted by hand alone.
- This is recommended for short sights and high accuracy is not required.

ABNEY HAND LEVEL:

- Also known as clinometer. It is similar to hand level with the difference that the bubble tube is movable with respect to the sighting tube.
- Vertical angles can also be measured.

LEVELLING STAFF:-

- A levelling staff is a straight, rectangular, wooden rod graduated into metres and smaller divisions.
- The reading given by the line of sight on a levelling staff is the height of the line of collimation from the point on which the staff is held vertically.

SELF READING LEVELLING STAFF:

- These may be 3-5 ~~metre~~ in length. A solid staff is usually 3m long, and a folding staff is generally 4m in length. The folding staff is made of two pieces each of 2m length.
- The minimum graduation on the staff is 5mm

INVAR PRECISION LEVELLING STAFF:

- It is used for precise levelling work and is 3m long
- An Invar band graduated at 5 or 10 mm intervals is fitted to a wooden staff.

SOPWITH TELESCOPIC STAFF:

- It is 14 ft. long and made into three pieces, the top and middle ones being 4 ft 5" and the bottom one is 5 ft. long. Each length slides into the lower length when folded.

TARGET STAFF:

- It is 13 ft. long and consists of two lengths held together by means of a brass clamping screw. One of the lengths can be slided over the other. Both the faces are graduated but in opposite directions. It is facilitated with movable target having a vernier that can facilitate reading.

TEMPORARY ADJUSTMENTS:

- The temporary adjustments consists of setting up, levelling and elimination of parallax.

SETTING UP:

- While locating the level, the ground point should be so chosen that (a) the instrument is not too low or to high to facilitate reading on a bench mark (b) the length of back sight should preferably be not more than 98.0 m and (c) the back sight distance and fore sight distance should be equal. and the foresight should be so located that it advances the line of levels.

- Setting up includes fixing the instrument and approximate levelling by leg adjustment.

FIXING THE INSTRUMENT OVER TRIPOD:

- The clamp screw of the instrument is released. The level is held in the right hand. It is fixed on the tripod by turning round the lower part with the left hand and is firmly screwed over the tripod.

LEG ADJUSTMENT:

- The instrument is placed at a convenient height with the tripod legs spread well apart and so adjusted that the tripod head is nearly horizontal as can be judged by eye. Fix any two legs of the tripod firmly into the ground and move the third leg right or left in a circumferential direction untill the main bubble is approximately at the centre. The third leg is then pushed in to the ground.

LEVELLING UP :

Levelling with a three-screw head:

(1) The clamp is loosened and the upper plate is turned until the longitudinal axis of the plate is parallel to

a line joining any two levelling screws, say A and B.

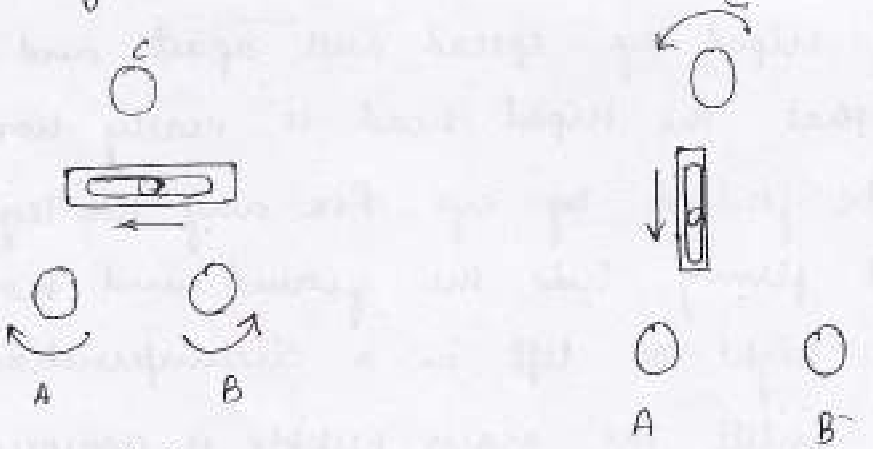
(2) The foot screws are turned uniformly towards eachother or away from each other until the plate bubble is central.

(3) The telescope is rotated through 90° so that it lies over the third foot screw.

(4) The third screw is turned until the plate bubble is central.

(5) The telescope is rotated through 90° to its original position and the above procedure is repeated till the bubble remains central in both the positions.

(6) The telescope is now rotated through 180°. The bubble should remain central if the instrument is in proper adjustment.



(a) (b)

ELIMINATION OF PARALLAX:

- It consists of focussing the eye piece and objective of the level.

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Focussing the eye-piece:

- The operation is done to make the cross-hairs appear distinct and clearly visible. The following steps are involved.

(i) The telescope is directed skywards or a sheet of white paper is held infront of the objective.

(ii) The eyepiece is moved in or out till the cross-hairs appear distinct.

Focussing the objective:

- This operation is done to bring the image of the object in the plane of cross-hairs. The following steps are involved.

(i) The telescope is directed towards the staff.

(ii) The focussing screw is turned untill the image appears clear and sharp.

PERMANENT ADJUSTMENTS:-

- These are the adjustments that are done to set the essential parts of the instrument in their true positions relative to each other.

- For a level, if care is taken to equalize backsight and foresight distances, any error due to imperfect permanent adjustment is eliminated.

PRINCIPAL OF REVERSAL (or) PRINCIPAL OF REVERSION:-

- The testing of the level is based on this principle, which states that if there exists any error in a certain part, it gets doubled by reversing, i.e. revolving the position of that part through 180°.

FUNDEMENTAL LINES OF A LEVEL:-

- These are the axis of the bubble tube, the vertical axis, the axis of telescope, and the line of collimation.

Relationship between fundemental lines:

- There exist fixed relationships between these fundemental lines. These relationships generally get disturbed because of mishandling of the level during its usage in the field and need frequent adjustment.

- The desired relationship of the fundemental lines are as follows:

(1) The vertical axis of the level should be perpendicular to the axis of the plate bubble tube.

(2) The line of collimation should be perpendicular to the vertical axis.

(3) The axis of telescope and the line of collimation should coincide.

- The following two permanent adjustments are required for a dumpy level:

(i) Desired Relation :

To move the vertical axis of the level perpendicular to the axis of the plate bubble tube.

Test :

(a) The instrument is levelled as described under temporary adjustments.

(b) Rotate the telescope through 180°. If the bubble runs out of the bubble tube centre, the adjustment is not in order.

(c) If it is so, count the number of graduations on the bubble tube by which the bubble has run out of its central position.

__Adjustment:__

(a) Bring the bubble halfway back to a central position by using the two foot screws. This makes the vertical axis truly vertical.

(b) Bring the bubble to the centre of its run by means of the capstan screw provided at one of the ends of the bubble tube. This makes the axis of the bubble tube truly horizontal.

(ii) __Desired Relation:__

To make the line of sight perpendicular to the vertical axis (or parallel to the axis of bubble) when the instrument is truly levelled.

Test:

(a) This test is known as the two-peg test.

(b) Choose two suitable points A and B about 60m apart and place the level mid way at C as shown below.

(c) Level the instrument and read the staff at A and B. Calculate the difference in elevation between A and B. The difference will be correct even if the line of sight is not parallel to the axis of tube as the error is directly proportional to the length of sight.

(d) Choose another point D in line with A and B about 15m ahead of B.

(e) Level the instrument at D and again take the observations at A and B.

(f) Calculate the difference in elevations. If it is same as calculated before (step c), the adjustment is correct.

(g) If not, the reading at A will have a bigger error than that at B, since the error is proportional to sight distance.

Adjustment:

(a) The error is removed with the capstan screws securing the diaphragm to the telescope.

(b) Make the diaphragm screws in steps and keep on reading at A and B, till the correct difference is obtained. This is, therefore, a trial and error procedure.

Alternative Adjustment:

(a) Workout the reading that should be obtained at A from D. to make the line of sight horizontal.
Let reading at A from C − reading at B from C = h_1

and reading at A from D − reading at B from D = h_2

Required increase in the reading at A = $(h_1 - h_2) \times \frac{DA}{BA}$

(b) Correct the staff reading at A.

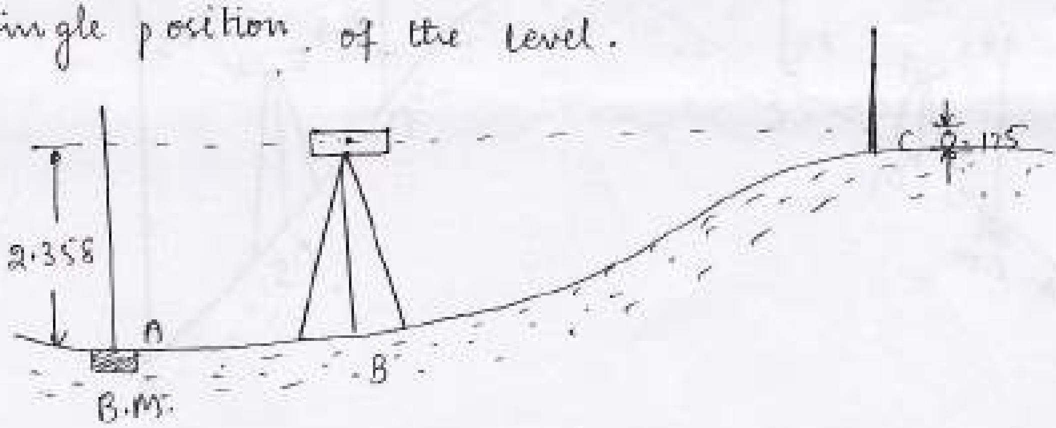
(c) Keep the staff at A and take the observation from D

(d) Diaphragm capstan screws are moved to get the same staff reading as calculated above. (Step a)

PRINCIPLES OF LEVELLING :-

SIMPLE LEVELLING :

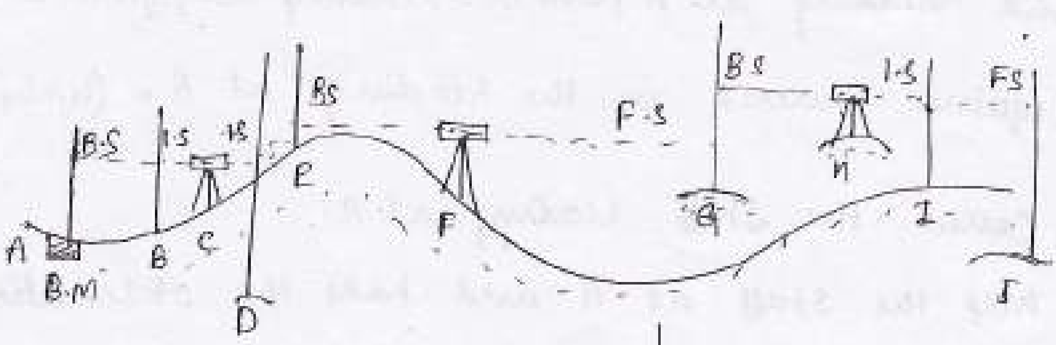
- It is the simplest operation in levelling, when it is required to find the difference in elevation between two points, both of which are visible from a single position of the level.

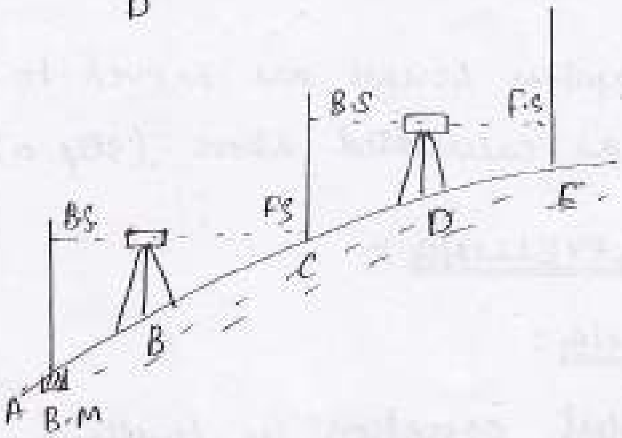


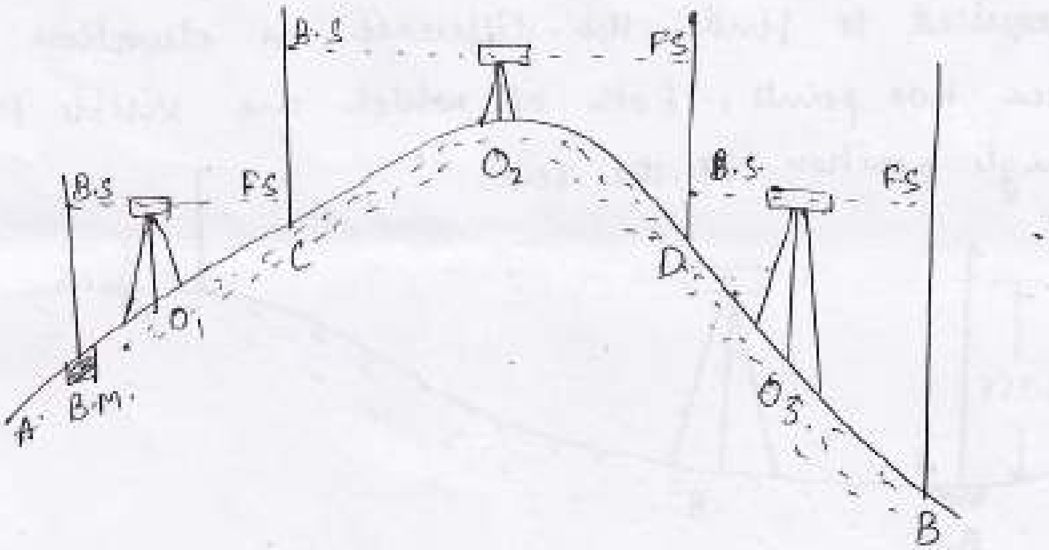
DIFFERENTIAL LEVELLING :

- Determining the difference in elevation between two or more points without any regard to the alignment of the points is called differential levelling.

It is used when (a) two points at a large distance apart (b) the difference in elevation between the two points is large and (c) some obstacle intervenes between the points.

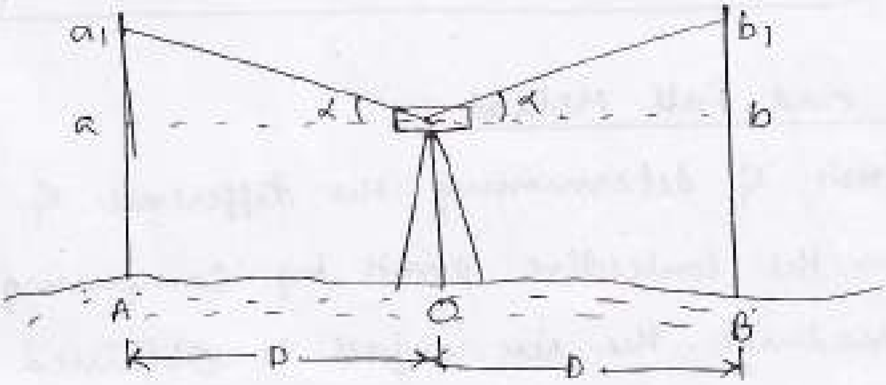






BALANCING BACKSIGHT AND FORESIGHT DISTANCES:-

- The essential condition in levelling is that the line of collimation should be horizontal when the staff readings are being taken. The line of collimation is horizontal only when the bubble is at its centre. But this can seldom be ensured with absolute exactness and usually, when the bubble appears to be central, the line of collimation will make a small angle with the horizontal. Since the error is proportional to the length of sight, the error due to non-parallelism can be eliminated by keeping the lengths of backsight and foresight nearly equal. Therefore, to find the true difference of levels between two points, the level must be kept exactly midway between them, but not necessarily on the line joining them.



BOOKING AND READING THE LEVEL:-

- The observations are recorded in a level book. There are two methods of booking and reading the levels of the points from the observed staff readings.

(1) Collimation Method or Height of Instrument Method:-

- The elevation of plane of collimation or height of instrument for the first setup of the level is determined by adding backsight to the reduced level of a B.M.
- The reduced levels of intermediate points and the first change point are obtained by subtracting the staff readings. The rise or fall is obtained by

subtracting the staff readings taken on these points and a new plane of collimation is set by taking a B.S. on the change point. The height of instrument is obtained by adding this B.S. to its R.L. which was already calculated and the process continues.

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

(V) <u>Rise and Fall Method</u>:

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

Check:

$\Sigma B.S. - \Sigma F.S. = \Sigma \text{Rise} - \Sigma \text{fall} = \text{Last RL} - \text{first R.L}$

METHODS OF LEVELLING:

(1) RECIPROCAL LEVELLING:

- It is the operation of levelling in which the difference in elevation between two points by two sets of observations.
- This method is very useful when the instrument cannot be setup between the two points due to an obstruction such as a valley, river, etc and if the sights are much longer than those which are ordinarily permissible.
- For such long sights the errors of reading the staff the curvature of earth, and the imperfect adjustments of the instrument become prominent. Special methods like reciprocal levelling should be used to minimese these errors.
- In this method the instrument is setup near one point say A on one side on the valley, and a reading is taken on the staff held at A near the instrument and on the staff at B on the other side of valley. Let these reading b would have an error due to curvature, refraction & collimation.
- Let these readings be c and d. The near reading c is without error, where as reading d would contain an error e due to the reasons discussed above. Let h be the true difference of elevation between A and B.

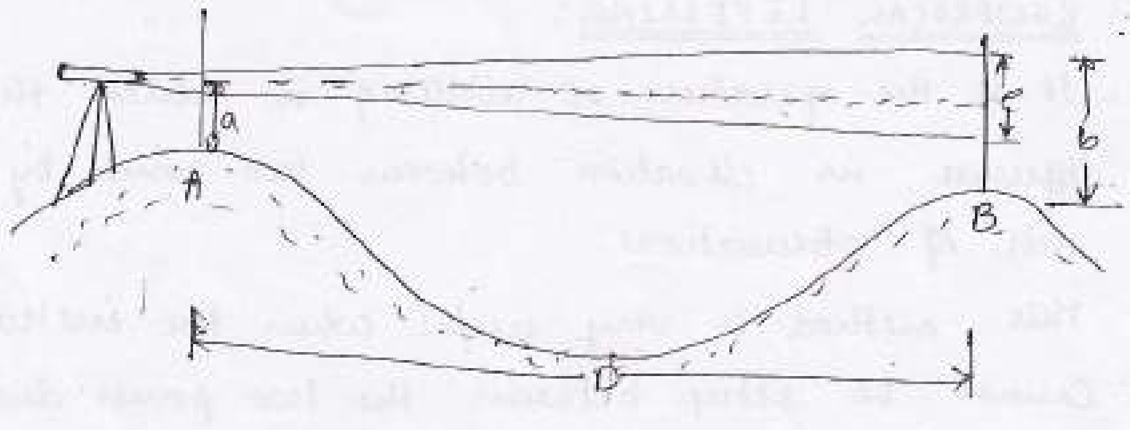


Fig (a)

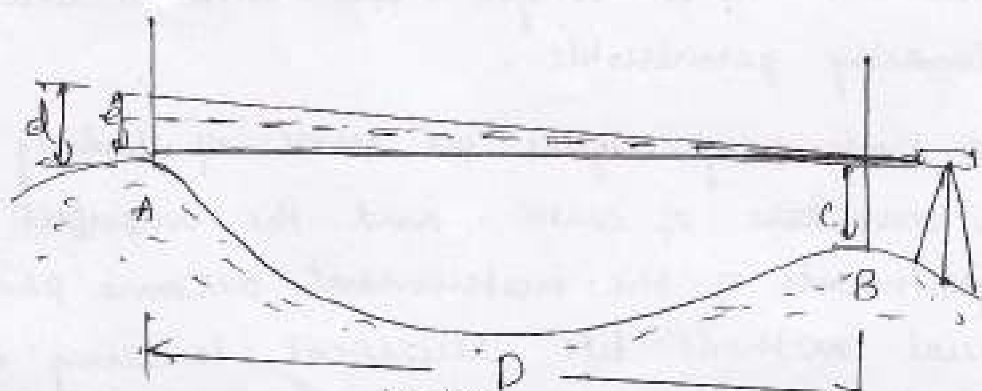


Fig (b)

In the first case (Fig (a))

$$h = (b-e) - a \rightarrow (1)$$

In second case (Fig (b))

$$h = c - (d-e) \rightarrow (2)$$

Adding (1) & (2) we get

$$2h = b - e - a + c - d + e$$

$$2h = b - a - c - d$$

$$2h = (b-a) + (c\ d)$$

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

As 'e' is eliminated like this, therefore reciprocal levelling eliminates the effect of atmospheric refraction and earth curvature, as well as the effect of not adjusting the line of collimation.

(2) PRECISE LEVELLING:

- This is the operation of levelling in which precise instruments are used.
- In ordinary levelling, the distances between check points are relatively short.
- In precise levelling, the level loop may be of substantial length and efforts are made to control all the sources of errors.
- The most important error control in precise levelling is the balancing of foresight and backsight distances. This eliminates the collimation error and errors due to curvature, and minimizes errors due to refraction.
- Temperatures are read at intervals to correct the graduations along the length of the staff.
- Precise levelling is used for establishing benchmarks with high precision.

(3) FLY LEVELLING:

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

(4) CHECK LEVELLING:

- It is the operation of running levels to check the accuracy of the benchmarks previously fixed. At the end of each day's work, a line of levels is run, returning to the B.M. with a view check the work done on that day.

(5) TRIGONOMETRIC LEVELLING:

- This is an indirect method of levelling in which the difference in elevation of the points is determined from the observed vertical angles and measured distances.
- The vertical angles are measured with a transit and the distances are measured directly (plane survey) or computed trigonometrically (geodetic survey).
- This is commonly used in topographical work to find out the elevation of the top of buildings, chimneys, church spires, and so on.

(6) BAROMETRIC LEVELLING:

- The principle used in barometric levelling is that the elevation of a point is inversely proportional to the weight of the air column above the observer.
- The instrument used for measuring pressure is called Barometer. The modified form of a barometer used to find relative elevations of points on the surface of earth is called Altimeter.

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- The method used to measure elevations with an altimeter is known as single Base method. Two altimeters are required. One altimeter is placed at a point of known elevation and the other altimeter is placed at the desired point whose elevation is desired and the readings of these two barometers are noted.

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- The difference in elevation between the two points may be obtained by the following formula.

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$$H = 18336.6 \left(\log_{10} h_1 - \log_{10} h_2\right)\left[1 + \frac{T_1 + T_2}{500}\right]$$

where H = the difference in elevation between two points

h_1, h_2 = the barometric readings (in cm) at the lower and higher points respectively.

T_1, T_2 = temperatures of air (in 0°C) at the lower and higher points respectively.

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(7) HYPSOMETRY:

- The altitude of various points may be obtained by using an instrument known as hypsometer.
- It works on the principle that a liquid boils when its vapour pressure is equal to the atmospheric pressure.
- It may be noted that the boiling point of water is lowered as the pressure decreases i.e., as a higher altitude is attained.

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- This method consists in determining the boiling point temperatures at various station. The corresponding atmospheric pressures may be obtained from the tables. In the absence of tables, the following approximate formula may be used.

$$h = 76.00 \pm 2.679\,t$$

where h = pressure in cm

t = difference of boiling point from 100°c

- The difference in elevation between two points is obtained by

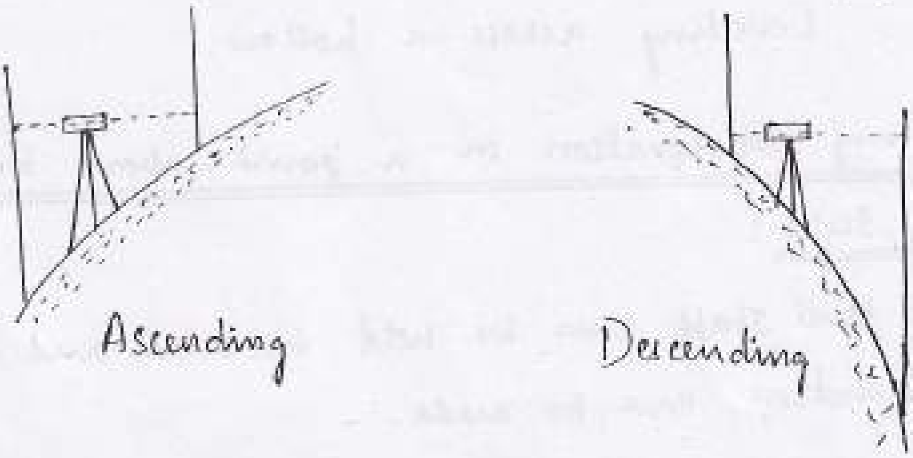
$$H = 18336.6\left(\log_{10} h_1 - \log_{10} h_2\right)\left[1 + \frac{T_1 + T_2}{500}\right]$$

LEVELLING DIFFICULTIES:

(1) Ascending or Descending of a hill:

- A plumb bob must be used to check the verticality of the staff, as it is difficult to ascertain the verticality of the staff on slope.
- While ascending a hill it is difficult to take foresight of the staff, as the staff may be held at a higher level and it is possible to take foresight only near the foot of the staff. Similarly in case of descending a hill, the backsight may be taken at the foot of the staff which is difficult.

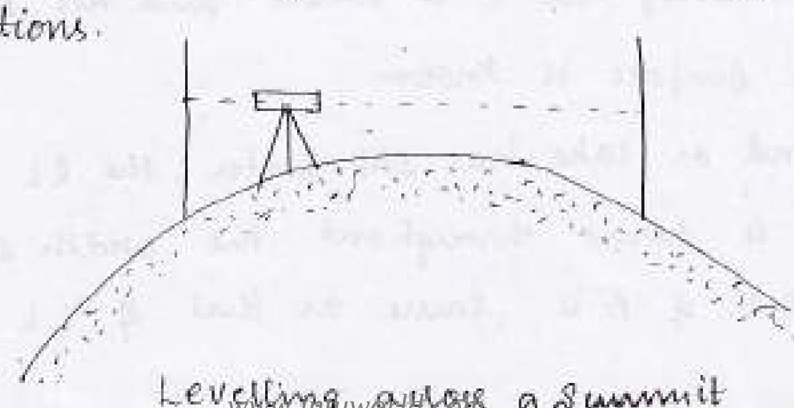
To overcome this difficulty, the Staff is placed near the instrument during a foresight while ascending a hill, and during a backsight while descending the hill. Another way can be to place the instrument away from the line of levels and take zig-zag sights.



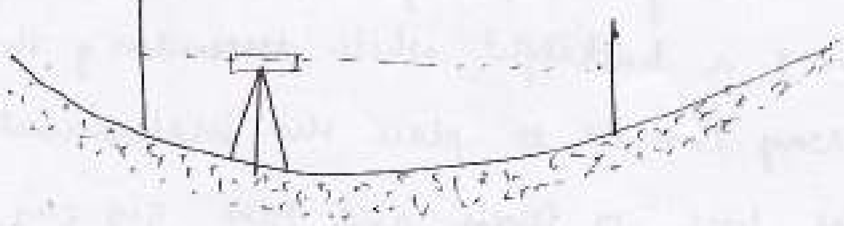
Ascending Descending

(2) Levelling across a Summit or a hollow:

- Care should be exercised in selecting a suitable position for the level when a Summit or a hollow is encountered.
- If the instrument is set on one side of the summit or hollow as shown in fig, a lot of time and effort is saved.
- Also, near the summit the level should be set sufficiently high, and near hollow it should be sufficiently low to facilitate all the required observations.



Levelling across a Summit



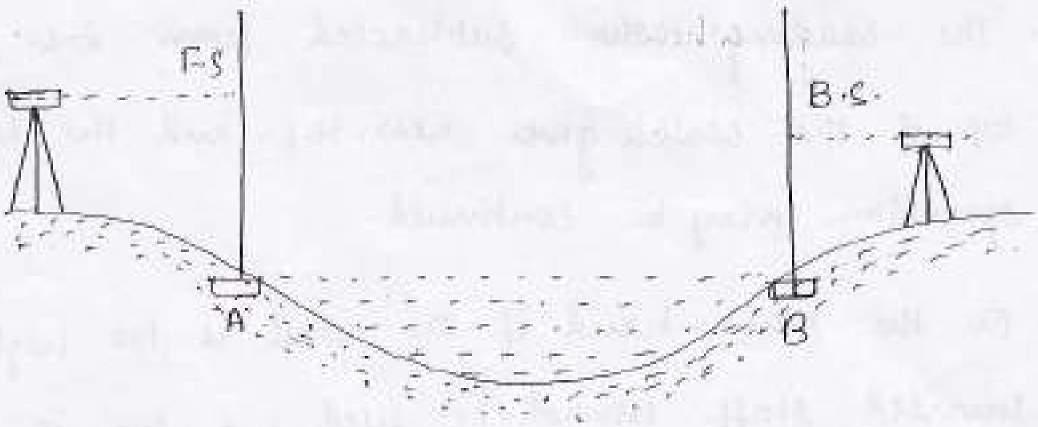
Levelling across a hollow

(3) **Taking observation on a point above the line of sight:**

- The level staff can be held inverted and the observation can be made.
- The staff reading thus obtained is added to the height of instrument instead of subtracting to find the R.L of the point which is above line of sight.

(4) **Ponds and lakes:**

- When a pond or lake is too wide, it cannot be sighted across.
- This can be overcome by driving two pegs say A and B on opposite sides of the pond or lake and flush with the water surface.
- The staff reading at A is taken and the RL of A or the water surface is known.
- As the pond or lake has still water, the RL of surface of water is same throughout the width of water. Therefore R.L. of A is same as that of R.L. of B.



- Now the instrument is shifted to the other side of pond and the staff reading at B is added to the R.L. of B (or A), and H.I. of instrument is known and levelling can be continued.

(5) Levelling Across a River:

- To level across a river, the method of reciprocal levelling is used.

(6) Levelling past a Wall:

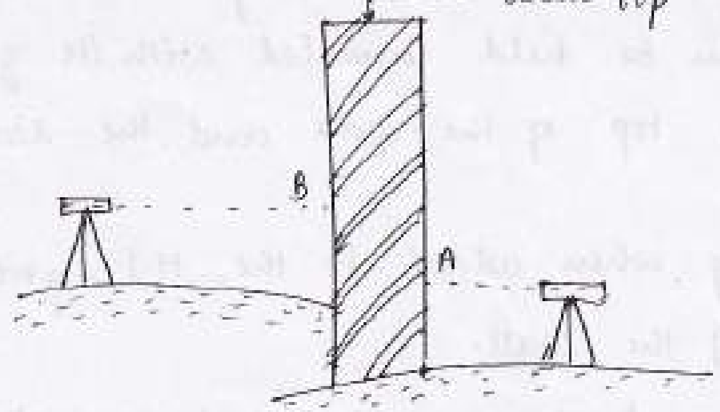
- During levelling, if a wall falls on the course, the R.L. of the top of the wall is found by inverted staff reading when the heigt of the wall above the line of sight is less than the staff length.
- The staff can be held inverted with its zero end touching the top of the wall and the reading is observed.
- This reading when added to the H.I., gives the R.L. of the top of the wall.
- The instrument is then shifted to the other side of the wall. The staff is kept inverted with its zero end, touching the top of the wall and facing the instrument.

Surya

- The reading when subtracted from R.L. of the top of the wall, gives new H.I. and the levelling operation may be continued.

- On the other hand if the wall is too high and an inverted staff cannot be used, a tape is used. With the instrument to one side of the wall, a mark is made on the wall when the line of sight strikes it, say a point A. The height from A to the top of the wall is measured with a tape suspended from the top of the wall. When this height is added to the H.I., the R.L. of the top of the wall is determined.

- The instrument is shifted to the otherside of the wall and same procedure is repeated for measuring the height of wall with same tape as it is done when the instrument was at the previous station



Height when subtracted from the R.L. of the wall gives the new H.I. The levelling operation is then continued

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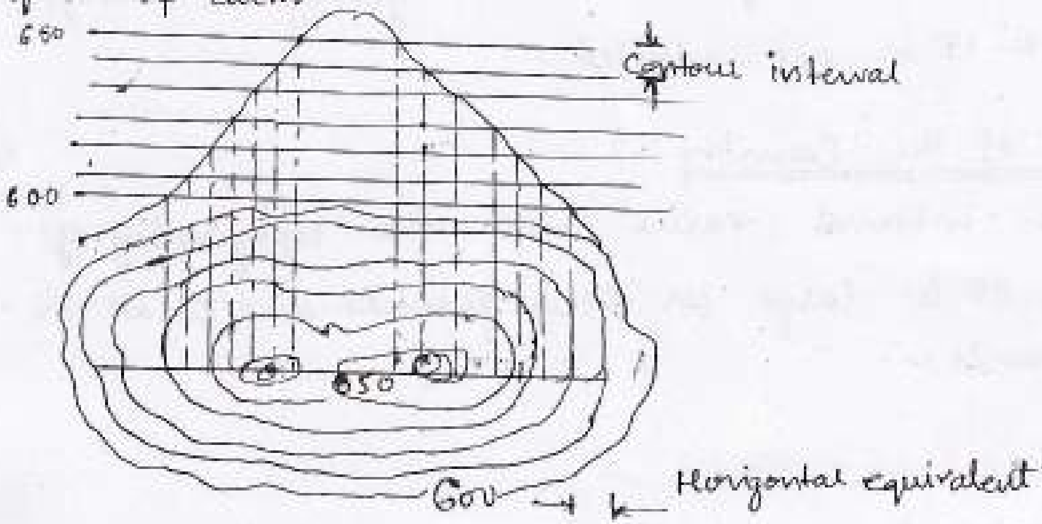
CONTOURING:-

CONTOUR: A contour may be defined as an imaginary passing through points of equal elevation.

(or)

It is defined as the intersection of a level with the surface of earth.



CONTOUR INTERVAL:-

- The vertical distance between consecutive contours is termed as contour interval
- It is desirable to have a constant interval throughout the map.

The contour interval depends on the following factors

(1) **Scale of the Map:**

Contour interval is inversely proportional to the scale of the map. for a topographic map, the interval may range as shown below

Ground Surface	Large scale (1cm = 1-10m)	Intermediate Scale (1cm = 10-100m)	Small scale (1cm = 100m onwards)
Flat	0.2 - 0.5m	0.5 - 1.0m	1 - 3m
Rolling	0.5 - 1m	0.5 - 1.5 m	2 - 5m
Hills	[illegible]	[illegible]	[illegible]

(2) Purpose of the map:

- Contour interval is kept large upto 2.0 m for projects such as highways and railways, whereas it is kept as small as 0.5 m for measurement of earth works, building sites, dams etc. For a city survey, a contour interval of 0.5m may be adopted, and for more extended surveys such as a geological survey, usually 6-15 m are adopted.

(3) Nature of the Country:

- Contour interval varies with the topography of the area. It is large for steep grounds and small for flat grounds.

(4) Time:

- Contour interval is kept large when time is less.

(5) Funds:

- Contour interval is kept large when funds are short and limited.

HORIZONTAL EQUIVALENT:-

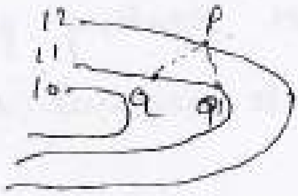
- The horizontal distance between consecutive contours is termed as horizontal equivalent.
- Steeper the ground, lesser the horizontal equivalent.

CONTOUR GRADIENT:

- A line lying on the ground surface throughout and maintaining a constant inclination is called contour gradient.

GRADE CONTOURS:

- The lines having equal gradient along a slope are called grade contours.
- The difference in elevation of two points of grade contours divided by the distance between them is always a constant gradient.



PQ = PQ'

The gradient of PQ = $\frac{(12-11)}{PQ}$

The gradient of PQ' = $\frac{(12-11)}{PQ}$

As PQ = PQ'

$$\therefore \boxed{\frac{12-11}{PQ} = \frac{12-11}{PQ'}}$$

Therefore PQ and PQ' are Grade contours as their gradients are equal.

USES OF CONTOURS:-

(i) With the help of contour map proper and precise location of engineering works such as roads, canals etc can be decided.

(ii) In location of water supply, water distribution and to solve the problems of stream pollution, etc.

(iii) Planning and designing of dams, reservoirs, aqueducts, transmission lines.

(iv) To select sites for new industrial plants.

(v) To ascertain the intervisibility of station.

(vi) To ascertain the profile of the country along any direction.

(vii) To estimate quantity of cutting, filling and the capacity of reservoirs.

GHAT TRACER :-

- This is an instrument used for locating points on a given contour gradient (or) to measure slope or gradient between two points.

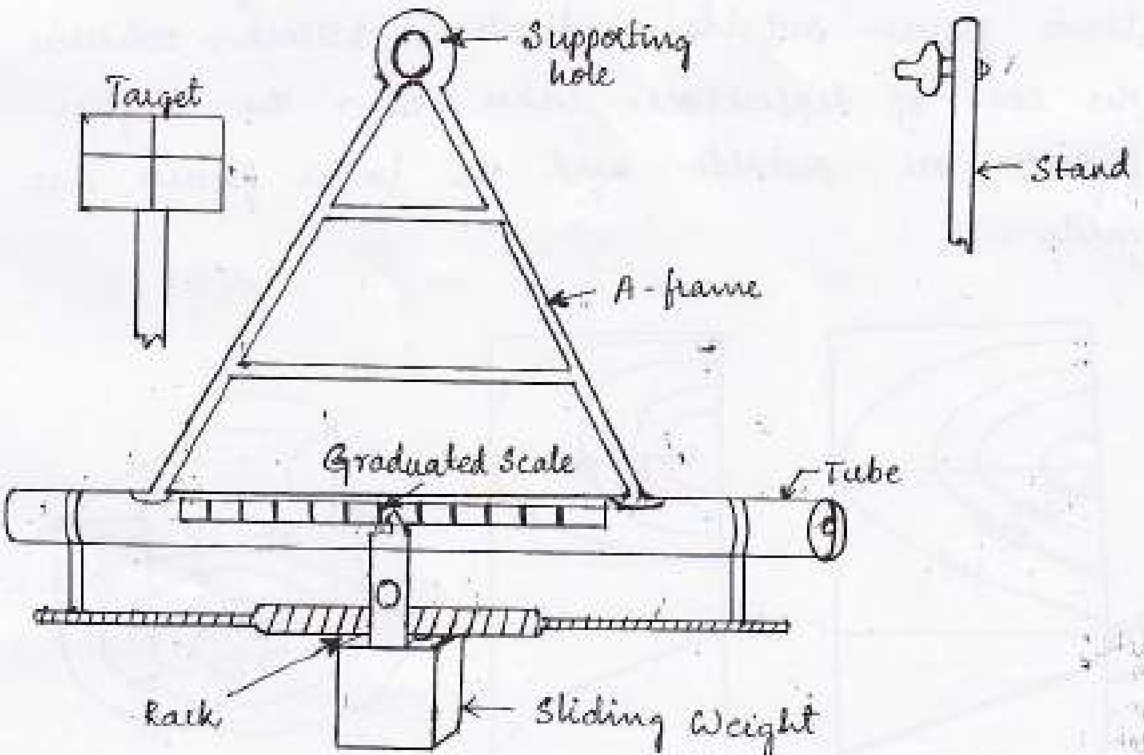
CONSTRUCTION :

- It consists of a hollow tube with an eye-hole at one end and cross wire at the other end to provide a line of sight. It is attached to a sliding A - shaped bracket with a hole for suspension. A weight is attached to the tube.

When the weight is at zero, the line of sight is horizontal. In case the weight is towards the observer, the line of sight is elevated and when towards the cross-wire, it is depressed. The scale attached to the tube gives the gradient.

WORKING :

- The instrument is placed on a point A, with its centre above it on the line, say AB whose gradient is to be measured. The target is placed at the same height as that of the centre of tube and kept on the other point B. The observer sees through the eye-hole and moves the weight till the target is bisected. the corresponding reading on the tube is noted. Incase the points are to be established along a given gradient say 1 in 30, from a point say A, the instrument is kept at A with the reading on the tube as 30. the target, set at the same height as that of the centre of the tube is directed to move along the line of sight till it is bisected. This fixes the point, say B, on the desired gradient. the instrument is moved from A to B and the procedure is repeated for any number of desired points.



GHAT TRACER

CHARACTERISTICS OF CONTOUR LINES:

(i) All the points on a contour line have the same elevation. the elevations of the contour are indicated either by inserting the figure in a break in the respective contour or printed close to the contour.

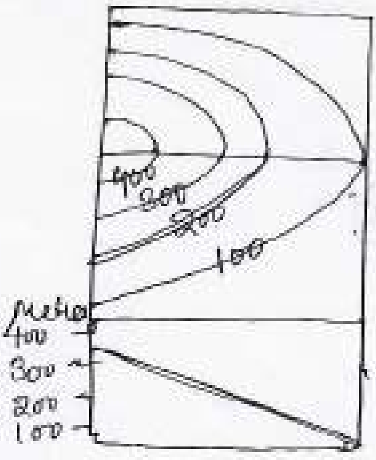
When no value is present, it indicates a flat terrain. A zero meter contour line represents the coast line.

(ii) Two Contour lines do not intersect each other except in the cases of an overhanging cliff or a cave penetrating a hillside.

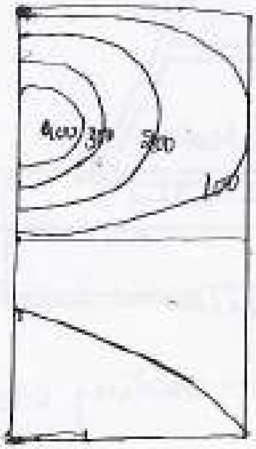
(iii) A Contour line must close onto itself, not necessarily within the limits of a map.

(iv) Equally Spaced contour represent a uniform slope and contours that are well apart indicate a gentle slope.

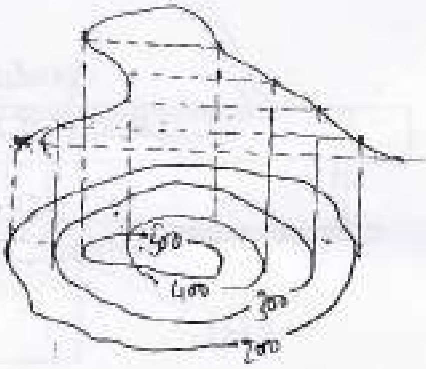
(v) A set of close contours with higher figures inside and lower figures outside indicate a hillock, whereas in the case of depressions, lakes, etc., the higher figures are outside and the lower figures are inside.



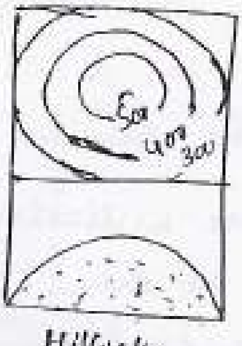
Gentle Slope



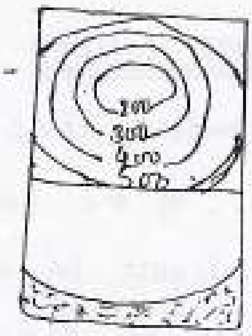
Uniform Slope



Overhanging cliff.

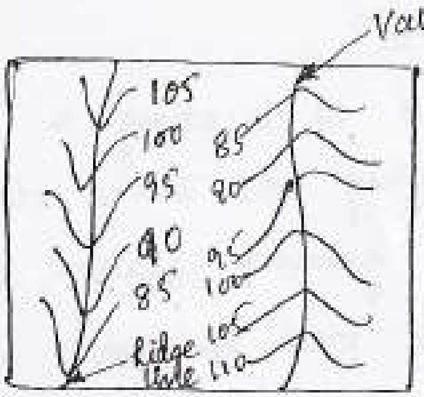


Hillock

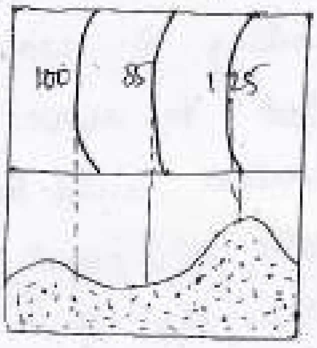


Depression

(vi) A watershed or rigid line (line joining the highest points of a series of hills) and the thalweg or valley line (line joining the lowest points of a valley) cross the contours at right angles.



(vii) Irregular contours represent uneven ground.



Uneven Ground

(viii) The direction of steepest slope is along the shortest distance between the contours. The direction of the steepest slope at a point on a contour is, therefore, at right angles to the contour.

Among PQ, PQ₁ and PQ₂, PQ is the steepest slope in the figure.

METHODS OF CONTOURING:-

DIRECT METHODS:

The field work in contouring consists of horizontal and vertical control. the horizontal control for a small area can be exercised by a chain or tape and by compass, theodilite or plane table for a large area. For vertical control either a level and staff or a hand level may be used.

(1) By Level and Staff:

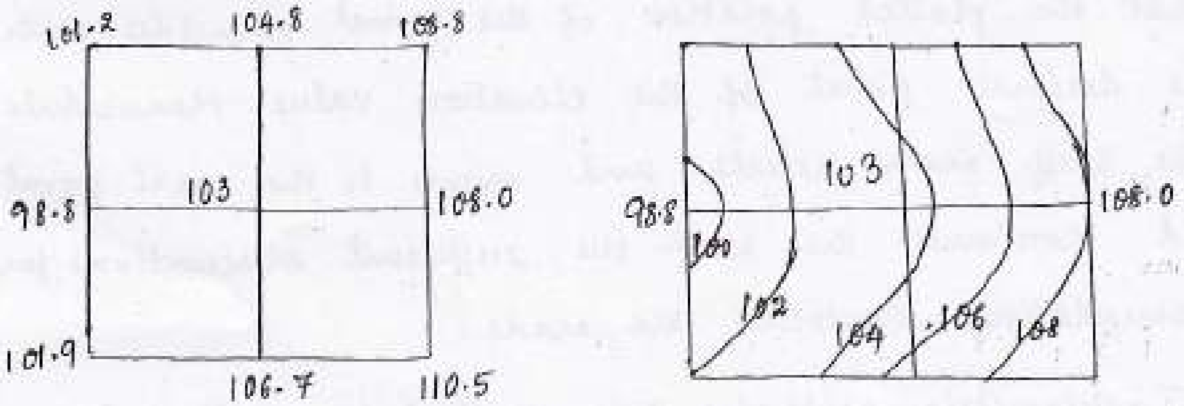
- The method consists of locating a series of points on the ground having the same elevation. To do this an instrument ground station is selected so that it commands a view of most of the area to be surveyed. The height of the instrument is fixed from the nearest benchmark. For a particular contour value, the staff reading is worked out. The staff man is then directed to move right or left along the excepted contour until the required reading is observed. A series of points having the same staff readings, and thus the same elevations, are plotted and joined by a smooth curve.

(2) By hand level:

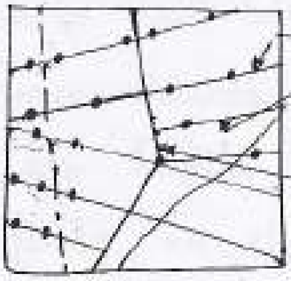
- The principle used is the same as that used in the method using a level and staff. However, this method is very rapid and is preferred for certain works. The instruments used are a hand level, giving an indication of the horizontal line from the eye of the observer, and level staff or a pole having a zero mark at the height of the observers eye and graduated up and down from this point. When an observation is made on the staff or pole, the reading on it is the difference in elevation between the foot of the observer and that of the pole. In this method the instrument man stands over the bench mark and the staff man is moved near to a point on the contour which has to be plotted. As soon as the instrument man observes the required staff reading for a particular contour, he instructs the staff man to stop and locate the position of the point.

INDIRECT METHODS:-

(1) Method of Squares: This is also called coordinate method of locating contours. The entire area is divided into squares or rectangles forming a grid. The elevations of the corners are then determined by spirit levelling. The levels are then interpolated. This method is very suitable for a small open area where contours are required at a close vertical interval.



(2) Method of Cross-Sections: In this method a transit traverse is run. Then suitably spaced sections are projected from traverse lines. The observations are made in the usual manner with a level, clinometer, or theodolite at points on these transverse lines. The contours are then interpolated. This method is suitable for road, railway and canal survey.



(3) Plane table Method : A plane table is placed on the traverse station and an alidade is sighted on a rod with two targets at a fixed distance apart (1-2m). The direction of the line is drawn along the ruling edge of the alidade. With a tangent clinometer the vertical angles are read corresponding to the two targets. The distance and elevation of the staff point is reduced by trigonometric relations. The contours are then interpolated. The observer scales the computed distance along the plotted line to locate the point and writes the computed elevation in such a way that the plotted position of the point coincides with the decimal point of the elevation value. Meanwhile the staff man selects and moves to the next point and continues the work till sufficient observations for interpolating contours are made.

(4) Tacheometric Method : This method is particularly suitable for hilly areas and at places where plane tabling is impractical. First of all, reconnaissance of the area is done and a network of traverses is arranged in such a way that the entire area can be covered. The traverse stations are so chosen that large vertical angles, particularly for long sights are avoided. From these traverse stations a number of

radial lines are drawn at some angular interval depending upon the nature of the country. A tacheometer, fitted with an anallactic lens, is placed on the traverse stations. The observations corresponding to cross-wire, stadia wires and vertical angles are carried out on all the control stations and on the points of detail. The elevations and distances are then calculated and from the observed data, contours are interpolated.

INTERPOLATION OF CONTROLS:-

(1) **By Estimation**: This is a very crude method and is usually adopted where the ground forms are quite regular, the scale of the map is small, and high accuracy is not required. The positions of the contour points between the ground points are estimated and contours are drawn through them. It is assumed that the slope between the ground points is uniform.

(2) **By Arithmetic Calculations**: This method is used when high accuracy is required and the scale of the map is of intermediate or large. In this method the distance between two points of known elevations are accurately measured. Then with the help of arithmetic calculations, the positions of the required elevation points are computed.

Let A and B be two points with RL. 52.60 m and 55.80 m respectively. and at a distance of 16.00 m apart. Let the contour interval be 1.00 m and let it be required to locate a contour between the two points with value 53.00 m. The contour can be located as follows.

Difference of level between A and B = 55.80 − 52.60
= 3.20 m

Difference of level between point A and 53.00 m contour
= 53.00 − 52.60 = 0.40 m

Distance of 53.00 m contour from point A

$$= \frac{0.40}{3.20} \times 16 = 2.00 \text{ m}$$

(3) <u>By Graphical Method:</u> when high accuracy is required and many interpolations are to be made, this method of plotting contours proves to be the most rapid and convinient.

On tracing paper parallel lines are drawn at some fixed interval, say 0.5 m. Every tenth line is made thicker. Let A and B be two points of elevation at 50.50 m and 64.50 m, respectively. The tracing paper is placed with point A on the line 50.50 m and is turned till the point B is on line 64.50 m. The intersections of the line AB and the lines of the required elevation point will give the position of the point on the respective contour.

DETERMINATION OF CAPACITY OF A RESERVOIR BY USING CONTOURS:-

- Reservoirs are made for water supply and for power or irrigation projects. A contour map is very useful to study the possible location of a dam and the volume of water to be confined. All the contours are closed lines within the reservoir area.
- The areas $A_1, A_2, A_3, \ldots, A_n$ between successive contour lines can be determined by a planimeter and if h is the contour interval, the capacity of the reservoir can be estimated by the application of either the trapezoidal or the prismoidal formula.

Trapezoidal formula

$$\text{Volume, } V = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \cdots + A_{n-1}\right]$$

Prismoidal formula

$$\text{Volume, } V = \frac{h}{3}\left[A_1 + A_n + 4(A_2 + A_4 + \cdots + A_{n-1}) + 2(A_3 + A_5 + \cdots + A_{n-2})\right]$$

OPTICAL CHARACTERISTICS OF TELESCOPE:-

Definition: It is the capability of a telescope to produce a sharp image.

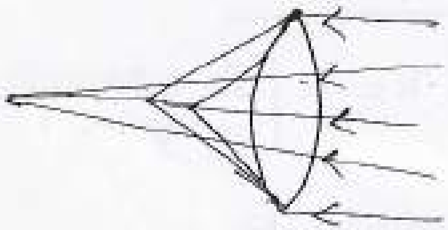
Resolution (or) Resolving Power: It is the power of a telescope to form distinguishable images of objects separated by small angular distances.

Magnification: The apparent increase in the angular size of the object when viewed through a telescope. Compared with the direct view of the same object.

Field of view (or) Size of field: It is the whole circular area seen at one time through the telescope.

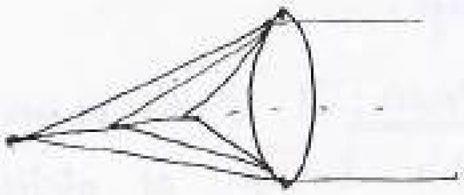
Illumination (or) Brightness: It depends on the magnifying power and the number and quality of lenses. It is inversely proportional to magnification and number of lenses.

Aplanation: Aplanation is the absence of spherical aberration (spherical aberration is the defect of a truly spherical lens, where all the rays are not collected at same point



Spherical aberration

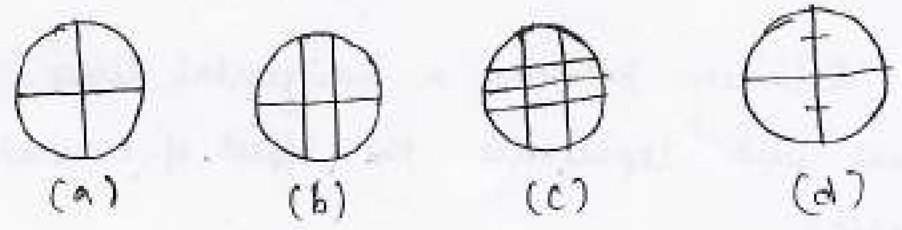
Achromatism: Achromatism is the absence of chromatic aberration (Chromatic aberration is the defect of a lens, where the rays passing through the lens are refracted and converging at different points depending upon the colour of light i.e, VIBGYOR



Chromatic Aberration.

Different types of Diaphragm of Telescope :

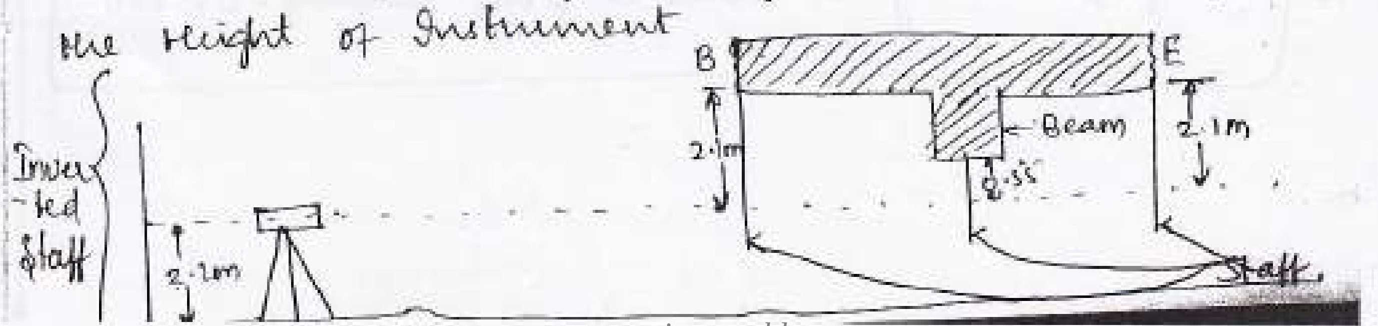
The following are the different types of diaphragms in telescopes.



(a), (b), (c) are used in levels. The horizontal hair is used to read the staff and two vertical hairs enable the surveyor to see if the staff is vertical. The two extra horizontal hairs are used to find the staff intercept while computing distances by Tacheometry.

INVERTED STAFF :-

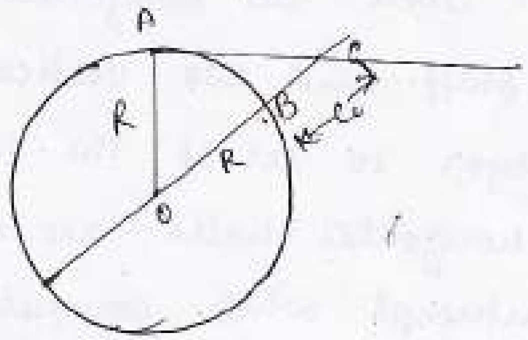
When the point, whose elevation is to be found, is much above the line of sight (i.e. projection from the face of a building, under side of beams, girders arches etc.), the staff is placed inverted with its zero end touching the point. The reading on the staff is taken in the usual manner. Such an observation is entered in the level field book with a minus sign, for convenience. The R.L. of this point can be obtained by simply adding the staff reading to the height of Instrument



CURVATURE AND REFRACTION :-

Curvature Correction (C_c): The effect of curvature is to cause the objects sighted, to appear lower than they really are.

The vertical distance between a horizontal line and the level line represents the effect of curvature of the earth



Here BC = Curvature correction

$\therefore$ BC = C_c is given by the formula $\boxed{\frac{D^2}{2R}}$

where D = Horizontal distance between level and staff = AC

and R = Radius of earth = 6370 km

$$\therefore C_c = \frac{D^2}{2R} = \frac{D^2}{2 \times 6370} = 7.849 \times 10^{-5} D^2 \text{ km}$$

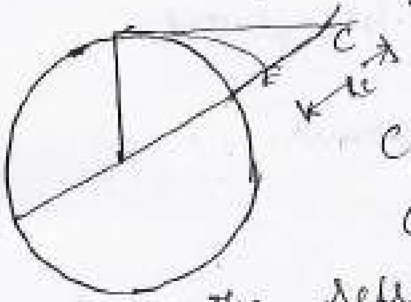
(or)

$$\boxed{C_c = 0.0785 D^2 m}$$

- Since the curvature increase the staff reading, the correction is therefore subtractive

$\therefore$ True staff reading = observed staff reading $- 0.0785 D^2$

Refraction Correction (Rc): The effect of refraction is to make the objects appear higher than they really are



$C_E = R_c$

CE is the amount of refraction correction.

The refraction correction can be taken as 1/7 th of curvature correction

$$R_c = \frac{1}{7} \times C_c = 0.0112\ D^2 m$$
$$(or)\ 1.12 \times 10^{-5}\ D^2\ km$$

The correction due to refraction is additive.

Combined Correction: Since, the effect of curvature and refraction when combined is to make the objects sighted appear low, the overall correction is subtractive.

∴ Combined Correction = $-0.0785 D^2 + 0.0112\ D^2$

(⊖ve sign is used for subtractive nature and ⊕ ve for additive nature)

$= -0.0673\ D^2$ (subtractive) in metres

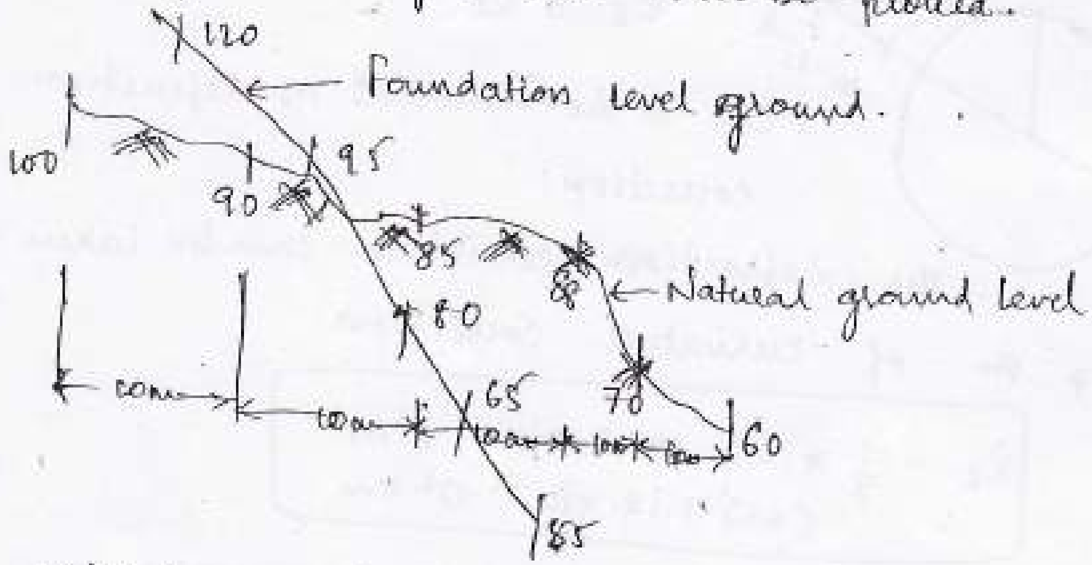
or $6.73 \times 10^{-5}\ D^2 km$

∴ True staff Reading = Observed staff Reading $- 0.0673\ D^2$

PROFILE LEVELLING (or) LONGITUDINAL SECTIONING (L.S):-

- It is the operation to determine the elevations of points spaced apart at known distances along a given line in order to obtain the accurate outline of the surface of the ground profile.

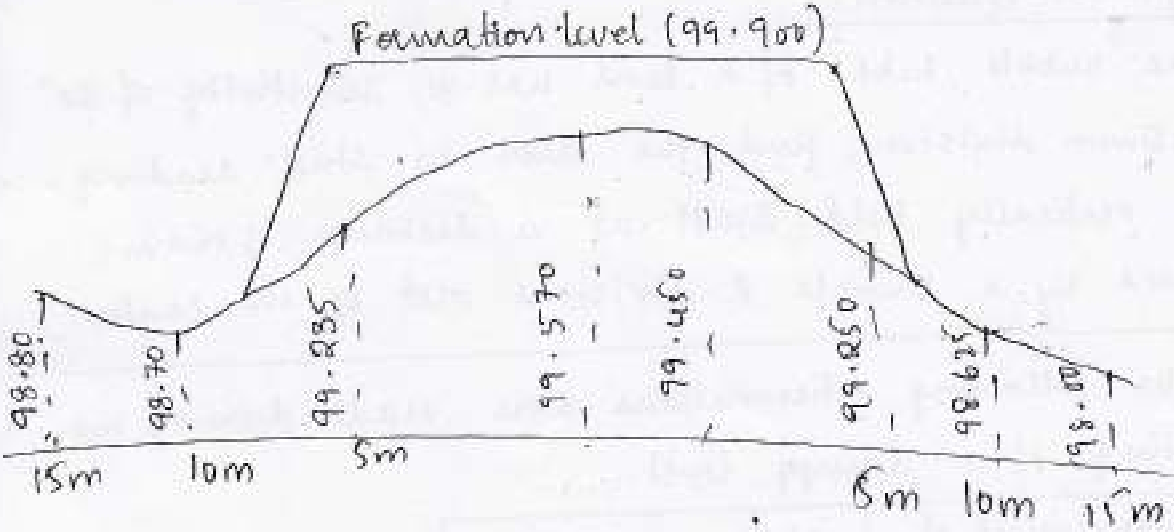
- The purpose of profile levelling is to provide data from which a vertical section of the ground surface along a surveyed line can be plotted.



The natural ground levels (R.L.s) of the ground along the proposed road are calculated. The profiles (or) R.L.s of the natural ground along with the formation levels of the ground are plotted as a graph where the vertical ordinates represent elevations and horizontal ordinates represent horizontal distance between the points.

CROSS-SECTIONING:-

It is the operation of levelling to determine elevation of the points at right angles (across) on either side of the centre of the proposed route. The detailed information regarding the levels of the ground on either side of the longitudinal section helps in computing the quantity of earth work. The cross-sections are plotted in the same manner as longitudinal-sections.



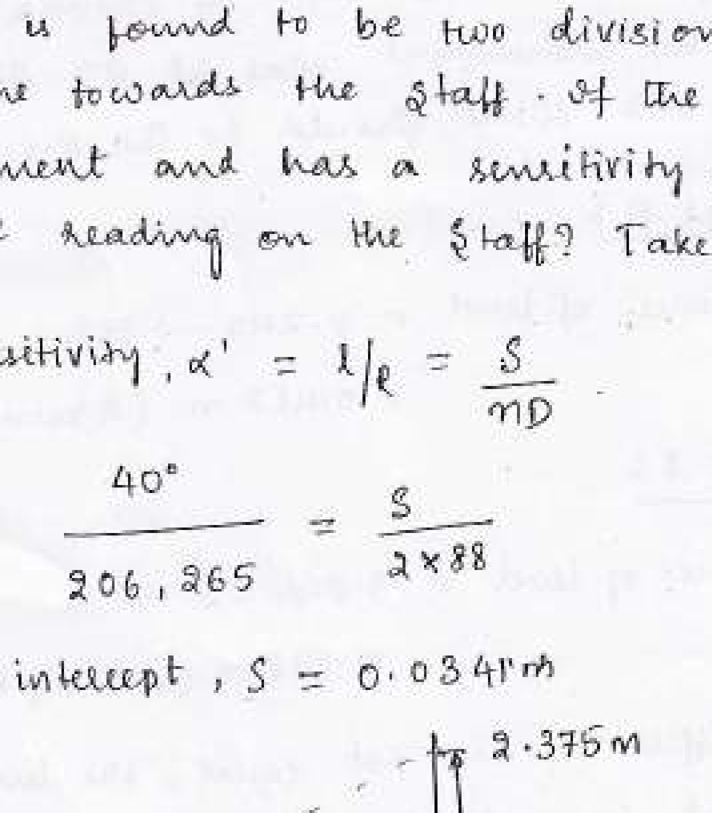
NUMERICALS

1) A level sight on a staff held vertical at distance of 88 m from the instrument reads 2.375 and the bubble is found to be two divisions off the centre of the towards the staff. If the level tube is in adjustment and has a sensitivity of 40", what is the true reading on the staff? Take $\sin 1'' = 1/206{,}265$ radians

Bubble Sensitivity, $\alpha' = l/R = \frac{S}{nD}$

$$\frac{40''}{206{,}265} = \frac{S}{2 \times 88}$$

Staff intercept, $S = 0.0341\text{ m}$



True Reading on staff

$= 2.375 - S$

$= 2.375 - 0.0341$

$= 2.3409 \simeq 2.340\text{m}$ (approximately)

Assignment Question:

If the bubble tube of a level has a sensitivity of 30" per 2mm division, find the error in staff reading, on a vertically held staff at a distance of 150 m, caused by a bubble 2 divisions out of the centre.

(2) The following observations were made during the testing of a dumpy level.

Instrument at	Staff readings on	
	A	B
A	1.792	2.244
B	2.146	3.044

Distance AB = 150 m. Once the instrument in adjustment? To what reading should the line of collimation be adjusted when the instrument was at B? If the R.L. of A = 432.052. What should be the R.L. of B?

Sol: Instrument at A:

Apparent difference of level = 2.244 − 1.792

= 0.452 m (A being higher)

Instrument at B:

Apparent difference of level = 3.044 − 2.146

= 0.898 m (A being higher)

Since the two differences are not equal, the line of collimation is not in adjustment.

True difference of level (true fall from A to B)

$$= \frac{0.452 + 0.898}{2} = 0.675 \text{ m}$$

R.L. of A = 432.052 m

R.L. of B = R.L. of A − true difference of level

(true fall from A to B)

Note : ⊖ve sign is used as there is fall from A to B

R.L. of B = 432.052 − 0.675

= 431.375 m

Collimation error when the instrument is at B.

correct reading on B = 3.044 m

correct reading on A will be

= 3.044 − 0.675

= 2.369 m

The observed reading on A (2.146 m) being less than the correct one (2.369 m), the line of collimation is inclined downwards

the amount of inclination (or) collimation error = 2.369 − 2.146 = 0.223 m

Assignment Question :

The following observations were taken during the testing of a dumpy level.

Instrument at	Staff reading at A	Staff reading at B
A	1.275	2.005
B	1.040	1.660

Once the instrument in adjustment? To what readings should the line of collimation be adjusted when the instrument is at B?

→ (3) The following consecutive readings were taken with a dumpy level: 6.21, 4.92, 6.12, 8.42, 9.1, 6.63, 7.91, 8.26, 9.71, 10.21. The level was shifted after 4th, 6th and 9th readings. The R.L of first point was 125.00. Rule out a page of level field work and fill all the columns. Calculate the reduced levels and apply usual checks by both height of instrument method and rise and fall method.

Sol

Height of Instrument Method:

Station	B.S.	F.S.	I.S.	H.I (or) Collimation	R.L.	Remarks
1	6.21			131.210	125.00	B.M.
2			4.92		126.290	
3			6.12		125.090	
4	9.1	8.42		131.890	122.790	C.P.
5	7.91	6.63		133.170	125.260	C.P
6			8.26		124.910	
7	10.21	9.71		133.670	123.460	C.P.

$\Sigma B.S. = 23.22$; $\Sigma F.S. = 24.76$

Check: $\Sigma B.S. - \Sigma F.S.$ = Last R.L. − First R.L. = −1.54m

Rise and Fall Method

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remark
1	6.21					125.00	B.M.
2		4.92		1.290		126.290	-
3		6.12			1.200	125.090	-
4	9.1		8.42		2.300	122.790	C.P
5	7.91		6.63	2.470		125.260	C.P
6		8.26				124.910	
7	10.21		9.71			123.460	C.P.
	ΣB.S		ΣF.S.	ΣRise	ΣFall		

Check: Σ B.S. − Σ F.S. = Σ Rise − Σ fall = Last R.L. − First R.L. = −1.54

(4) Complete the following level-book and find the R.L's of all stations including BM-A. Also apply the arithmetical check.

B.S.	I.S.	F.S.	Ht. of Collimation	R.L.	Remarks
3.145			514.835	511.690	BM-A
	2.725			512.110	
0.975		1.855	513.955	512.980	C.P.
1.365		2.450	512.870	511.505	C.P.
	0.475			512.395	
2.805		2.405	513.270	510.465	C.P.
3.065		1.685	514.650	511.585	C.P.
1.500		1.400	514.750	513.250	C.P.
		2.750		512.00	B.M-B.
ΣBS = 12.855		ΣFS = 12.545			

Check :-

Σ B.S. − Σ F.S. = 12.855 − 12.545 = 0.310 m

Last R.L. − First R.L. = 512.00 − 511.690 = 0.310 m

∴ Σ B.S. − Σ F.S = Last R.L − First R.L = 0.310 m

Assignment question :

he following consecutive readings were taken with a level and 4.0 m staff on a continuously sloping ground at a common interval of 30 m : 0.780, 1.535, 1.955, 2.430, 2.985, 3.480, 1.155, 1.960, 2.365, 3.640, 0.935, 1.045, 1.630 and 2.545.

The reduced level of the first point A was 180.750 m. Rule out a page of a level field book and enter the bove readings. Calculate reduced levels of points by limation system, and rise and fall system. Apply usual hecks.

(5) Fill up the missing entries. Also apply usual checks

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remarks
1	3.125					124.18	BM
2	2.265		1.800	1.325		125.505	CP
3		2.320			0.055	125.450	
4		1.920		0.400		125.850	
5	1.040		2.655		0.735	125.115	CP
6	1.620		3.205		2.165	122.950	C.P
7		3.625			2.005	120.945	
8			1.480	2.145		123.090	

$\Sigma B.S. = 8.05$; $\Sigma F.S = 9.14$; $\Sigma Rise = 3.87$; $\Sigma fall = 4.96$

Check :

$\Sigma B.S. - \Sigma F.S. = 8.05 - 9.14 = -1.09$

$\Sigma Rise - \Sigma Fall = 3.87 - 4.96 = -1.09$

Last R.L − First R.L. = 123.090 − 124.18 = −1.09

$\therefore \Sigma B.S. - \Sigma F.S. = \Sigma Rise - \Sigma Fall$ = Last RL − First RL = −1.09

Assignment Question:-

Fill in the missing entries and apply usual checks

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remarks
1	5.250					?	B.M
2	1.755		?		0.750	?	C.P
3		1.950				?	
4	?		1.920			?	
5		2.340		1.500		?	
6		?		1.000		?	
7	1.850		2.185			250.00	CP
8		1.575				?	
9		+?				?	
10	?		1.895		1.650	?	CP
11			1.350	0.750		?	Last Point

(6) A dumpy level was setup at L, exactly midway between A and B, 50 m apart. The readings on the staff when held on A and B were, respectively, 1.40 m & 2.40 m. The instrument was then shifted and setup at point L_2 on the line BA produced and 10 m from A. The readings on the staff held at A and B were, respectively 1.50 and 2.60. Determine the correct readings and the R.L. of B if that of A is 200.00

Sol: True difference of elevation when the level is kept midway. = Difference in staff readings.

$$= \underset{(B)}{2.40} - \underset{(A)}{1.40} = 1.00\text{ m}$$ (A being at higher elevation)

Apparent difference of elevation, when the level is kept at a distance of 10m from A

= Difference in staff readings

$$= \underset{(B)}{2.60} - \underset{(A)}{1.50} = 1.10\text{ m}$$ (A being at higher elevation)

Collimation error for a distance of 50 m between A & B

= Difference of true difference of elevation and apparent difference of elevation

$= 1.10 - 1.00 = 0.100$ m

Finding out whether the line of collimation is inclined upwards or downwards:

Assuming staff reading at A is correct, when the level is kept at 10 m from A, as the sight distance is small.

∴ Correct reading at A = 1.50 m

Correct reading at B = Correct reading at A + true difference of elevation

$= 1.500 + 1.00$

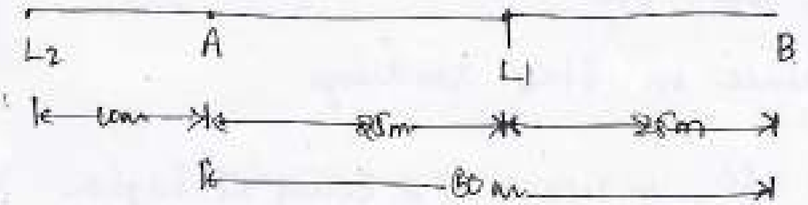
$= 2.500$ m

(+)ve sign is used as A is at higher elevation and staff reading at B would be higher.

But observed reading at B (2.600 m) is more than the correct staff reading at B (2.500 m).

Therefore the line of collimation is inclined upwards

Finding the collimation errors at A and B, when instrument is at L_2:



At A from L_2:

Collimation error for 50m = 0.100 m

Collimation error for 10 m at A = ?

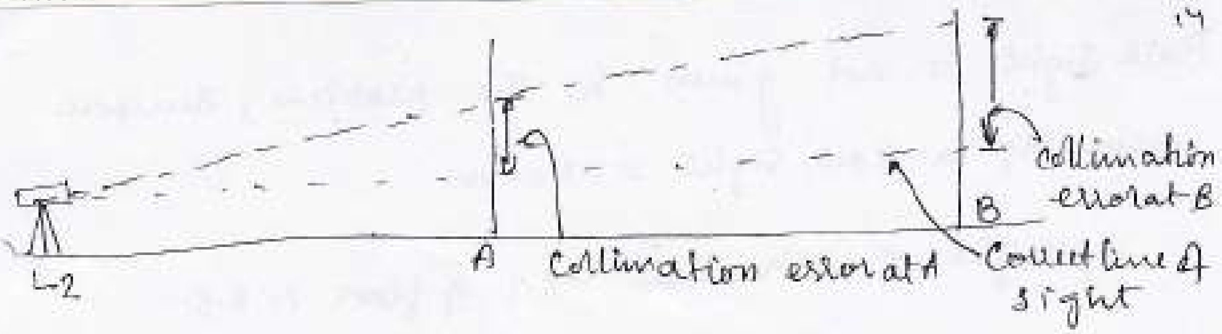
$$\frac{10 \times 0.100}{50} = 0.02 \text{ m}$$

At B from L_2:

collimation error for 50 m = 0.100 m

Collimation error for 60m at B = ?

$$\frac{60}{50} \times 0.100 = 0.120 \text{ m}$$



Correct Staff readings at A and B:

at A = Observed Staff reading − Collimation error at A (at A from L_2)

= 1.500 − 0.020 = 1.480 m

at B = observed Staff reading at B from L_2 − Collimation error at B

= 2.600 − 0.120 = 2.480 m

Note: Error will be deducted from observed Staff readings, if line of Collimation is inclined downwards and added to the observed Staff reading when line of Collimation is inclined downwards.

Check : 2.480 − 1.480 = 1.00 m = True difference of elevation.

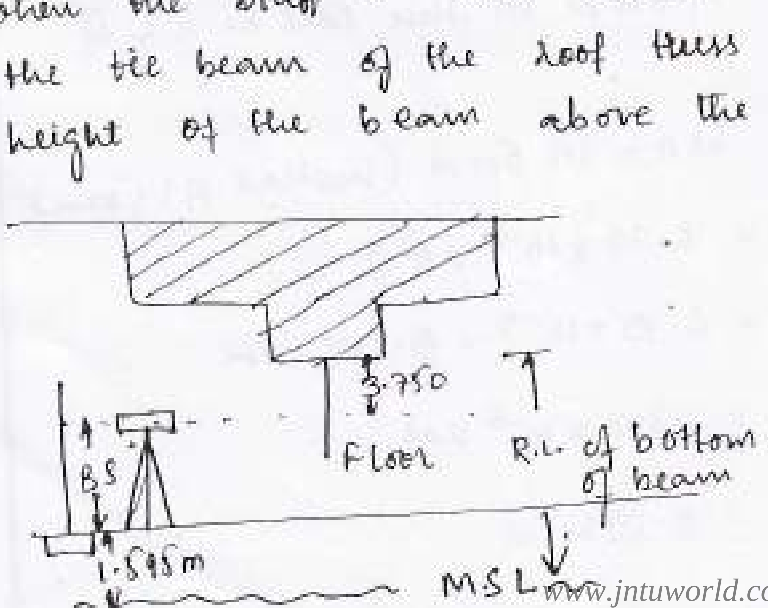
R.L. of B = R.L. of A − True Difference of elevation

= 200.00 − 1.000 = 199.00 m

(True fall from A to B)

→⑦ R.L. of a factory floor is 1.595 m and Staff reading when the Staff is held inverted with bottom touching the tie beam of the roof truss is 3.750 m. Find the height of the beam above the floor.

[R.L. of any point cannot be usually 1.595 m, except where the point is very nearer to the sea]



Back Sight is not given in the Problem, therefore assuming a Back Sight = 1.800 m

$\therefore$ Height of Instrument = R.L. of floor + B.S.

= 1.595 + 1.800 = 3.095 m

R.L. of bottom of beam (as per inverted Staff concept)

= H.I. + Reading on inverted staff

= 3.095 + 3.750 = 6.845 m

Height of the bottom of the beam from the floor

= R.L. of bottom of beam − RL of floor

= 6.845 − 1.595 = 5.250 m

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(8) Find out the difference in levels between points A and B if curvature and refraction effects are taken into consideration for the following case.

R.L. of A = 100.00

Height of Instrument at A = 1.500

Reading of staff at B = 1.800

Distance AB = 450 m

Sol: H.I. at A cannot be 1.500 m in this case as R.L. of A is already 100.00 m.

Therefore assuming H.I. at A = 101.500 m (instead of 1.500 m)

$\therefore$ Combined correction $= 6.73 \times 10^{-5} \times D^2$

$= 6.73 \times 10^{-5} \times (0.45)^2$ km

$= 1.363 \times 10^{-5}$ KM

= 0.0136 m

Sol

Correct staff readings:

When the instrument at A, there is no error

∴ the reading at A would be correct staff reading.

∴ Correct staff reading at A = H.I. − R.L.

= 101.500 − 100.00

= 1.500 m

Correct staff reading at B = Observed staff reading at B − Combined correction

[∵ Combined correction is subtractive]

∴ = 1.800 − 0.0136 = 1.786 m

∴ True difference of levels between A and B

= 1.786 (B) − 1.500 (A) = 0.286 m (True fall from A to B)

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(9) Reciprocal levelling between two points A and B, 630.5m apart, on opposite sides of a river gave the following results:

Instrument at	Height of Instrument	Staff at	Staff reading
A	1.360 m	B	1.585 m
B	1.335 m	A	0.890 m

Determine the difference in levels between A and B and amount of collimation error.

Note: If H.I. is given, R.L should also be given. Therefore in the problem, RL is not given, the H.I. column should be considered as staff reading at instrument itself.

Difference of elevation between A and B is given

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

$= \frac{1}{2}[(1.585-1.360)+(1.335-0.890)]$

$= 0.335\,m$ (True fall from A to B)

Finding out total error:-

instrument at A:

Correct reading at A = 1.360 m

Correct reading at B = observed reading at A + True difference of elevation

(⊕ve sign is used as A is at higher elevation and B is very high staff reading)

$= 1.360 + 0.335 = 1.695\,m$

Total error:

Total error = Difference of obs. reading & correct reading at B

$= 1.695 - 1.585 = 0.110\,m$

Combined error due to curvature and Refractions

$= 6.73 \times 10^{-5} \times D^2\ km = 6.73 \times 10^{-5} \times (0.6305)^2$

$= 2.6754 \times 10^{-5}\ km$

$= 0.0267\,m$

Total error = combined error [curvature correction + Refractive correction] + Collimation error

∴ Collimation error = Total error − Combined error