Introduction :-

Levelling is a method of Surveying used for determination of the difference of Elevations (or) levels of various points on the Surface of the Earth.

The Elevation of a point is its vertical distance above (or) below a reference level, called as Datum. The most commonly used datum is the Mean Sea level (MSL).

Levelling is most commonly used in Engineering works such as :- 1) Design of Highways, railways, Canals Etc.
2) For determining the undulations of the Earth Surface.
3) Layout of construction projects.
4) Controlling the various Elevations in buildings, bridges Etc..

Definition of Mean Sea level (MSL) :-

1) Vertical line :- 1) It is basic line of reference in levelling.
2) It is the line along the direction of gravity

2) Level Surface :-

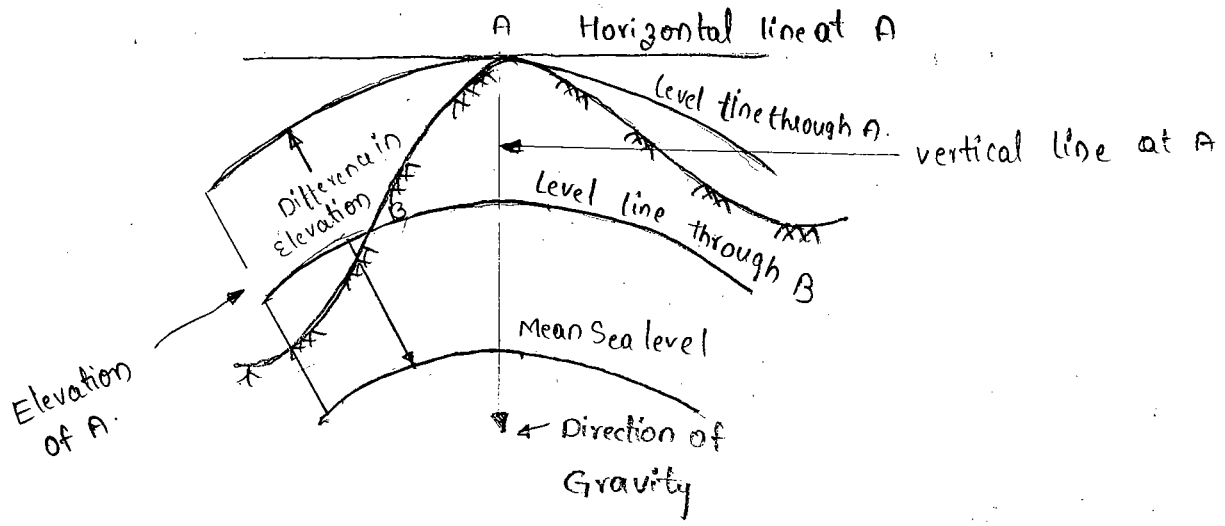
The level surface is a surface that is perpendicular to direction of gravity at every point. It is a curved surface.

Mean Sea level (MSL):-

The Water level in a Sea also represents a level Surface if it is not affected by tides. The mean Sea level is commonly taken as the reference level Surface.

Geoid:- The mean Sea level at a particularly location on Earth if Extended in all directions over the Entire Earth would form an undulating Spheroid ... called geoid.

Basic Definations:-



1) Level line:-

level line is a line lying in a level Surface and it is normal to plumb line at all points And it is a Curved Surface.

2) Datum :- It is a level Surface which is taken as a reference Surface for determination of Elevations of various points.

3) Elevation :- It is the vertical distance of the point above (or) below the datum Surface

4. Altitude :-

It is the vertical distance of the point above mean Sea level, the Elevation is same as the altitude.

5. Difference of Elevations :-

It is the vertical distance between the level Surface passing through the two points.

6. Reduced level (RL) :-

The R.L of a point is its height relative to datum. It is calculated height of point above (or) below the datum.

7. Horizontal plane :-

It is a plane perpendicular to the direction of gravity.

8. Horizontal line :-

It is a line in a horizontal plane, and $\perp^{lar}$ to Vertical line.

9. Vertical plane :-

It is a plane which contains the vertical line at that point. It may be noted that infinite no. of vertical planes can contain a vertical line.

BENCH MARKS (B.M) :-

Bench mark is a permanent reference point whose Elevation (or) reduced level is known. All levelling operations starts from Bench marks

Types of Bench marks :-

The various types of Bench marks are :-

1) Great Trigonometrical Survey Bench mark (GTS) :-

These Bench marks are established through out India by the Survey of India department a Central Govt. agency with head quarters of Dehradon (U.P) with highest degree of precision their positions and Elevations.

(ii) Permanent Bench mark :-

These are the bench marks Established from G.T.S bench marks by the State Govt. agencies in their own states on well defined permanent objects such as top portion of parapet wall of culvert ibridges Etc.

iii) Arbitary Bench mark :-

These are the Bench marks whose Elevations are arbitary anumed for levelling on small area. The Elevations assumed do not refer to any fixed datum as M.S.L.

iv) Temporary Bench mark :-

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.

Different methods of levelling :-

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 w.r.t horizontal line of sight.

Types (or) classifications of direct levelling methods :-

1. Simple levelling :-

This is the easiest method. The method is used for determination the difference of Elevations of two points.

2. Differential levelling :-

This method is used when the two points whose difference of Elevations is required are situated quite apart. (or) when difference of Elevation is high.

3. check levelling :-

It is a type of differential levelling done for the purpose of checking of Elevation which have already been obtained.

4. fly levelling :-

This type of differential leveling is used for the determination of approximately Elevations of different points. The fly levelling is done with rapidity, but low precision is required.

5. Profile leveling :-

This is a type of differential leveling done for the purpose of determining the Elevation of the ground Surface along a fixed line.

6. Cross - Sectioning levelling :-

The profile levelling and cross-Section are similar. This type of differential levelling, is to determine the difference of Elevation of Ground Surface along the lines ⊥lar to centre line.

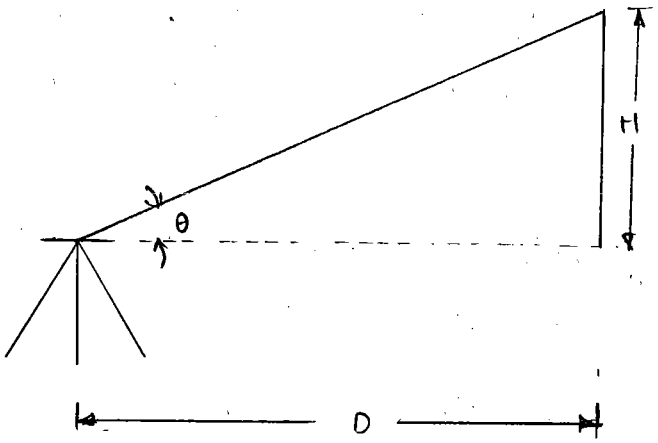
7. Reciprocal levelling :-

8. Hypsometric levelling :-

2. ~~(Hypsometric levelling)~~ -

2. Trigonometric levelling) :-

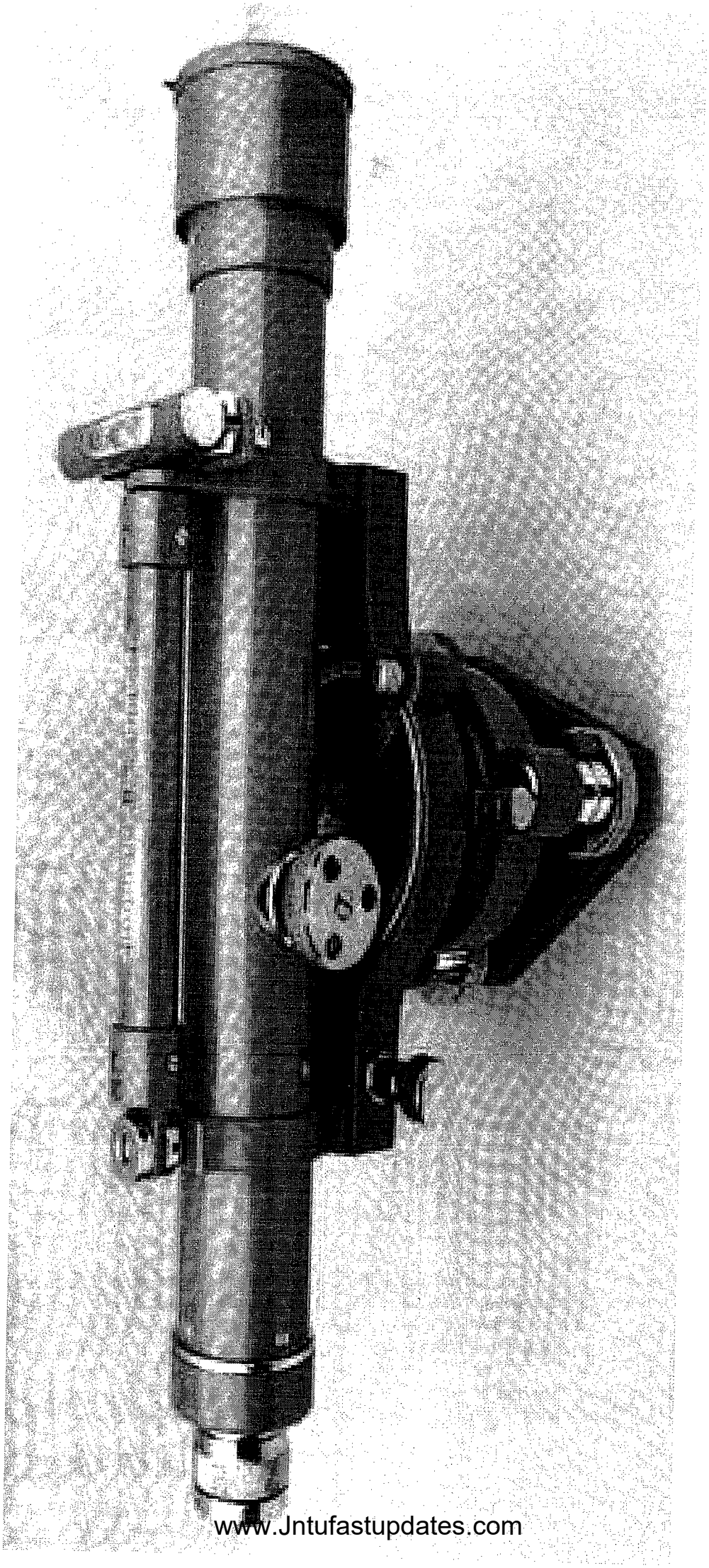
Trigonometric levelling is generally used when direct levelling becomes difficult. For Example, the Elevations of inaccessible points, Such as mountain peaks, top of towers etc .. Can be determined by trigonometric levelling.

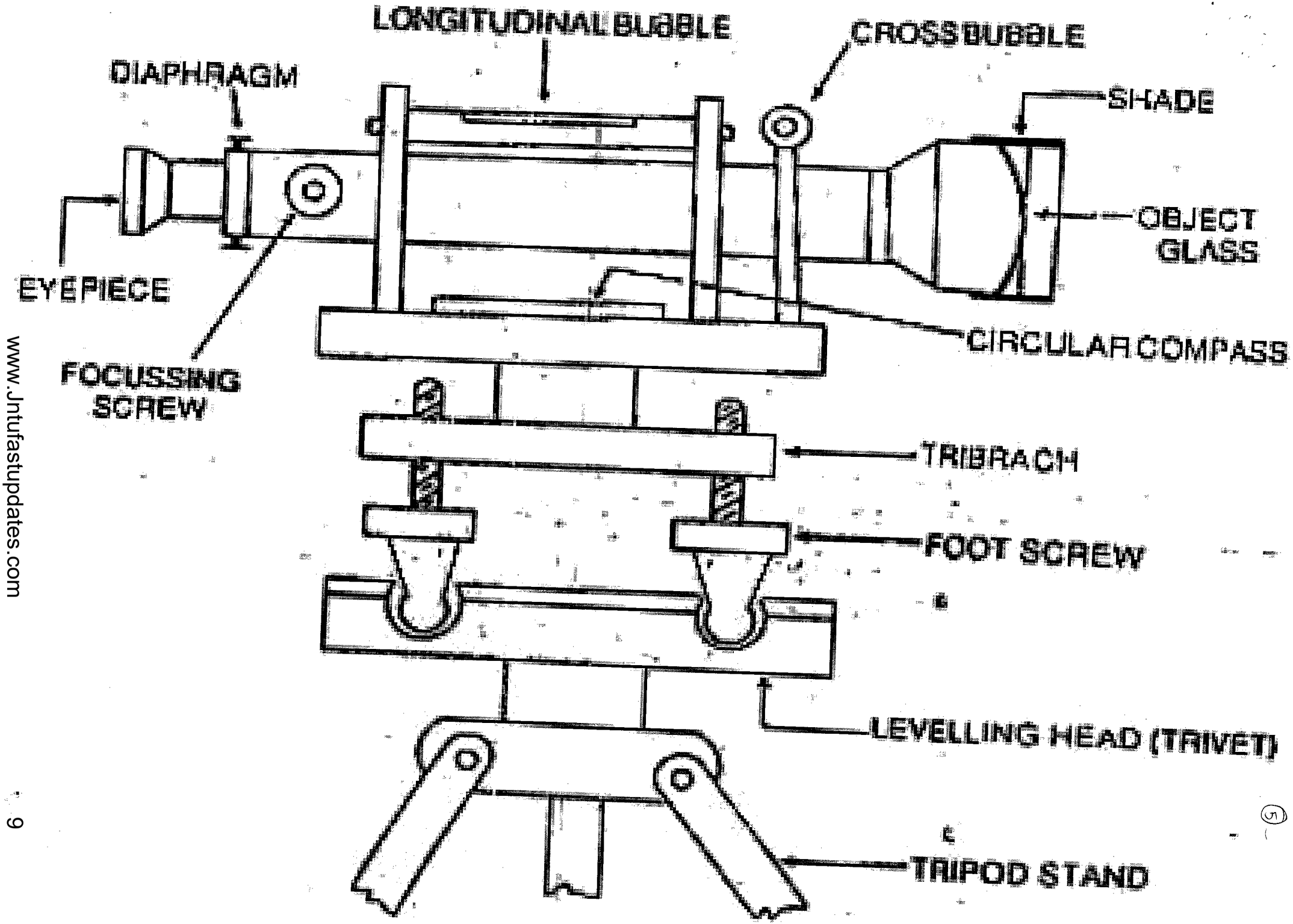


$H = D \tan\theta$

H = Height of the tower

D = Horizontal distance





3. Barometric levelling.
4. Hypsometric levelling.

Types of levelling Instruments :-

(1) Dumpy level
2) Wye level
3) Cushing level
4) Tilting level.

1) Dumpy level :-

1) A levelling instrument, is also called the level, is used for the determination of levels.
2) And in modern form of dumpy level also called " Solid Dumpy level ".
3) The vertical spindle and the telescope can neither be rotated about its longitudinal axis nor removed from its Supports.
4) This levelling instrument is more stable when compared to others and retains its permanent adjustment for a long time.

Parts of Dumpy level :-

1. Telescope
2. Eye-piece
3. Ray Shade
4. object glass
5. longitudinal Bubble.
6. Focusing Screw.

7. Foot Screws
8. levelling head (Trivet)
9. Tribrach
10. Circular Compass
11. Diaphragm
12. Cross-Bubble.

Adjustments of levelling instrument :-

1. Temporary adjustments
2. Permanent adjustments

1. Temporary adjustments :-

(i) Fixing the instrument on the tripod.
(ii) Approximate levelling by tripod legs.
iii) Accurate levelling by foot screws.
iv) Focussing the Eye piece.
v) Focussing the object glass.

(i) Fixing the instrument on the tripod :-

Release the clamp screw of the instrument and hold the instrument in the right hand and fix it on the tripod which has been adjusted to convienient height. Screw the instrument firmly.

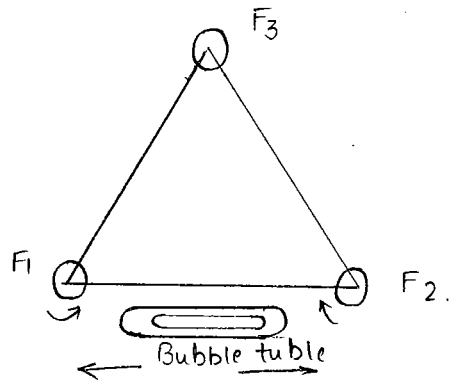
(ii) Leg Adjustment : Approximate levelling :-

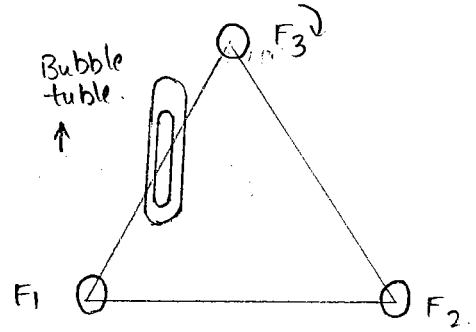
It should be seen that the foot screws are at the centre of their run. By keeping the two legs fixed into the ground

the third leg is moved radially (or) circumferentially till the main bubble and cross bubble are approximately in centre of their runs.

iii) Accurate levelling by foot screws :-

After the approximately levelling by tripod legs, place the telescope parallel to pair of foot screws and bring the bubble to the centre of its run by turning these screws Equally either both inwards (or) both outwards. The telescope is then turned through 90° so that it made to lie over the third foot screws. Then by rotating the third foot screws bring the bubble in the centre. Now the telescope is brought back to its original position and the bubble is again centred and then it process is repeated till bubble remains in centre in both the position





(Temporary) Accurate levelling by three foot screws.

(iv) Focussing the Eye piece :-

Hold a white sheet of paper infront of the objective of telescope at a distance of about 10 to 20cm and rotate the Eye piece until the cross wires are seen distinctly.

v) Focusing the objective (or) object Glass :-

Direct the telescope towards the staff and on looking through the Eye piece bring the image of the staff between the two vertical hairs of the diaphragm. If the clamp and tangent Screw are provided they should be used for correct sighting adjust the objective by turning the focussing Screw until the parallax is removed. It may be noted that the Parallax is completely Eliminated when there is no change in staff reading when Eye is moved up and down.

Terms used in levelling :-

Line of collimation :-

Line of collimation or line of sight is the line joining the point of intersection of the cross wires of the diaphragm to the optical centre of the objective and its imaginary continuation.

Reduced level :-

The Vertical distance measured above (or) below the mean Sea level (or) Bench mark is called as reduced level.

Bench mark :-

Bench mark is a permanent reference point whose Elevation (or) reduced level is known. All levelling operations starts from Bench marks.

Back Sight Reading :-

Back Sight reading is a reading taken by levelling instrument on a levelling staff held at a point whose Elevation is known.

It is the very first reading taken on a Bench mark after Setting up of the instrument.

v) Height of Instrument :-

It is the Elevation of the line of collimation when the levelling instrument is perfectly levelled. The B.S reading is to be added to the R.L of Bench mark, to get the Elevation of the Collimation plane (or) height of collimation.

vi) Fore Sight Reading :-

Fore Sight reading is the staff reading taken on a point whose Elevation is to be found out. It is the last reading taken before shifting the level. This reading is to be Subtracted from the Elevation of plane of collimation to get the reduced level of the station.

vii) Intermediate Sight :-

An intermediate sight (I.S) is any other staff reading taken on a point of unknown Elevation from the same set up of the level. All sights which are taken between the back sight and fore sight are intermediate sights.

viii) change point :- A change point is a point denoting the Shifting the level. It is a point on which fore and back sights are taken.

ix) Station :-

A station is a point whose Elevation is to be determined. It may be noted that Station is a point where the staff is held but not the point where the set up.

Reduction of levels :-

(i) Height of Instrument method (or) Collimation method.

(ii) Rise and fall method.

Height of collimation method :-

1) To known Elevation of point of B.m to be added to Backsight.

2) To known the Reduced level, Subtract intermediate Sight to Height of instrument.

3) If the Station has changed the Subtract H.I to F.S and new R.L is taken and add it to B.S.

Formulas :-

H.I = Bench mark + Back Sight

R.L = H.I - Intermediate Sight

On completing the reduction of levels, the accuracy of arithemetical work can be checked as follows.

Check :-

$\Sigma BS - \Sigma FS$ = First RL - Last RL.

Height of Instrument method:-

(1)

Station	B.S	I.S	F.S	H.I	R.L	
A	0.780			180.780	180.00	B.M
		1.535			179.245	
		1.955			178.825	
		2.430			178.350	
		2.985			177.795	
B	1.155		3.480		177.300	C.P
		1.960			176.495	
		2.365			175.090	
C.	0.935		3.640		174.815	C.P
		1.045			174.905	
		1.630			174.120	
D			2.545		173.205	C.P.
	2.870		9.665			

Check:-

$\Sigma BS - \Sigma FS$ = last RL - first RL

$2.870 - 9.665 = 173.205 - 180.00$

$+6.795 = +6.795$

$6.795 = 6.795$

check is Correct.

(ii) Rise & Fall method :-

(1) In this method the difference of levels between Consecutive points are determined Comparing Each point with that immediatly preceding it.

(2) If the difference is positive then it is Rise
If the difference is negative then it is Fall.

(3) To find the R.L, then if the value is Rise add it.
To find the R.L, when if the value is False Subtract it.

check :-

$\Sigma BS - \Sigma FS$ = Sum of rises - Sum of falls = last RL - first RL

Rise and Fall problem

Eg : 2

Station	BS	IS	F.S	Rise	Fall	R.L
A	1.310					100.00
E		2.100			0.790	99.210
B	1.420		2.245		0.145	99.065
F		1.620			0.200	98.865
C			2.150		0.530	98.335
	2.730		4.395		1.665	

check :-

$\Sigma BS - FS = \Sigma Rise - \Sigma Fall$ = last RL ~~-~~ First RL

$2.730 - 4.395 = 0 - 1.665 = 98.335 - 100.00$.

$-1.665 = -1.665 = -1.665$

check is OK.

Missing Entries in a level book :-

Some of the Entries in a level book are sometimes found missing. Sometimes a Surveyor forgets to record an Entry. In such cases, this method is used.

Station	BS	IS	FS	Rise	Fall	RL	Remarks
1.	2.150					450.000	B.M1
2.	1.645		?	0.500			
3.		2.345			?		
4.	?		1.965	?			
5.	2.050		1.825				
6.		?		?		451.730	
7.	-1.690		?	0.120			B.M2
8.	?		2.100		?		
9.			?	?		449.100	B.M3

F.S of 2nd station = 2.150 - 0.500 = 1.650

Fall at station 3 = 2.345 - 1.645 = 0.700

Rise at station 4 = 2.345 - 1.965 = 0.380

B.S at station 4 = 1.825 - 0.400 = 1.425

Fall at station 8 = 2.100 + 1.690 = 3.790.

R.L :-

Rise at station 6 = 451.730 - 449.780 = 1.950

Rise at Station 9 = 449.100 - 448.060 = 1.040

I.S at station 6 = 2.050 - 1.950 = 0.100

F.S at station 7 = 0.100 - 0.120 = -0.020.

Ans

Station	BS	IS	FS	Rise	Fall	RL	Remarks
1.	2.150					450.00	B.M1
2.	1.645		1.650	0.500		450.500	
3.		2.345			0.700	449.800	
4.	1.425		1.965	0.380		450.180	
5.	2.050		1.825		0.400	449.780	
6.		0.100		1.950		451.730	
7.	-1.690		-0.020	0.120		451.850	B.M2.
8.	2.865		2.100		3.790	448.060	
9.			1.805	1.040		449.100	B.M3
Sum	8.445		9.345	3.990	4.890		

check :-

$\Sigma BS - \Sigma Fall = \Sigma Rise - \Sigma Fall = last\ RL - First\ RL$

$8.445 - 9.345 = 3.990 - 4.890 = 449.100 - 450.000$

$-0.900 = -0.900 = -0.900$

$\therefore$ check is OK.

Comparison between H.I and Rise & Fall method :-

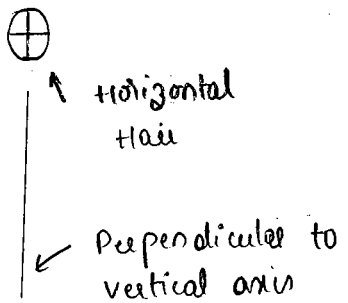
Height of collimation	Rise & Fall
This method is Simple and easy	This method is complicated and some what more tedious
Reduction of level is Easy	Reduction of levels takes more time.
Visualisation is not necessary regarding the nature of the ground.	Visualisation is necessary regarding the nature of ground.
There is no check for intermediate sight reading.	Complete check is there for all reading.

Permanent adjustments of Dumpy level :-

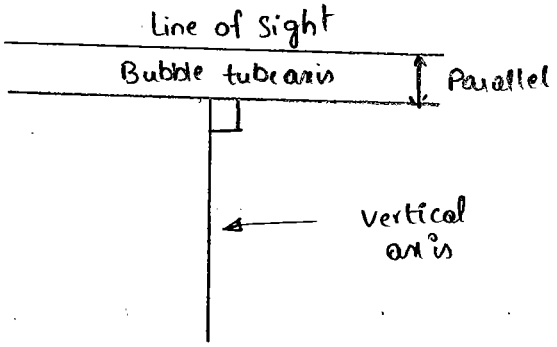
The object of the permanent adjustment of the levelling instrument is to Establish the fixed relationship blw its fundamental axis

For dumpy level to be in proper adjustment the following three conditions should be satisfied.

1) The axis of bubble tube should be $\perp^{lar}$ to vertical axis of the instrument.
2) The Horizontal cross hair should be in a plane $\perp^{lar}$ to vertical axis
3) The line of collimation should be parallel to axis of bubbletube.



Side view :-



Errors in levelling :-

1. Instrumental Error :-
   (i) Error due to imperfect adjustment.
   (ii) Error due to sluggish bubble.
   (iii) Error due to defective staff.
   (iv) Error due to defective tripod.
   v) Error due to faulty focusing tube.

2. Personal Errors :-
   (i) Careless setting up and levelling the instrument
   (ii) Bubble being out of centre.
   (iii) Imperfect focusing.
   (iv) Non-verticality of the staff.
   v) Telescope staff not fully extended
   (vi) Error in sighting.

Errors due to Natural Causes:-

(i) Curvature of Earth and Refraction
(ii) Effect of Sun and Wind.
iii) Variation in temperature.
iv) Shimmering Effect.
v) Settlement of tripod.
vi) Settlement of the turning point.

Mistakes in levelling:-

1. Mistakes in Readings:-

(i) Reading the staff in Wrong direction
(ii) Reading the stadia hairs instead of the central horizontal hair

2. Mistakes in Recording:-

(i) Recording the reading in the Wrong column of the level book.
(ii) Omitting the record of an Entry altogether.

3. Mistakes in Computation:-

The mistakes in Computation can be detected by arithmetic check.

Reciprocal levelling:-

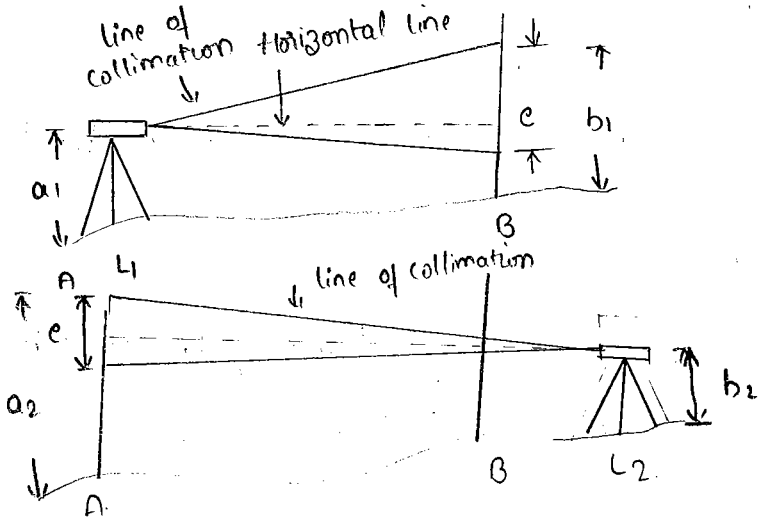
Reciprocal levelling is used to determine the difference of Elevation blw two points which are quite apart and when it is

not possible to Set up the levelling instrument midway blw the points.

Procedure :-

1) Drive pegs at A and B. Set up the instrument near Peg A at L_1 Take reading a_1 and b_1 on the staff holds at A and B respectively. a_1 is taken through the objective L_1 near 'A'

2) Shift the instrument to 'L_2' near the peg B. Take reading a_2 and b_2 on the staff held at A and B. 'b_2' is taken from objective.



let d = true difference between A and B

e = Error due to Curvature & collimation

The correct reading on B in first setup = $b_1 - e$.

from 'A' the true difference blw A & B = $b_1 - e - a_1$

$= (b_1 - a_1 - e) \quad -(1)$

From B the correct reading on A = $a_2 - e$

From B the true difference blw A & B = $b_2 - (a_2 - e)$

$= b_2 - a_2 + e \quad -(2)$

Adding both the Equations

$$2d = b_1 - a_1 - e + b_2 - a_2 + e$$

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

Total Error :-

$$\boxed{e = \frac{(b_1 - a_1) - (b_2 - a_2)}{2}}$$

Note :-

e_c = Error due to Curvature $= -0.0785\, d^2$

e_r = Error due to refraction $= 0.0112\, d^2$

$e_l = e - 0.0785\, d^2 + 0.0112\, d^2$

$= e - 0.0673\, d^2$.

Example on Reciprocal levelling :-

① Reciprocal levelling blw two points A & B 700 m apart on opposite sides of a river gave the following results.

Instrument at	Height of Instrument	Staff above Peg	Staff reading.
A	1.450	1.675	B
B	1.425	0.980	A.

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

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

Difference blw A & B $= \frac{(1.675 - 1.450) + (1.425 - 0.980)}{2}$

$= \frac{0.225 + 0.445}{2}$

$= 0.335$

Total Error $= \frac{(b_1 - a_1) - (b_2 - a_2)}{2}$

$= \frac{(0.225 - 0.445)}{2}$

$= -0.11$ m

Collimation Error : $-0.11 - 0.0673\, d^2$.

$= -0.11 - 0.0673 \times \left(\frac{700}{1000}\right)^2$.

$= -0.11 - 0.0673 \times (0.7)^2$

$= -0.11 - 0.3297$

$= -0.14297$ in 700 mts

Contouring :-

A contour is an imaginary line on the ground obtained by joining points having same Elevation. It is the line of intersection of a level surface with the surface of the ground.

If several points on the ground surface having same elevation are plotted on plan or map, then the line joining these points is known as a 'contour line'.

Contour interval :-

(i) The vertical distance b/w any two consecutive contours is known as the contour intervals.

(ii) Horizontal Equivalent :-

The horizontal distance b/w any two consecutive contours is known as the horizontal Equivalent.

(iii) Purpose of the Map :-

The contour interval selected should be small so that the map serves the intended purpose. But at same time, it should not be too small for larger works, otherwise the cost of the work would be prohibitive.

(iv) Nature of Ground Surface :-

The contour interval depends on the nature of the ground. Flatter the ground surface, smaller will be the contour interval and more broken the ground, greater will be contour interval, so that they do not come to close Each other

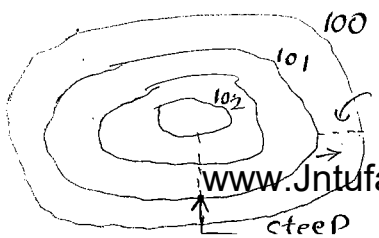
vi) Time and funds available for the Survey work :-

Smaller the contour intervals the Survey work will be more and the time and funds required will be more and vice versa.

S.NO	Purposes	Scale	Contour interval.
1.	Building sites	1:1000 or less	0.2 to 0.5m
2.	For reservoir sites and town planning work	1:5000 (or) 1:10000	0.5 to 2m
3.	location Survey	1:5000 to 1:20000	1 to 3m
4.	Topographical Survey	1:20000	3m (or) above.

characteristics of Contours :-

1. The contour lines are closed curves. However, they may close either on the map itself (or) outside the map, depending upon the topography.
2. As the perpendicular distance blw contour lines is the shortest distance, contours are always perpendicular to the direction of the steepest slope.
3. The Spacing blw contour lines depends upon the slope of the ground. In steep slopes, the spacing is small, but for gentle slopes, the spacing is large. As the difference of elevations blw two contour is constant.

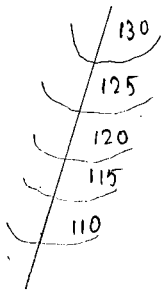


(4) If the contour lines are Equally Spaced they indicates a uniform slope

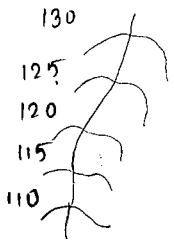
(5) If the contour lines are parallel, straight and Equally placed they represent a plane Surface.

← Plane Surface.

(6) A ridge line (Water Shed line) is indicated when the values inside the bend (or) loop are higher values where as a valley line is indicated when lower values are inside the bend (or) loop.

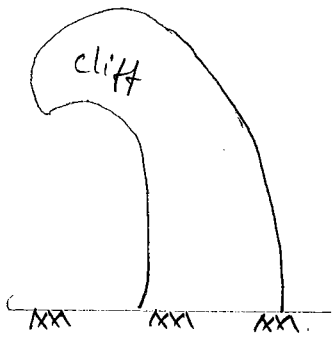


(a) Ridge line



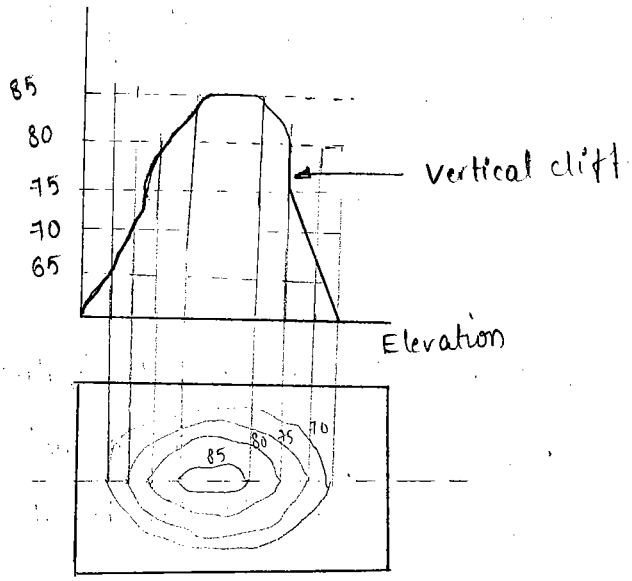
(b) Valley line.

7) A contour line has its own Elevation and therefore two Contour lines having different elevations will never intersect Each other, except in case of an Over hanging cliff.

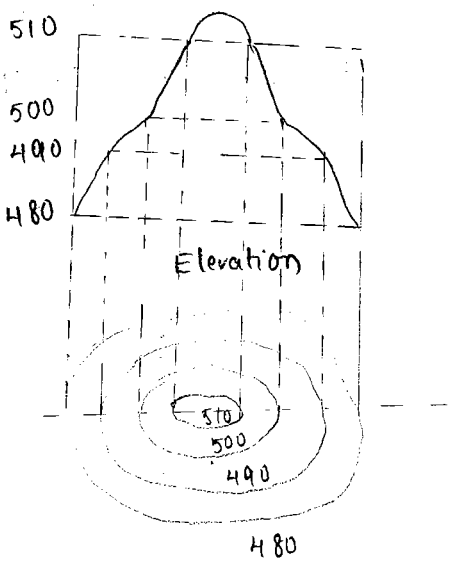


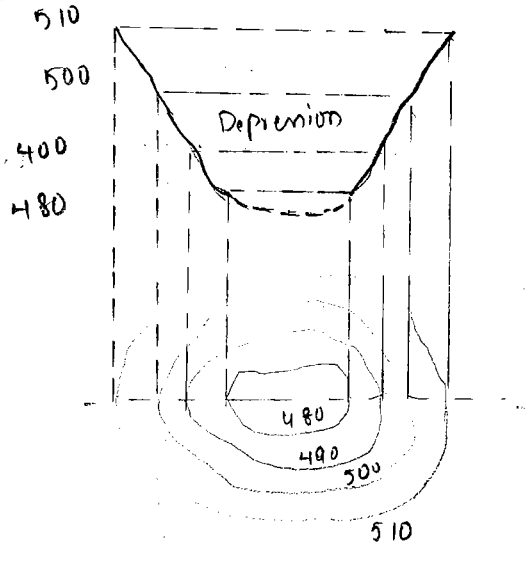
(a) Over hanging cliff (Elevation)

(8) When horizontal Equivalent blw the Contour lines is Zero they coincide to form a One line and indicate a vertical cliff.

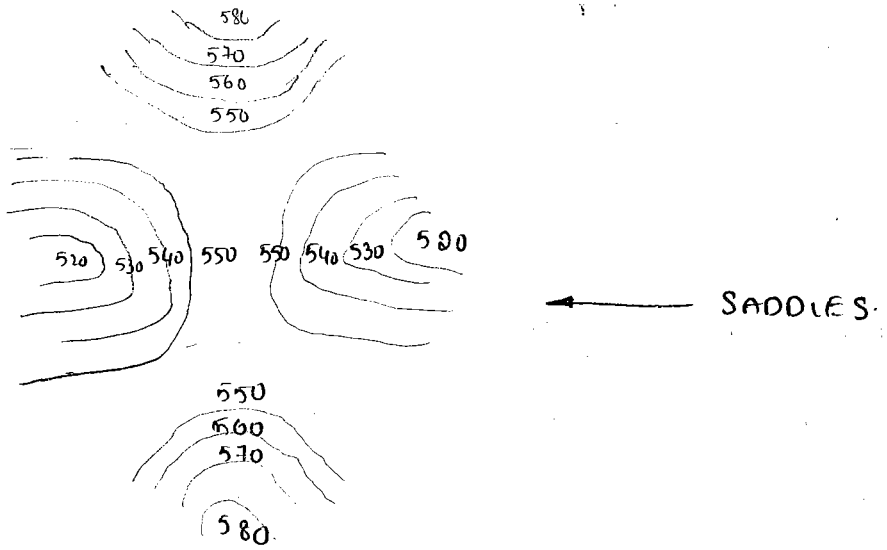


(9) A Series of closed Contour lines on the plan or map indicates Either hill or depression. In case of hill the value of Elevation go on increasing towards the center where as in case of depression these values goes on decreasing towards Centre





(9) The contour lines form fair loops in the case of 'saddles'. In this case the ground is sloping upwards on two sides and sloping downwards on the other two sides.



(10) Irregular contours indicate rough rugged terrain where as smooth contour denote gradual slopes and changes.

Uses of contour :-

(1) By inspection of a contour map information regarding the character of the tract of the country is obtained whether it is flat, undulating or, mountainous etc.

2) Selection of Suitable Site :-

The most suitable site for various Engineering works such as a reservoir, canal, sewer, road & railway may be selected if the contour map of area is available. The contour map will help in the preliminary selection.

Earth Work:-

The quantities of Earth work may be Computed from the contour maps.

4) Area of drainage (basins) (or) basin:-

Contours may be used to determine the area of drainage basin and capacity of the reservoir

(5) Intervisibility between two points:-

The contour map can be used to determine the visibility b/w two points on the Surface.

(6) location of a Route:-

A contour map is Extremely useful for locating the route of a highway, railway, Canal (or) Sewer line at a gradient line. This process is also known as the tracing of contour gradient

(7) Military operations can be planned with the help of contour maps.

Methods of Contouring :-

The methods of locating Contours depend upon the instruments using and available and the use of Contour map. For locating the point on the ground on a contour, its position is a horizontal plane and its Elevation Should be Known

The various methods of locating Contours may be classified as

(1) Direct method

(2) Indirect method

Direct method :-

In this method, the Contours to be plotted are actually located on the ground with a level by making various points on each contour. The horizontal positions of the points so located is then determined and the points are plotted on the plan.

Procedure :-

1) For locating the points of the Same Elevation, the instrument is Set up in a Commanding position L_1 in the area and accurately levelled.

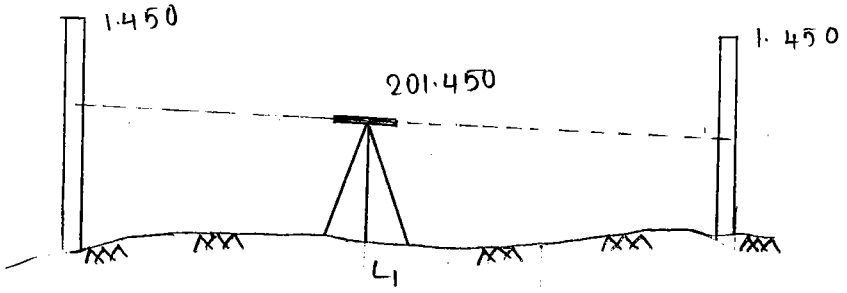
2) The Height of collimation is determined after taking a B.S on the B.M.

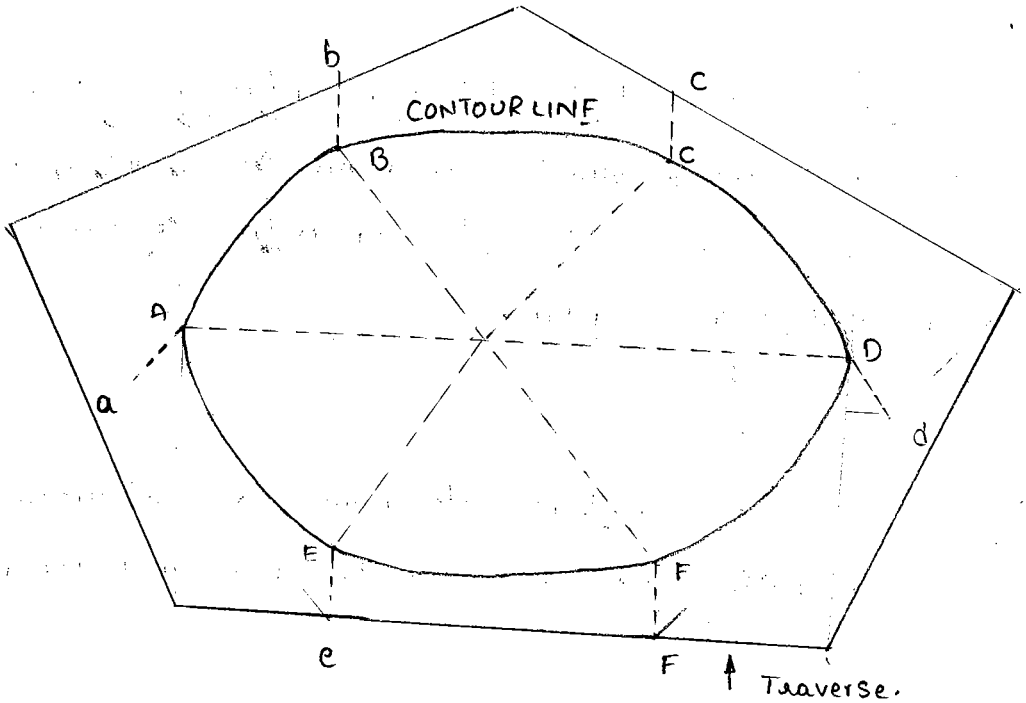
3) From the known H.I the required staff readings to fix points on various Contour points are obtained.

Illustration :-

let the H.I = 202.50

let the R.L of contour of 200.00 is to be traced on the ground.





(4) All the points which give a staff reading of 2.50 will be on the Contour of 200.00

(5) To locate the R.L of contour 199.00 the staff reading for other Contour can be determined.

(6) The instrument man directs the staff man to move until the staff reading of 2.50 is obtained to locate the Contour of 200.

7) The points so determined is marked by means of stake.

(8) All the points such as A, B, C, D, E and F are located on the Contour.

9) These points are to be Conducted by Compas Survey (or) plane table Survey.

(10) The points are then plotted on the plan and contours drawn by joining them by dotted curved lines.

Advantages of Direct method :-

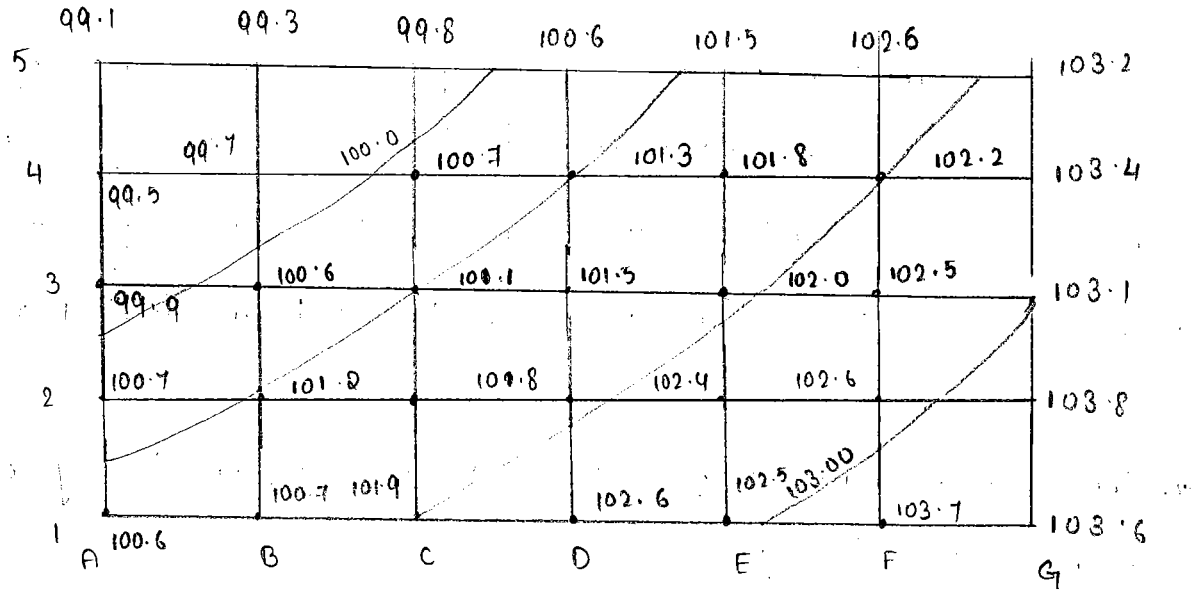
1) The method is more accurate than the indirect methods, as the points are directly located on the Contour

Disadvantages :-

This method is slow and tedious. It is not suitable for contouring large areas.

Indirect methods of Contouring :-

(i) Grid method :-



1) The grid method is used when the area to be contoured is not very large and the ground is not much undulating.

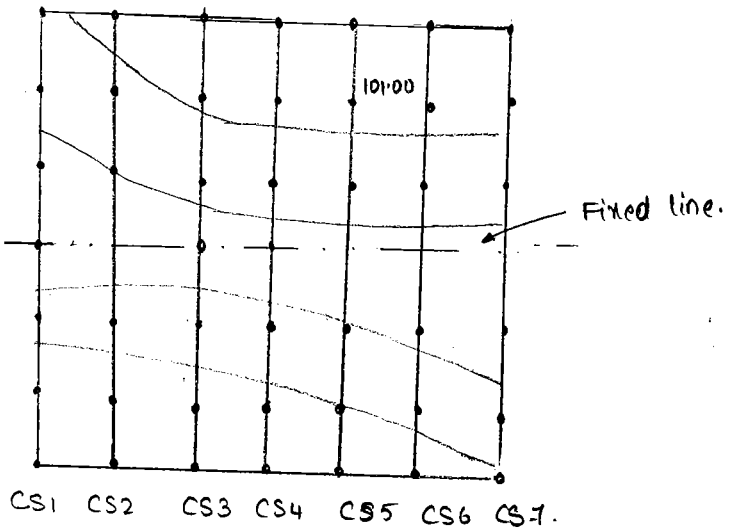
2) If the area is not large, it is divided into a grid of series of squares The grid size may vary from 5m x 5m x 25m x 25m depending upon the nature of the ground, the contour interval and scale of the map. The grid corner are marked on ground and spot levels of these corners are determined.

3) The grid is plotted to the scale of the map and the spot levels of the grid corners are entered, the contours of desired values are then locked by interpolation

(4) Theodeolite is used to layout the lines at right angles to each other

(5) Tape or, cross staff may also be used if theodeolite is not available.

(b) Cross- Section method :-



(1) The cls method is generally used for the determination of contour along a fixed route such as canal, road, railway etc.

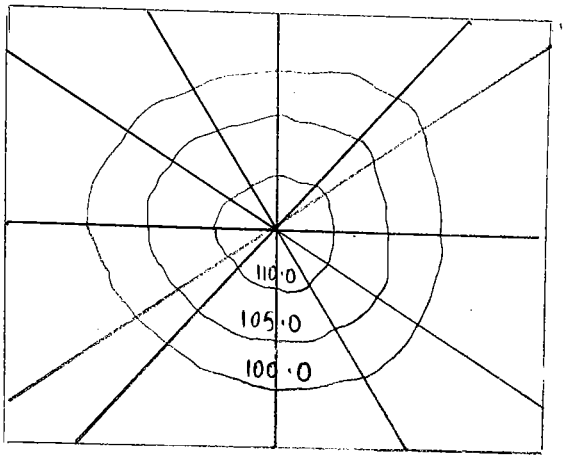
(2) cross-sections are located on the ground at right angles to fixed line at route.

(3) The cls line may be inclined at any angle to the centre line is necessary.

(4) The spacing should be kept small in ravines where contour change its direction.

(5) Finally, All points are plotted and interpolated.

3) Radial line method:-



For Contouring Small hilly areas, radial lines are run from the peak to cover the area. The guide points are taken on the radial lines and their Elevation are determined. The Contour lines are drawn by interpolation.

Direct method	Indirect method.
Most accurate but slow	Not so accurate but rapid
Expensive	cheaper
Not Suitable for hilly areas	Suitable for hilly areas
During the work Calculation can be done	Calculation are not required in the field.
calculation cannot be checked after Contouring	Calculation can be checked as and when required