Leveling and Its Objective

Leveling is branch of surveying the objective of which is

-to find the elevation of any given points w. r. t. a given or assumed datum and

- to establish points at a given elevation or at different elevations w. r. t. a given or assumed datum.

It deals with measurements in vertical plane

Leveling Instruments

A level – to define horizontal line.

A leveling staff or rod - to measure vertical dist.



Types of level:

- Dumpy level
- Y level
- Coke's reversible level
- Automatic level

Dumpy level



The Dumpy level is a simple, compact and stable instrument.

The telescope is rigidly fixed to its supports. Hence it cannot be rotated about horizontal axis.



Tilting Level

In this level the telescope tilts about its horizontal axis hence it is called tilting level



Wye level

The essential difference between wye level and other levels is that in wye level the telescope is carried by two vertical wye supports. The telescope can be rotated, moved or even raised in wyes.



Automatic level

It is also known as self aligning level. It is a recent development. The fundamental difference between auto level and other levels is that the levelling is not done manually but it is levelled automatically.

There are two types of automatic levels.

Optical one whose distinguishing feature is self-leveling i.e., the instruments gets approximately leveled by means of a circular spirit level and then it maintains a horizontal line of sight of its own.

Digital levels whose distinguishing features are automatic leveling, reading and recording.

Digital levels and its advantages

The advantages of digital levels are that observations are taken without the need to read a staff or record anything by hand.

It can also display the horizontal distance to the staff.

Removes two of the most common errors, reading the staff incorrectly and writing down the wrong value in the field book.

The on-board computer also calculates the heights required so that the possibility of making a mistake is removed.

This makes the digital level much faster to use.

Automatic level





Leveling Instruments - The level:

Level consists of essentially

- **Leveling head** – to bring the bubble in its centre
- **Tripod** – to sp the instrument
- **Telescope** –to provide L of S
- **Bubble tube** – to make the L of S horizontal





Leveling Instruments-Various Parts



1. Focusing screw
2. Eyepiece
3. Foot screw
6. Tangent screw
7. Circular bubble



4. Horizontal circle
5. Base plate
8. Collimator (sight)
9. Object lens

Functions of Salient Parts of a Level

Telescope: used to sight a staff placed at desired station and to read staff reading distinctly.

Diaphragm: holds the cross hairs (fitted with it).

Eye piece: magnifies the image formed in the plane of the diaphragm and thus to read staff during leveling.

Level Tube: used to make the axis of the telescope horizontal and thus the line of sight.

Leveling screws: to adjust instrument (level) so that the line of sight is horizontal for any orientation of the telescope.

Tripod stand: to fix the instrument (level) at a convenient height of an observer.

Leveling Instruments - Leveling Staffs

Levelling staff is a graduated rod of rectangular sec. May be made of teakwood, fiber glass or metal.

Levelling staffs are of two types

1. Self Reading staff
2. Target staff

Self Reading Staff: The self reading staff can be read directly by the level man looking through the telescope.

Self Reading Ordinary Staff - is solid and made of seasoned wood, it is 3 m long and graduated in the same way as the telescopic staff

Self-reading Levelling staff

It is a self-reading graduated wooden rod having rectangular cross section.

The lower end of the rod is shod with metal to protect it from wear and usually point of zero measurement from which the graduations are numbered.

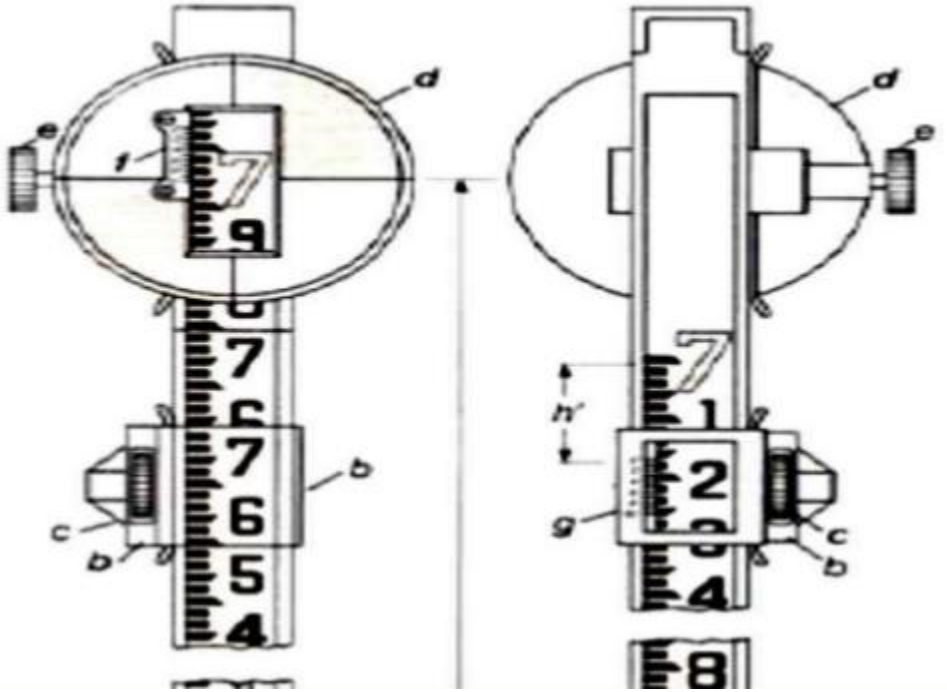
Staff are either solid (having single piece of 3 meter height) or folding staff (of 4 meter height into two or three pieces).



Leveling Instruments - Leveling Staffs

Target Staff: used for very precise works and sight. A movable target with a vernier is provided in this staff.

In target staff level man directs the staff man to move the target up and down until it bisects by the line of sight. The staff man observe the staff reading



Leveling Instruments - Leveling Staffs

Self Reading Folding Staff – is made up of well seasoned timber such as Cyprus.

It consists of two 2 m wooden pieces with a joint assembly.

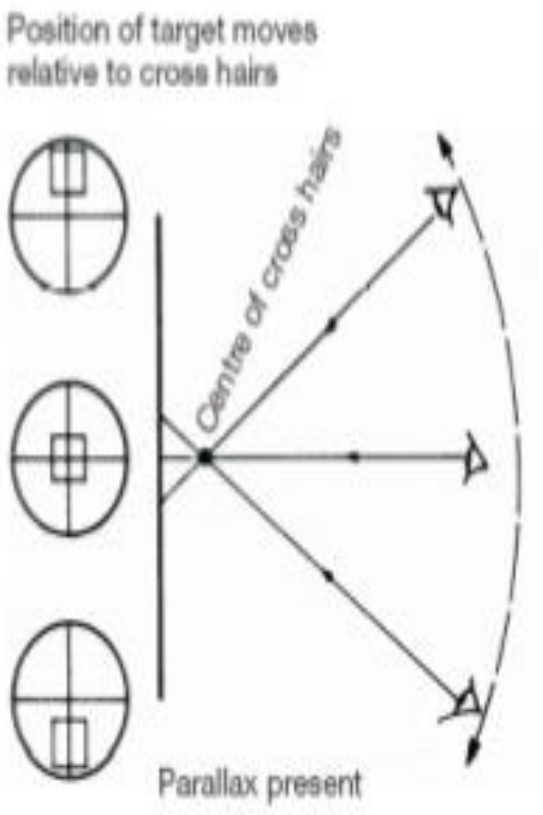
The staff is joined together in such a way that the staff may be folded from one another when required.

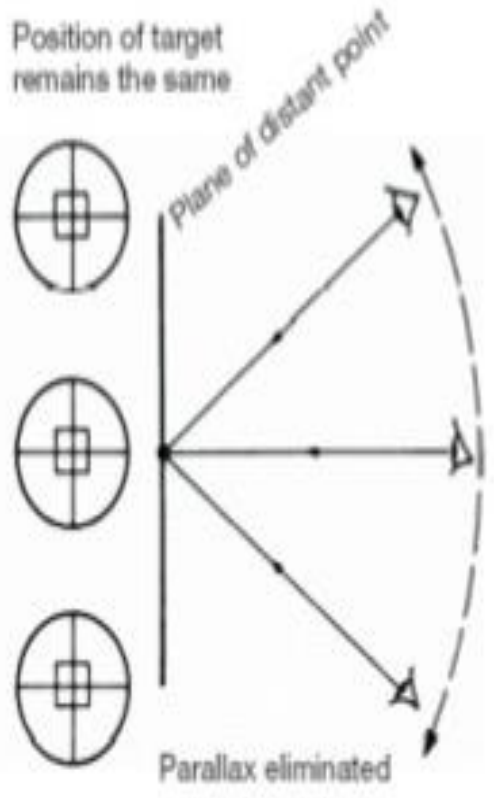


What is Parallax and How to eliminate it?

Parallax

If the image formed by objective lens is not in the same plane with cross hair, any movement of eye likely to cause an apparent movement of the image w.r.t the cross hair. This is called parallax.





Parallax and its elimination

Elimination of Parallax

Can be removed by forming or bringing the clear image of the object in the plane of cross hair by focusing operation. Focusing involves two parts as fol:

1. **Focusing the Eye piece**: The eye piece unit is moved in or out w.r.t. cross hair so that the cross hairs are clearly visible. By doing this cross hair are brought in the plane of distinct vision of the observer.

2. **Focusing the Objective**: Focus the objective to bring the image of the same in the plane of cross hair. This operation can be done by external (movement of objective or eyepiece) or internal (movement of internal focusing telescope) focusing.

Related Definition

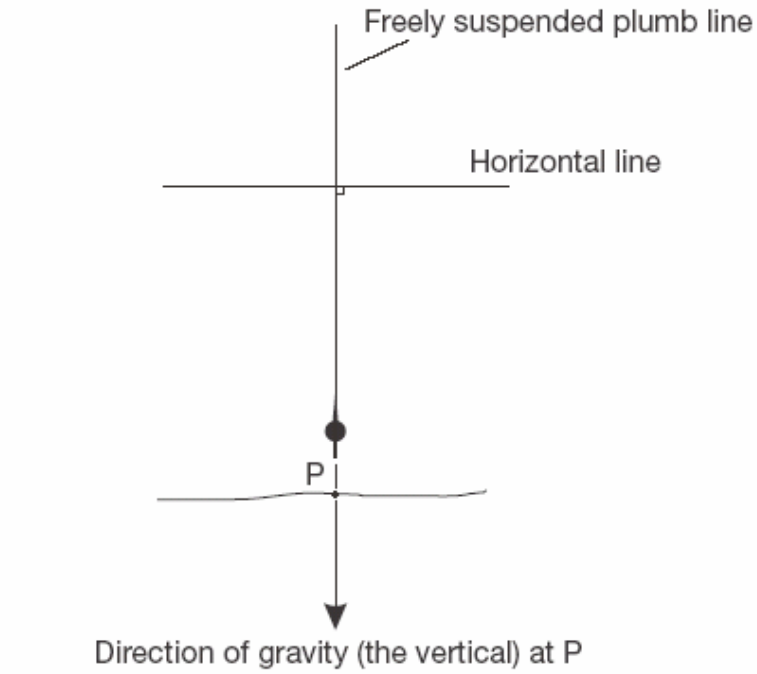
Level surface: Curved surface at each point is perpendicular to the direction of gravity /plumb line. Parallel to the mean spheroidal surface of the earth e.g. surface of a still lake. Every point on which is equidistant from the center of the earth.

Horizontal plane / surface: A plane tangential to the level surface. Perpendicular to direction of gravity (plumb line).

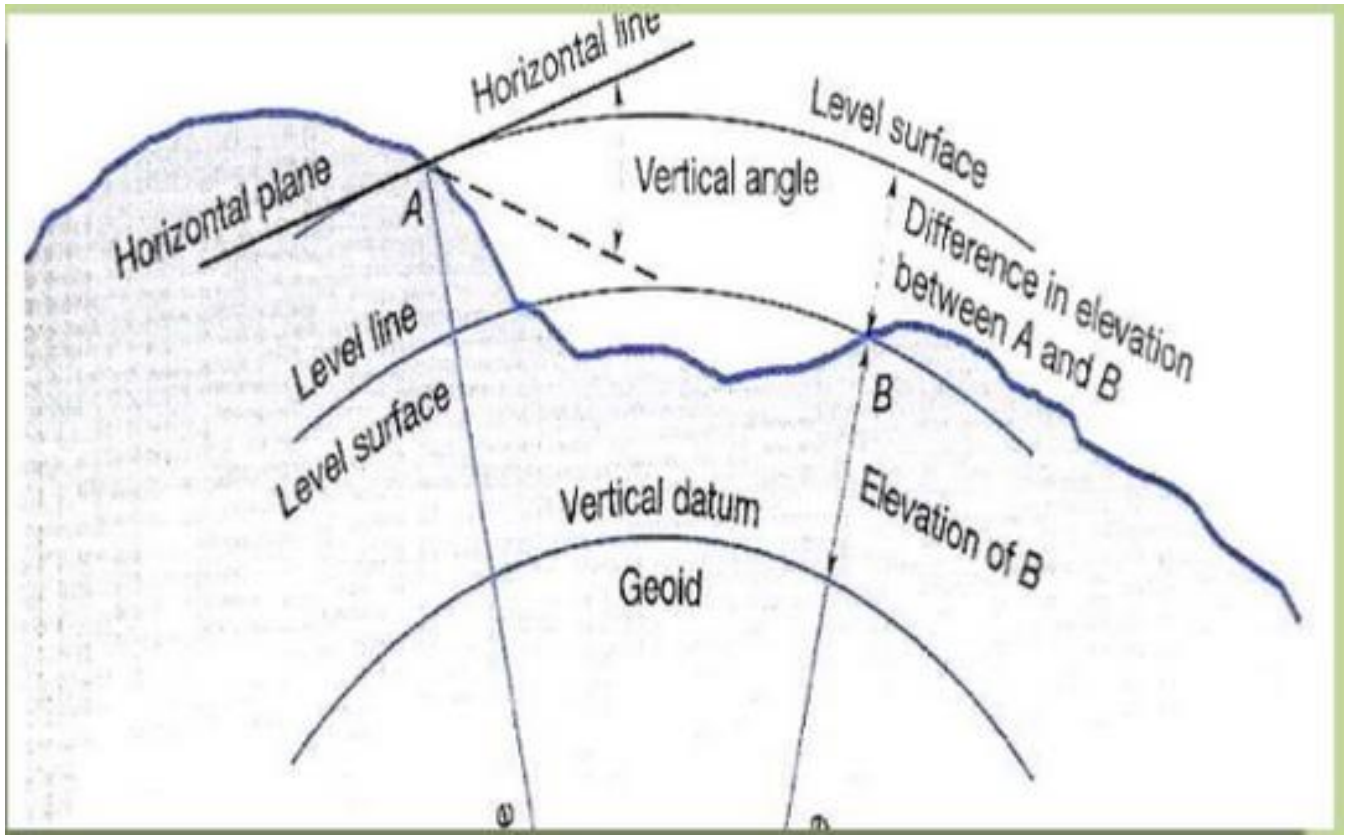
Level line:

Horizontal Line: It is any line lying in the horizontal plane. It is a straight line tangential to a level line.

Vertical line: It is a line normal to the level surface (a plumb line).



Related Definition



Related Definition

M S L: Average height of the sea for all stages of tides. At any particular place it is derived by averaging the hourly tide heights over a long period of 19 years. In BD MSL at Cox's Bazar is taken as zero.

Datum: an imaginary surface w.r.t. which ht of different points on earth's surface are determined. MSL is the most suitable datum.

Reduced Level (R.L.): Elevation of any point w.r.t. assumed datum.

Elevation: It is vertical distance of a point above or below the datum.
It is also known as the reduced level (R.L.). Plus or minus according as the point is above or below the datum.

Related Definition

Bench Marks: It is fixed reference point of known elevation (with respect to datum). Used as starting point or closing point as a check for leveling.

There are 4 kinds of bench marks

1. GTS (Great trigonometrically survey bench mark)
2. Permanent bench mark
3. Arbitrary bench mark
4. Temporary bench mark

Related Definition-Bench Mark

GTS Bench Mark

They are the bench marks established with very high degree of precision at regular intervals by the Survey of Bangladesh (SOB) all over the country Their position and R.Ls values above mean seal level at Cox's Bazar is given by the SOB.

Permanent Bench Mark

Permanent bench marks are fixed in between GTS benchmarks by govt. agencies such as railways, PWD, etc. This benchmarks are written on permanent objects such as milestones, culverts, bridges etc. Their value are clearly written and their position are recorded for future reference.

Related Definition-Bench Mark

Arbitrary Bench Marks

These are reference points whose R.L.s are arbitrarily assumed. They are used in small works such bench mark may be assumed as 100 or 50 m

Temporary Bench Marks

They are the reference points established during the levelling operations when there is a break in work, or at the end of day's work. The value of reduced levels are marked on some permanent objects such as stones, trees etc.

Related Definition

Station: A point whose elevation is to be determined. A point where staff reading is taken, not where thelevel is set up.

Back Sight, Intermediate Sight and Fore Sight:

Back sight / Reading (B.S. or B.R.): first staff reading of a point of known elevation. Purpose is to obtain the H.I. Also known as Plus Sight.

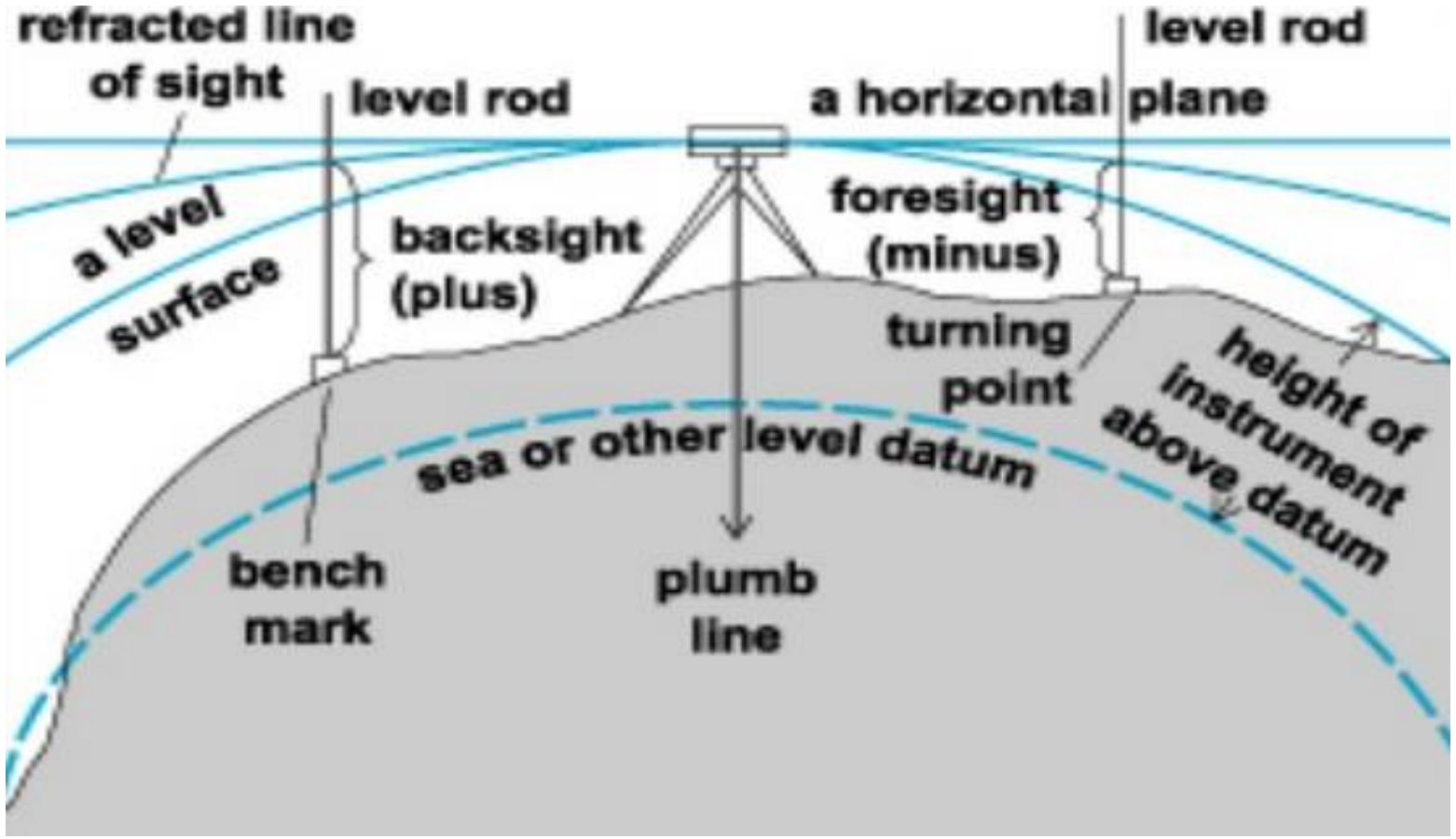
Fore Sight / reading (F. S. or F.R.): Last staff reading of a point. *Purpose is to determine the elevation of station. Also known as Minus* sight.

Intermediate Sight / reading (I.S. or I. R.): Staff readings of intermediate stations.

Change Point or Turning Point (C.P. or T.P.): point where both Back reading and Fore reading are taken.

Intermediate Station: point between two T.P. or Change points, between two position of instrument/level.

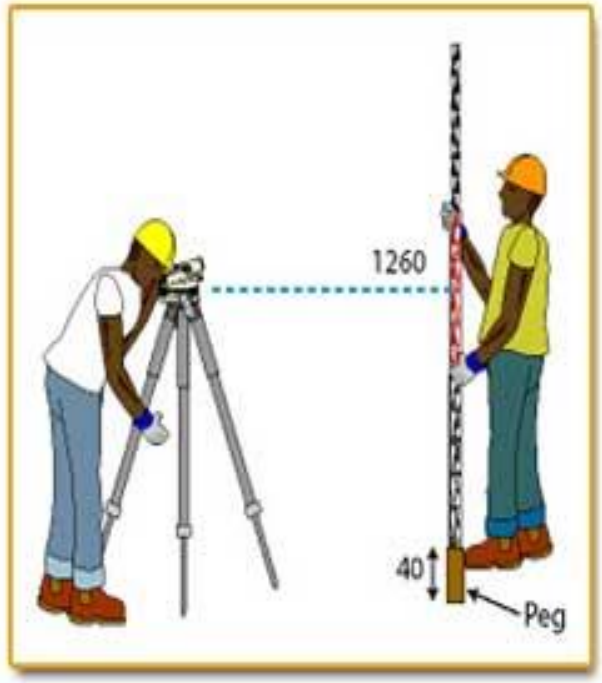
Related Definition

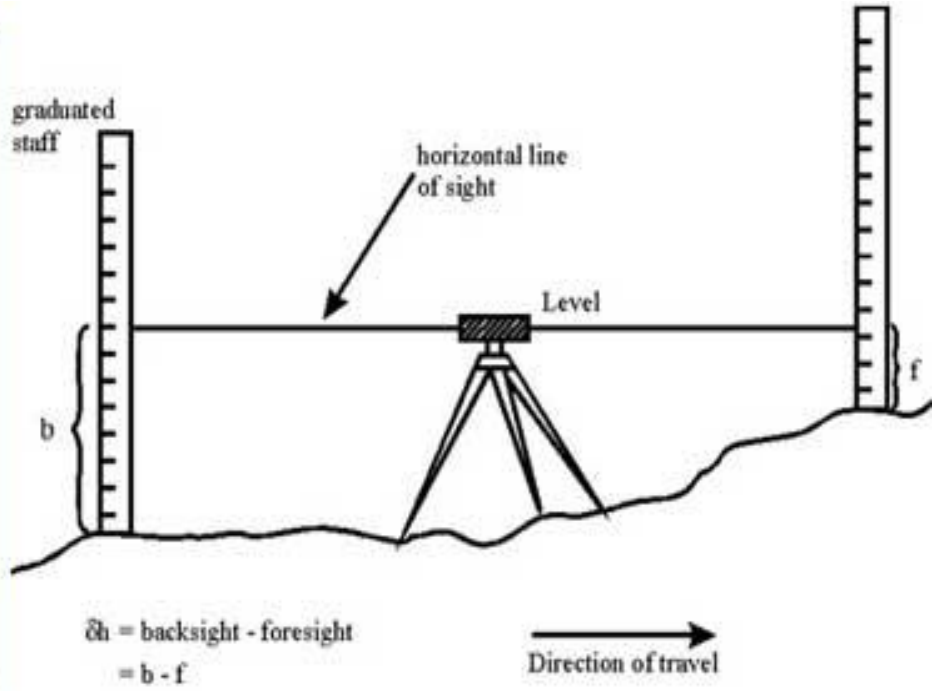


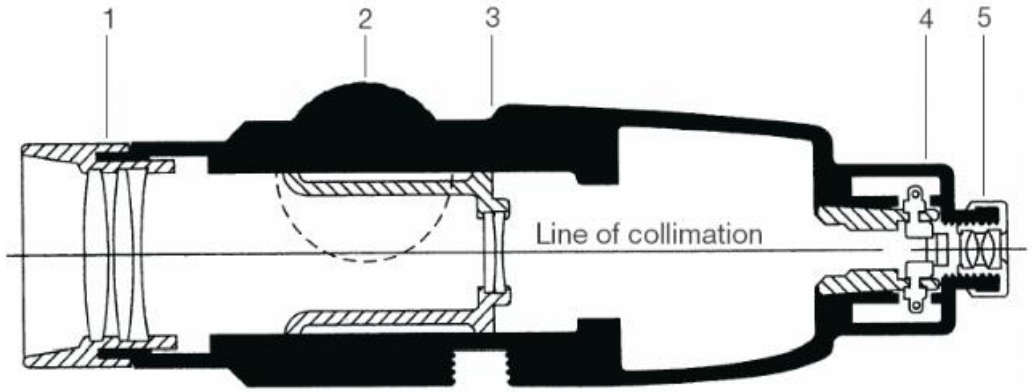
Related Definition

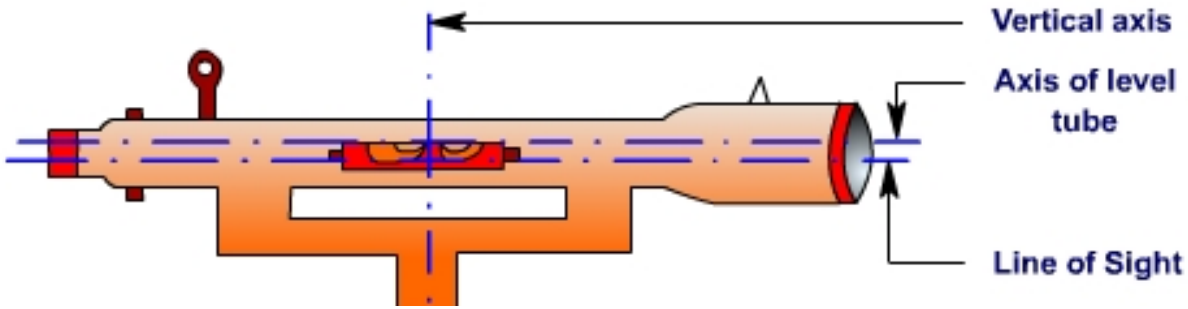
L of S / Line of Collimation

Height of Instrument (H.I.)









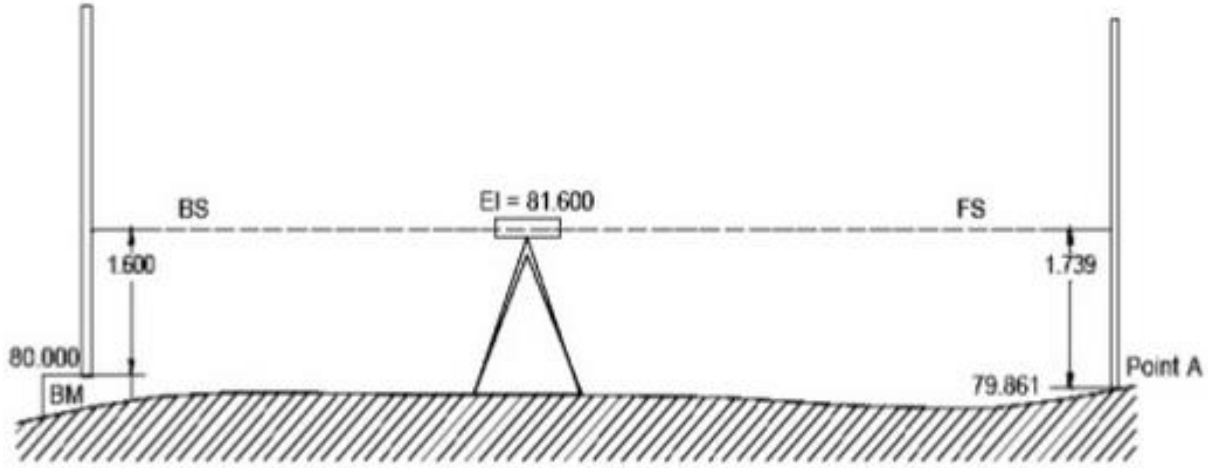
Classification of Levelling

- ✓Simple Levelling
- ✓**Differential or Fly Levelling**
- ✓Check Levelling
- ✓**Profile or Longitudinal Levelling**
- ✓Cross Levelling
- ✓**Reciprocal Levelling**
- ✓**Contouring**
- ✓Precise Levelling
- ✓**Trigonometric Levelling**
- ✓Barometric Levelling
- ✓Hypsometric Levelling

Classification of Levelling

Simple Levelling

It is the simplest method used, when required to find the difference in elevation between 2 points.



Precise Levelling

It is used for establishing bench marks for future public use. It is carried out with high degree of accuracy using advanced instruments and special attention or both.

Check levelling

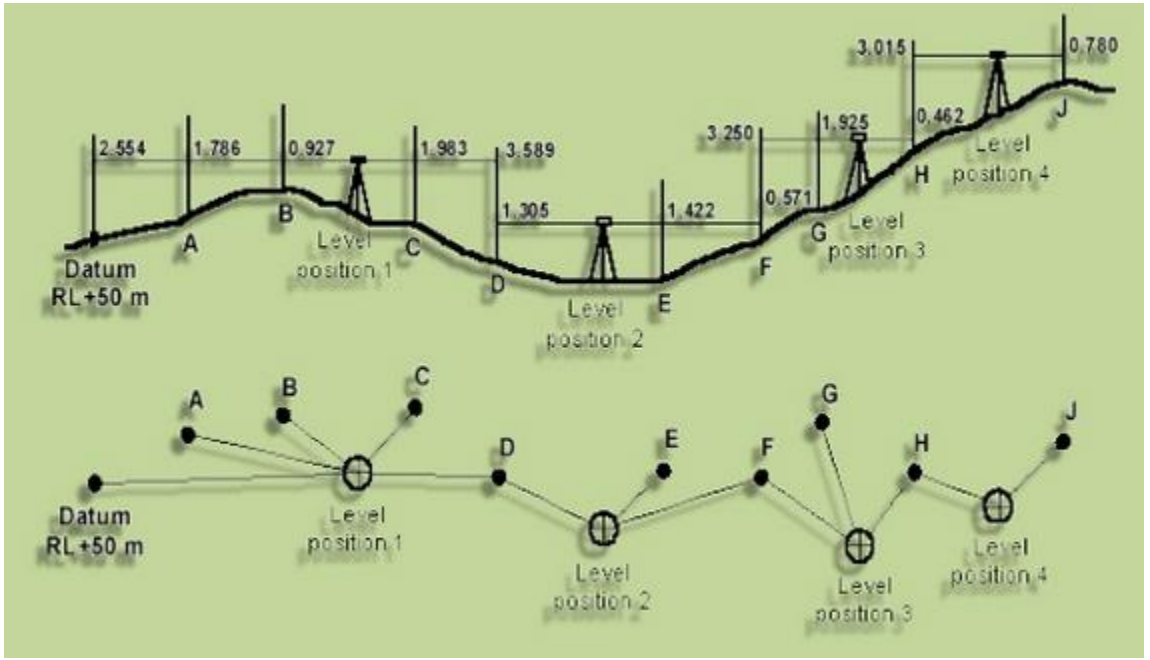
This kind of levelling is carried out to check the accuracy of work. It is done at the end of the days work in the form of fly levelling to connect the finishing point and starting point.

Classification of Levelling

Differential/Fly Levelling

This method is used to find the difference in the elevation of widely apart intervisible or non-intervisible points which cannot be determined in a single set up of an instrument. For each set up, staff readings are taken back to a point of known elevation (first sight from the B.M and forward to a point of unknown elevation) final sight to the terminal station.

It is a type of direct or spirit levelling.
Most precise and most commonly used.
Elevation of points are determined by measuring vertical distance w.r.t. horizontal line.



Classification of Levelling

Profile levelling

This method is used for taking levels along the centre line of any alignment like road, railway canal etc. The object is to determine the undulations of the ground surface along the alignment

The notes of profile leveling are recorded in a level note book where backsights, intermediate sights and foresights are placed in independent columns. The distances of points as well as direction of lines are also noted in separate columns

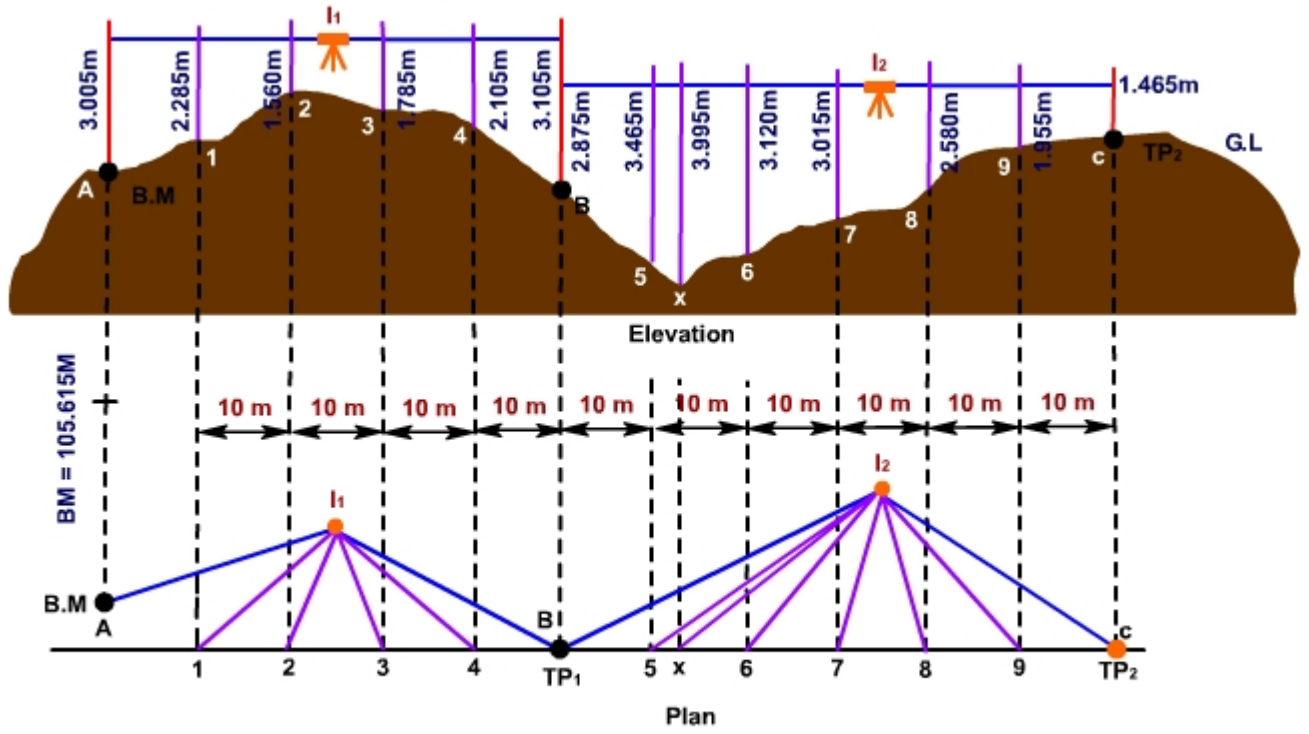


Figure 14.1 Profile Levelling

Classification of Levelling

Cross-Sectioning Leveling

This operation is carried out perpendicular to alignment usually at regular interval when required to know the traverse profile. The idea is to make an estimate of earthwork.

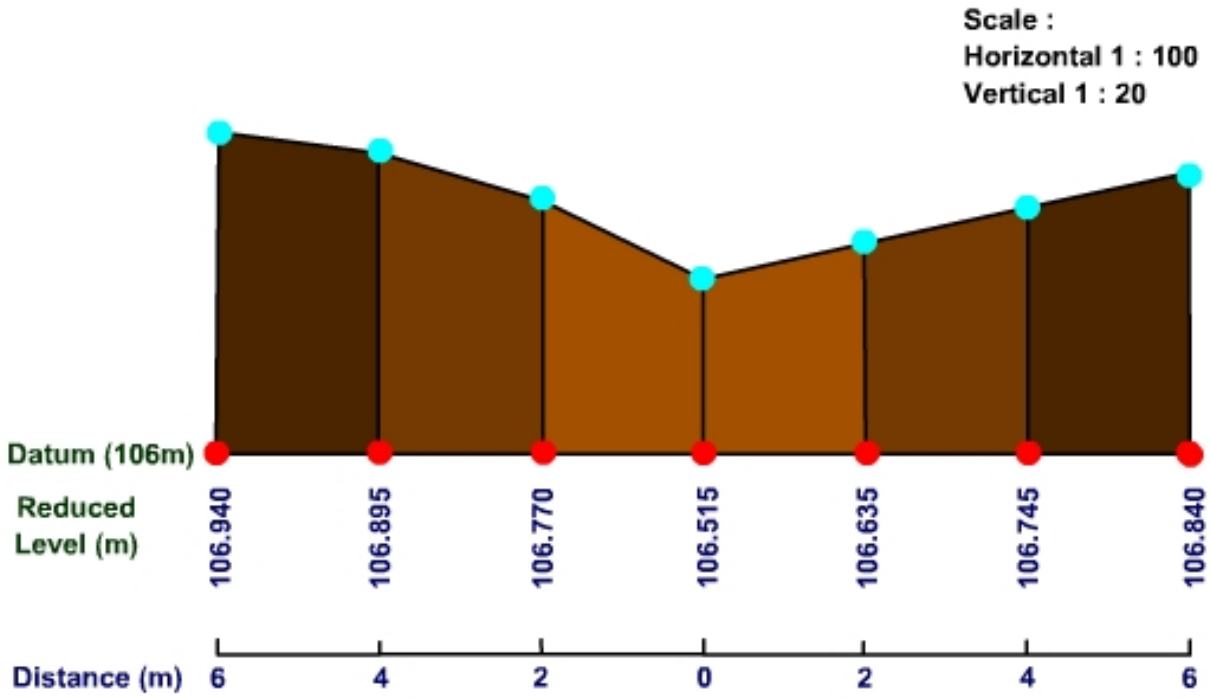


Figure 14.3 Cross-section along Stake 4 (0 + 40m)

Classification of Levelling

Barometric Levelling

In this method the altitude difference is determined by means of a barometer.

Based on the fact that the atmp pressure varies inversely with height.

It is chiefly used on exploratory or reconnaissance surveys.

Very rough estimation as atmp pressure at any point is constantly changing and barometer reading are affected by the temp of air

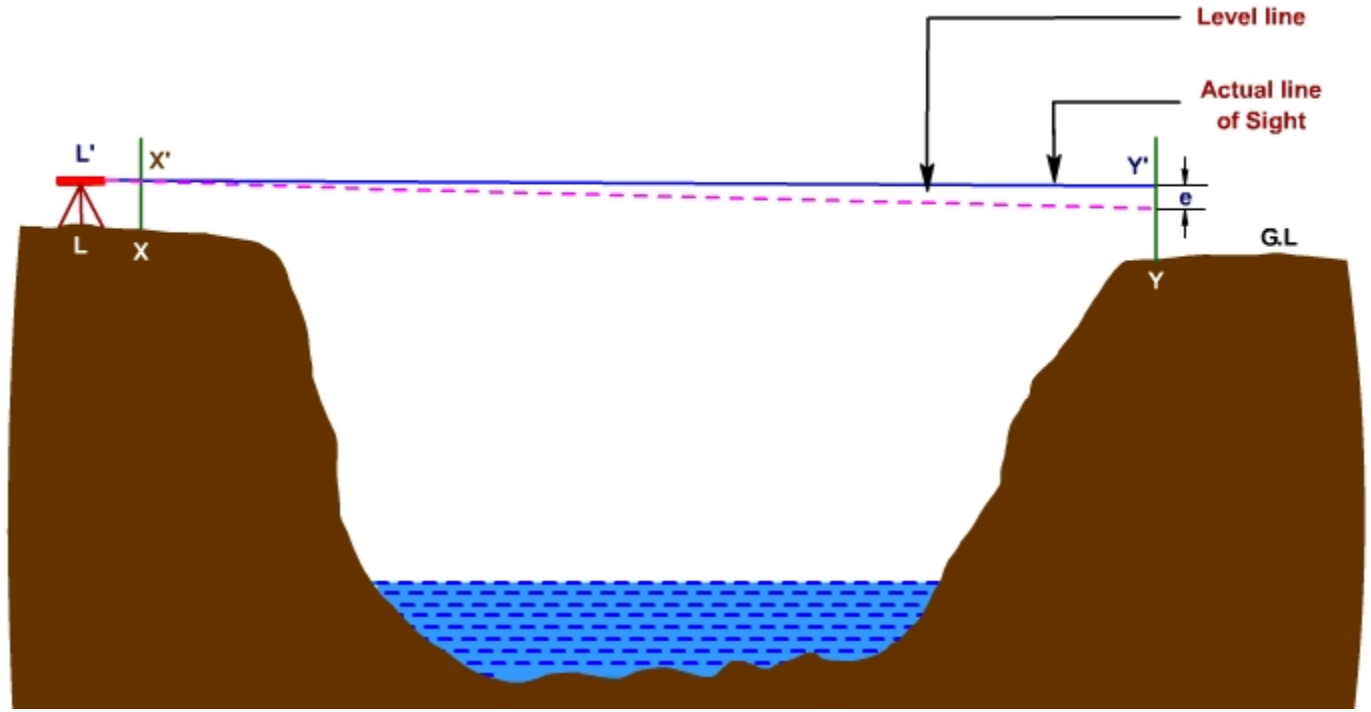
Hypsometric Levelling

The working of Hypsometry depends upon the fact that the temp at which water boils varies with the atmp pressure. The boiling point of water reduces at higher altitude thus knowing the boiling point of water, the atmp pressure can be calculated and knowing the atmp pressure altitude or elevation can be determined. Hypsometer is also called as thermo-barometer.

Classification of Levelling

Reciprocal Levelling

This method is adopted to accurately determine the difference of level between two points which are far apart and when it is not possible to setup level in midway between two points.

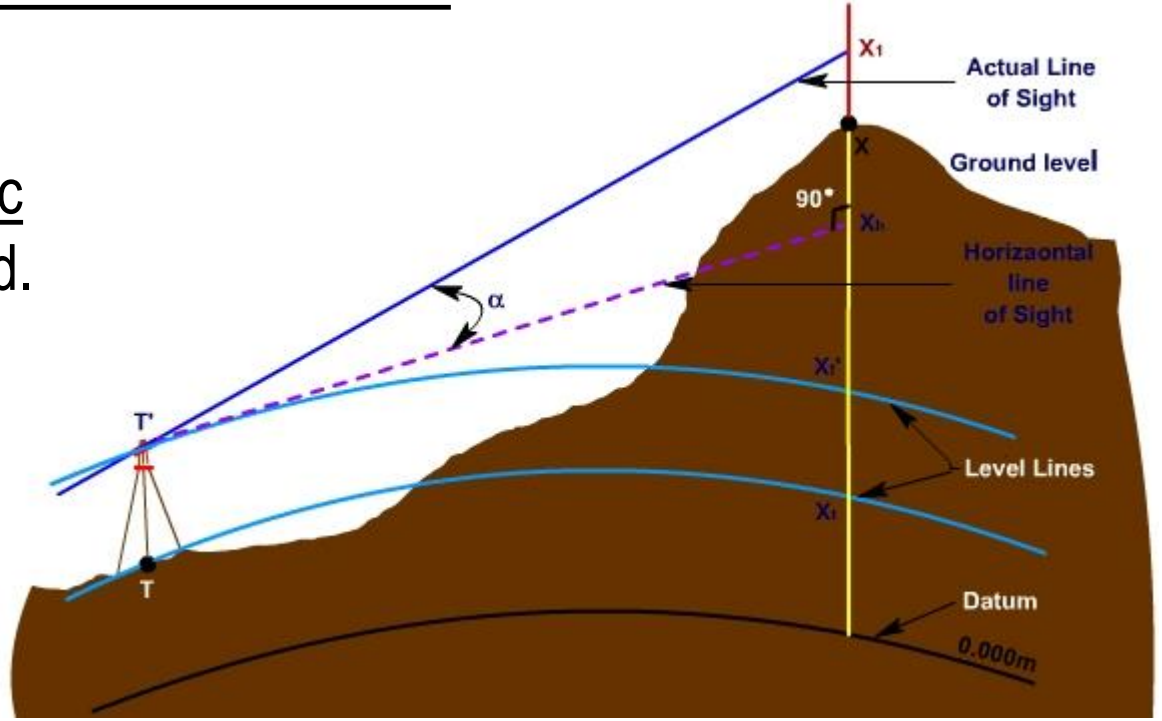


Classification of Levelling

Indirect or Trigonometric Leveling

Elevation of points are computed by measuring vertical angles and horizontal distance;
Less precise.
For rapid leveling or leveling in rolling ground or for inaccessible points.
In this method, theodolite is being generally used as an instrument.

Stadia Leveling : Modified form of trigonometric levelling where tacheometric principles are used.

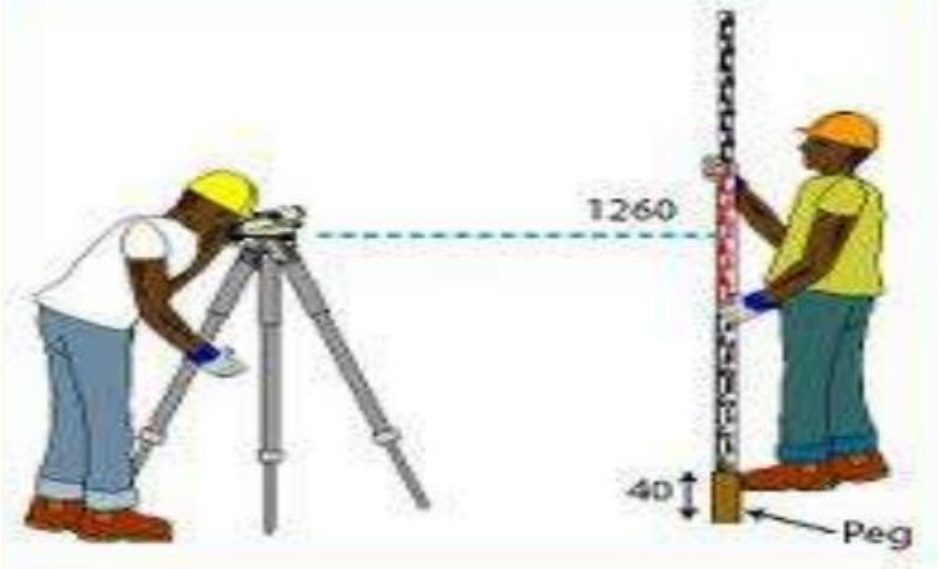


How to take the Reading?

When looking through the eye piece of the telescope, a set of lines called the **cross hairs (on diaphragm)** can be seen.

The image of the staff is brought to a focus in the plane of the diaphragm using the **focusing screw**. The **eyepiece** is rotated so that the cross hairs are in focus and its focal point is also in the plane of the diaphragm.

When looking into the telescope an observer will now see a magnified image of the leveling staff focused against the cross hairs.





Calculation of Reduced Level (R.L)

The observed staff readings as noted in a level book are further required to be manipulated to find out the elevation of points. The operation is known as reduction of level. There are two methods for reduction of levels:

Rise and Fall method and
Height of instrument method.

Field Book/ Level Book

A field book, also called level book is being used for taking down each staff reading during leveling and subsequently, used for finding out the elevation of points/ stations.

Field Book Page for Height of Instrument method

Obj/Point/Station	B.S	I.S	F.S	H.I	R.L	Dist	Remark
1							
2							
3							

Field Book Page for Rise and Fall method

Obj/Point/Station	B.S	I.S	F.S	Rise	Fall	R.L	Dist	Remark
1								
2								
3								

Calculation of Reduced Level (R.L)

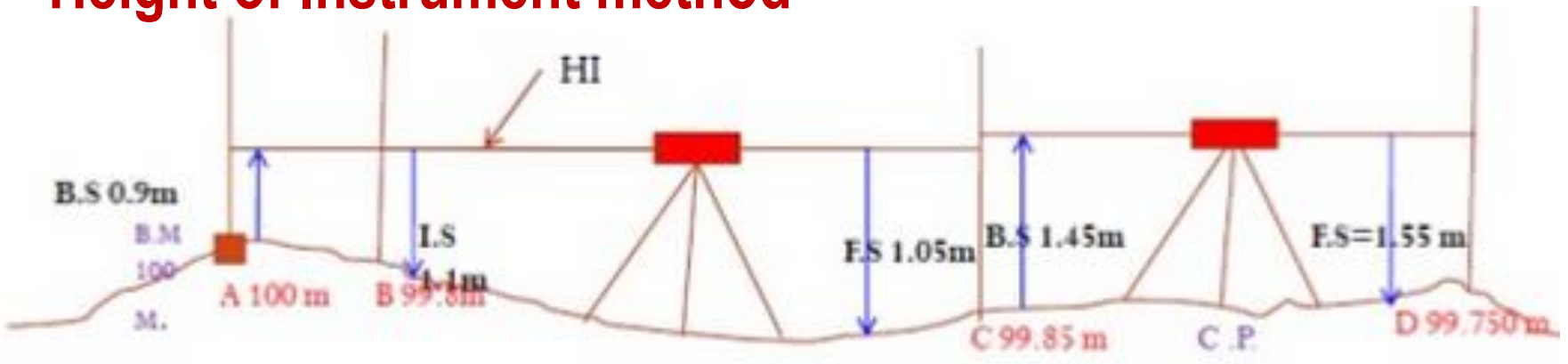
Height of Instrument method

- Height of instrument for the first setting= RL of BM + BS(at BM)
- Subtract the IS and FS from HI to get RL of intermediate stations and change points.
- Checking: ∑BS - ∑FS = Last RL – First RL.
- This is –ve for FALL and +ve for RISE.

Rise and Fall method

- Rise or Fall = difference between present staff reading and previous staff reading.
- Previous reading – present staff reading = +ve, denotes RISE.
- Previous reading – present staff reading = -ve, denotes FALL
- Checking: ∑BS - ∑FS = Last RL – First RL= ∑Rise - ∑Fall

Example - Height of Instrument method

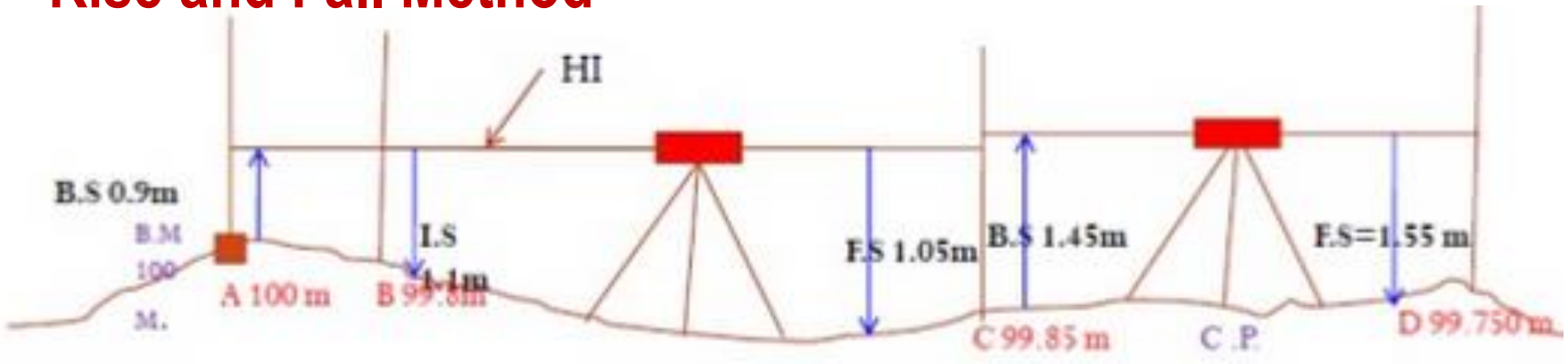


Sta	B.S (m)	I.S (m)	F.S (m)	H.I (m)	R.L (m)	Rmk
A	0.9			HI at A = RL of BM + Reading at A **100.90**	100	B. M
B		1.100			(RL of B= HI-Reading at B) 100.90-1.100 = **99.800**	
C	1.450		1.050	New HI at CP= RL of C+BS at C = 99.85+1.45 = **101.3**	(RL of C= HI-Reading at C) 100.9-1.05 = **99.850**	C. P
D			1.550		(RL of D= new HI-Reading at D) 101.3-1.550 = **99.750**	
SUM	2.350		2.600			

Checking: $\sum$BS - $\sum$FS = 2.350 – 2.600 = - 0.25

Last RL – First RL = 99.75 - 100 = - 0.25

Example - Rise and Fall Method



Sta	B.S (m)	I.S (m)	F.S (m)	Rise (m)	Fall (m)	R.L (m)	Rmk
A	0.9					100	B. M
B		1.100			(Prev Read – Read at B) = 0.9 – 1.10 = - **0.20**	RL of B = Prev RL – Fall = 100.00 -= 0.20 = **99.800**	
C	1.450		1.050	(Prev Read – Read at C) = 1.10 - 1.05 = + **0.05**		(RL of C= Prev RL + Rise) = 99.80 + 0.05 = **99.850**	C. P
D			1.550		(Prev Read – Read at D) =1.450 -1.550 = - **0.100**	(RL of D= Prev RL - Fall) 99.850 – 0.100 = **99.750**	
SUM	2.350		2.600	0.050	0.300		

Checking: ∑BS - ∑FS = 2.350 – 2.600 = - 0.250

Last RL – First RL = 99.75 - 100 = - 0.250

∑Rise - ∑Fall = 0.050 – 0.300 = -0.250

Example

The following consecutive readings were taken with a level and a 4 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 218.750 m.

Rule out a page of a level book and enter the above readings.

Calculate the reduced levels of the points by the collimation method, and rise and fall method.

Also, calculate the gradient of the slope.

Obsn	B S (m)	I S (m)	F S (m)	Rise (m)	Fall (m)	R.L (m)	Rmk
1	0.780					218.750	B.M
2		1.535			0.755	217.995 (RL of BM-Fall)	
3		1.955			0.420	217.575 (RL of Prev sta-Fall)	
4		2.430			0.475	217.100	
5		2.985			0.555	246.545	
6	1.155		3.480		0.495	216.050	CP1
7		1.960			0.805	215.245	
8		2.365			0.405	214.840	
9	0.935		3.640		1.275	213.565	CP2
10		1.045			0.110	213.455	
11		1.630			0.585	212.870	
12			2.545		0.915	211.955	
Sum	*2.870*		*9.665*	*0.000*	*6.795*		

Rise and Fall Method

If, Obsn 1-obsn 2= (-), then Fall
Obsn 1-obsn 2= (+), then Rise

Check:
Sum B.S. - Sum F.S. =
2.870 - 9.665 = -6.795 m

Last R.L. – First R.L. = -6.795 m

Gradient (fall) = [6.795 / (11 x 30)] = 1 in 48.565 (downward from A)

Obsn	B S (m)	I S (m)	F S (m)	HI (m)	R.L (M)	Dist (m)	Rmk
1	0.780			219.530 (RL of BM + BS)	218.750		B.M
2		1.535			217.995 (RL of BM- I.S)		
3		1.955			217.575 (RL of Prev sta-Fall)		
4		2.430			217.100		
5		2.985			246.545		
6	1.155		3.480	217.205 (216.050 + 1.155)	216.050		CP1
7		1.960			215.245		
8		2.365			214.840		
9	0.935		3.640	214.500 (213.565 + 0.935)	213.565		CP2
10		1.045			213.455		
11		1.630			212.870		
12			2.545		211.955		
Sum	*2.870*		*9.665*				

Ht of Instr (H.I) Method

Check:
Sum B.S. - Sum F.S. = 2.870 - 9.665 = -6.795 m

Sum Rise - Sum Fall = - 6.795 m

Last R.L. – First R.L. = -6.795 m

Gradient (fall) = [6.795 / (11 x 30)] = 1 in 48.565 (downward from A)

Example

The following readings are taken on continuous falling ground with staff of 4 m the are 0.4 m, 0.765, 1.270, 2.56, 3.22, 3.95, 0.390, 1.690, 3.5, 0.8, 1.920, 2.45, 3.98.

Enter the reading in the page of level book and calculate the RLs of all point if the first reading was taken on Benchmark of 100m.

Station	B.S (m)	I.S (m)	F.S (m)	H.I (m)	R.L (m)	Dist	Remark
1	0.400			100.400	100		B.M
2		0.765			99.635		
3		1.270			99.130		
4		2.560			97.840		
5		3.220			97.180		
6	0.390		3.950	96.84	96.450		CP
7		1.690			95.150		
8	0.8		3.5	94.14	93.340		CP
9		1.920			92.220		
10		2.450			91.690		
11			3.980		90.160		

Check:
Sum B.S. - Sum F.S. =
1.590 – 11.430 = - 9.840 m

Last R.L. – First R.L. =
90.160 – 100.000 = -9840 m

Example

1. The following staff readings were observed successively with a level the instrument is moved by third, sixth and eighth readings. • 2.228 :1.606 :0.988 :2.090 :2.864 :1.262 0.602 :1.982 :1.044 :2.684 m

Enter the reading in record book and calculate R.L. if the first reading was taken at a B.M of 432.383m

2. Data from a differential leveling have been found in the order of B.S., F.S..... etc. starting with the initial reading on B.M. (elevation 150.485 m) are as follows : 1.205, 1.860, 0.125, 1.915, 0.395, 2.615, 0.880, 1.760, 1.960, 0.920, 2.595, 0.915, 2.255, 0.515, 2.305, 1.170. The final reading closes on B.M.. Put the data in a complete field note form and carry out reduction of level by Rise and Fall method. All units are in meters.

3. The following readings were taken with a dumpy level and 4m leveling staff. The instrument was shifted after 3rd and 6th readings. The readings are 2.665, 3.225, 2.905, 1.85, 0.98, 2.62, 1.585, 0.96, 0.425. m Enter the above readings in a page of level book and calculate R.L. of points, if the first reading was taken with a staff held on B.M. of 240 m. use rise and fall method. Apply arithmetic checks

Curvature & Refraction Correction

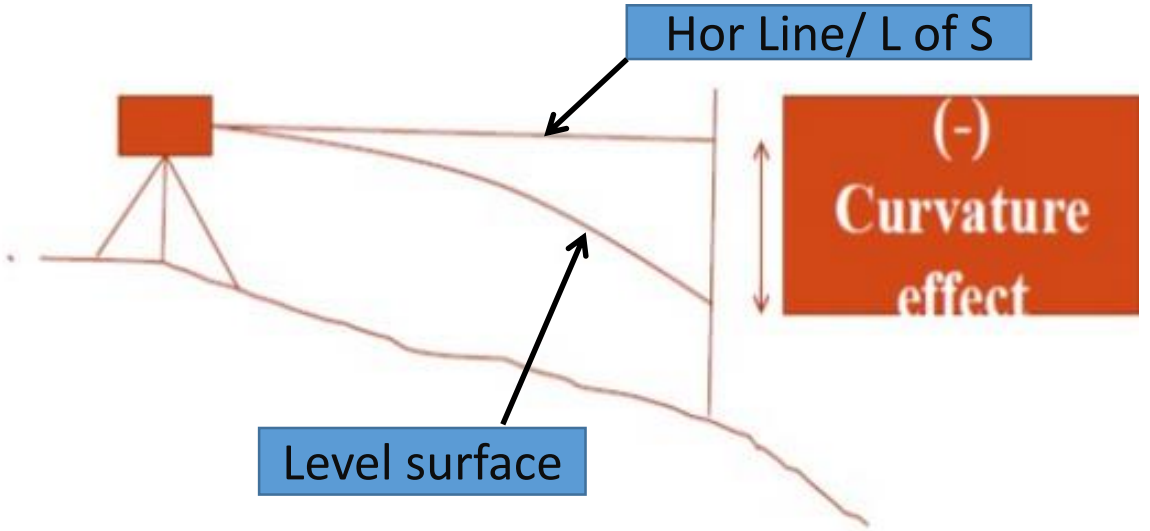
Curvature Correction, C_c

As per the definition of level surface and horizontal line, we know that horizontal line departs from the level surface because of the curvature of the earth.

The vertical distance between the L of S and level line at particular place is called the curvature correction.

The effect of curvature is to cause the object sighted to appear lower than they really are.

Curvature correction is always Subtractive(-)
True staff reading = Observed staff reading – curvature correction.

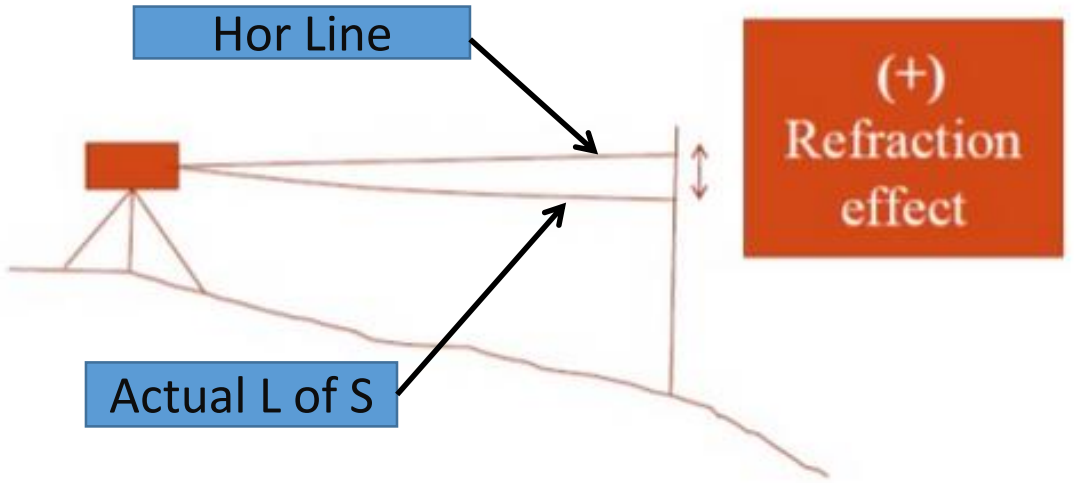


For short dist it does not make any different, but for long sights the curvature of earth can effect staff readings.

Curvature & Refraction Correction

Refraction Correction, C_r

The ray of light pass through layers of air of different densities and in the long sights, the horizontal L of S does not remain straight but it slightly bends downwards towards the earth surface due to refraction.



The effect of refraction is to make the object appear higher then they really are.

Refraction varies considerably with climate conditions.

Refraction is always additive.

True staff reading = Observed Staff Reading + Refraction correction C_r.

The amount of correction is one seventh of the curvature correction. $C_r = \frac{1}{7} C_c$

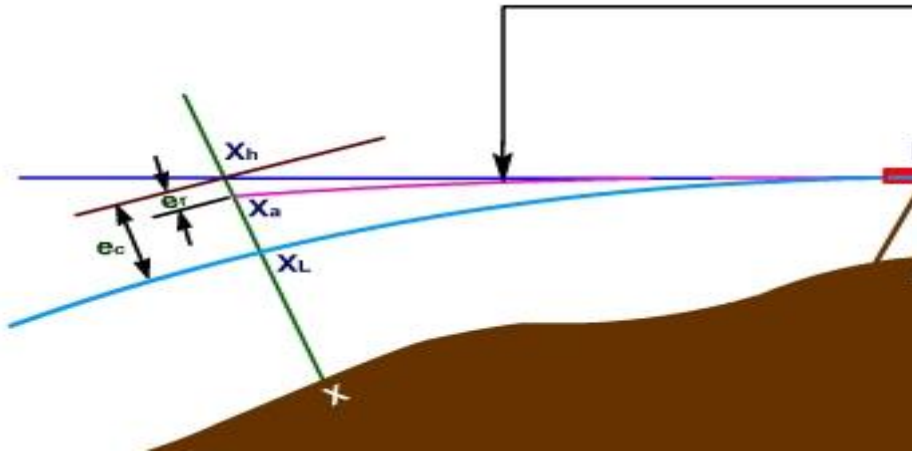
Corrections for Earth's Curvature & Refraction

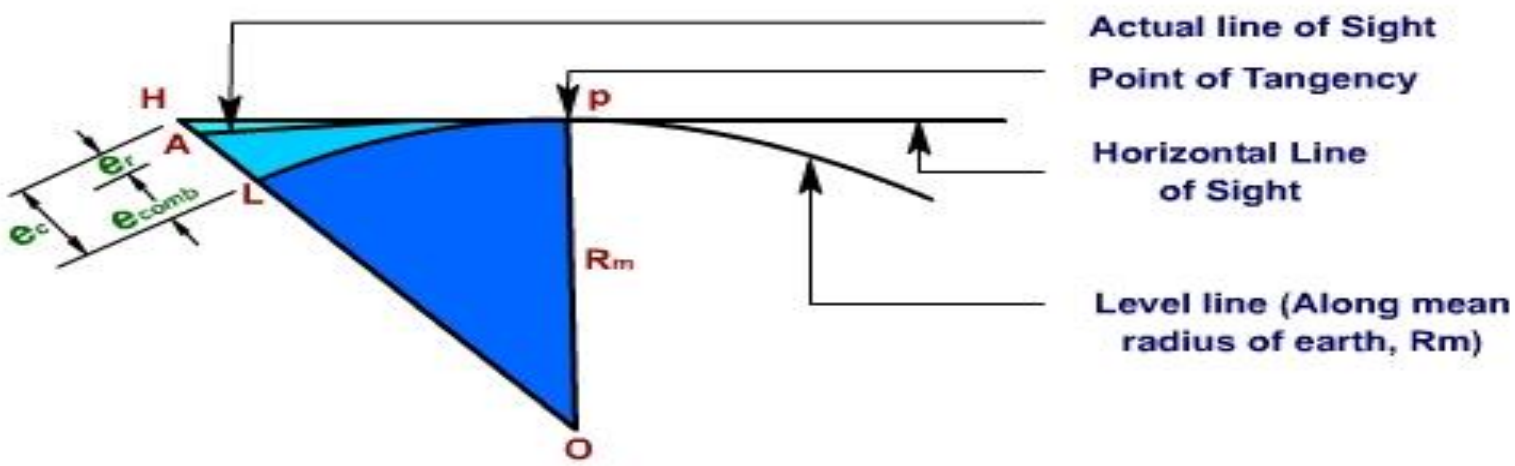
$$C_c = \frac{d^2}{2R} = 0.07857d^2 \text{ (subtractive)}$$

$$C_r = \frac{1}{7}\frac{d^2}{2R} = 0.01122d^2 \text{(additive)}$$

$$C = \frac{6}{7}\frac{d^2}{2R} = 0.06735d^2\ (substractive)$$

Where d is the horizontal distance between two points in km and R is the radius of earth in km = 6370 km.
In English unit, the result will be in ft, when d and R will be in miles (R= 3958 miles)





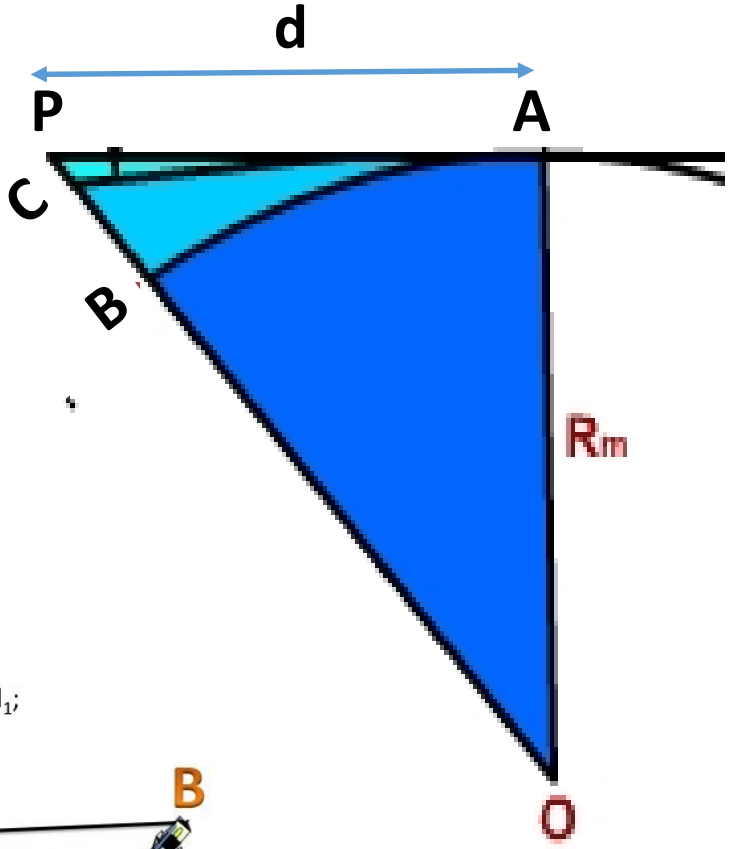
Distance to the Visible Horizon

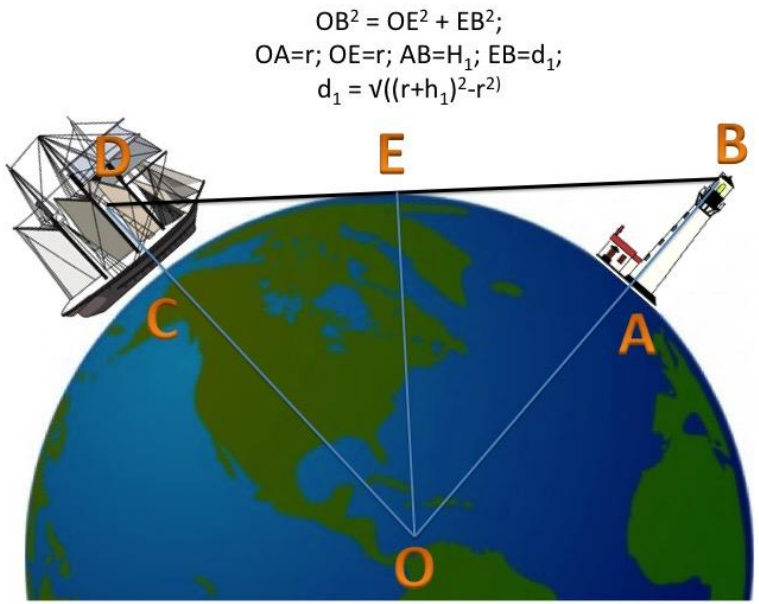
If P be the point of observation, its height is C and A be the point of horizon, Then the dist d from observer to the visible horizon is given by

$$d = \sqrt{\frac{C}{0.06735}} \text{ km}$$

$$= 3.853\sqrt{C} \text{ km, C being in m.}$$

Taking both curvature and refraction into account





Problem of Dist and Ht

Prob 9.8 to 9.13 of Book Surveying B.C PUNMIA

Prob 9.9: Find the combined correction of curvature and refraction for dist of (a) 3400 m and (b) 1.29 km.

Correction for curvature = $0.07857d^2$

Correction for refraction = one seventh of above.

Combined correction = $0.06735d^2$

(a) 0.779 m

(b) 0.112 m

Problem of Dist and Ht

Prob 9.12: An observer standing on a deck of a ship just sees a light house. The top of the light house is 42 m above the sea level and height of the observer's eye is 6 m above the sea level. Find the dist of the observer from the light house.

$d_1 = 3.853\sqrt{C_1}$ km = $3.853\sqrt{42}$ = 24.914 km

And $d_2 = 3.853\sqrt{C_2}$ km = $3.853\sqrt{6}$ = 9.438 km

So dist between observer and the light house is

= 24.914 + 9.438 = 34.352 km.

Reciprocal Leveling

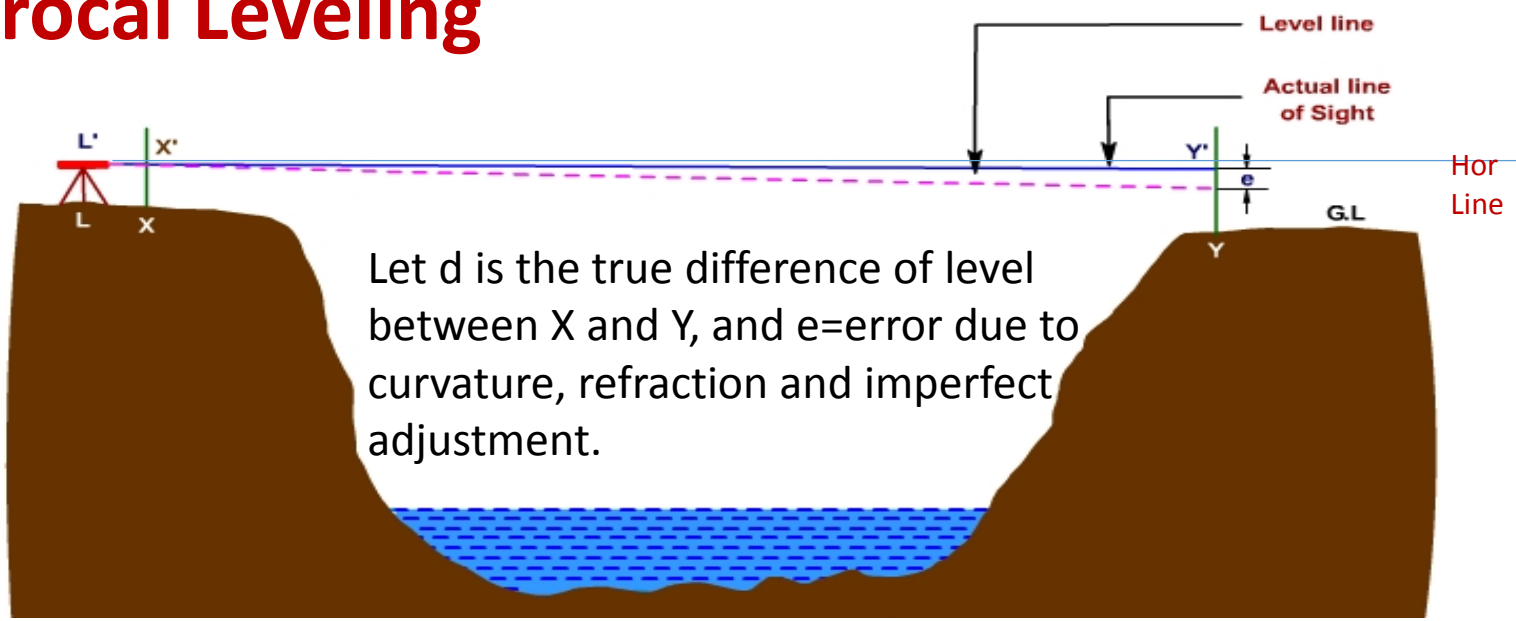
This method is adopted to accurately determine the difference of level between two points which are far apart and when it is not possible to setup level in midway between two points.

This method is used to obtain accuracy and to eliminate

i. errors in instrument adjustment,
ii. combined effect of earth curvature and refraction of atmpand
iii. variation in the average refraction.

Reciprocal Leveling

Let X and Y are two points on opposite banks. Need to find out the level difference between X and Y.
Setup level at L very near to X and readings (X_1 and Y_1) are observed.
The level is then set up near Y and staff readings (Y_2 and X_2) are taken respectively



Thus to eliminate the error take an average of the difference in elevation taken from 2 points, i.e.

from X the true difference will be = $(Y_1 - e) - X_1 = (Y_1 - X_1) - e$

from B the difference will be = $(Y_2 - e) - X_2 = (Y_2 - X_2) + e$

Adding these two eqn, we get $d = \{(Y_1 - X_1) + (Y_2 - X_2)\}/2$

***Therefore, the true difference in elevation is equal to the mean of the two apparent differences in elevations, obtained by reciprocal obsn. Here errors due to curvature, refraction and imperfect adjustment are eliminated*.**

Reciprocal Leveling

Prob: The fol readings were taken on opposite banks of a river.

Find (a)true R.L of Q, and (b). The combined correction of curvature and refraction

Instrument at	Staff Reading on		Remarks
	P	Q	Dist between P and Q = 1010 m, R.L of P = 126.386m
P	1.824	2.748	
Q	0.928	1.606	

(a) When obsn taken at P, apparent difference in elv = 2.748-1.824 = 0.924m, P is higher.

When obsn taken at Q, apparent difference in elv = 1.606-0.928 = 0.678, P is higher.

True difference in elv = (0.924 + 0.678)/2 = 0.801 m, P is higher.

So True eln of Q = 126.386-0.801 = 125.585 m

(b) Combined correction = $0.06735\ (1.010)^2$ = 0.069 m

So corrected R.L of Q = 125.585 – 0.069= 125.516 m.

Reciprocal Leveling

Ex15-1 In order to transfer reduced level across a canyon, a reciprocal leveling campaign was conducted. Simultaneous readings were observed using two levels one at each side of the canyon. Each of the levels are having same magnifying power and sensitiveness of level tube. With instruments interchanged during leveling operation yielded the following average readings:

Instrument station	**Average near readings, meter**	**Average distant, readings, meter**
X	1.780	2.345
Y	2.435	1.870

R.L of X = 101.345 m
Distance, XY = 1.025Km
$\mathbf{e}_{\text{curvature}} = \mathbf{0.0785\ XY^2}$

Find out the R.L. of unknown point. Comment on the errors associated with observations.

Solution :
The difference in elevation between X and Y is

$$\Delta h = \frac{(2.345 - 1.780) + (2.435 - 1.870)}{2}$$

$$= 0.565 \text{ m (Y lower than X)}$$

R.L. of Y (unknown Point) = R.L. of X - Dh = 101.345 - 0.565 = 100.780 m

Errors in Levelling

1. **Instrumental**: imperfect adjustment, sluggish bubble, mov of objective slide, non standard rod, defective joint etc.

2. **Natural:** Curvature, refraction, temp, settlement of tripod, wind variation etc.

3. **Personal:** Rod handling, reading the rod, sighting, recording, manipulation etc.

Balancing B. S and F.S.

- Error due to non parallelism of L of C and axis of bubble and error due to curvature and refraction may be eliminated by balancing B.S and F.S.
- Above errors can also be eliminated by using Reciprocal levelling

Difficulties in the levelling

Taking level of an overhead point

If we need RL of points like on chejja of the window, then the staff is inverted. This reading is entered as a negative reading. To get RL = HI – (- y), where “y” is the inverted reading. RL = HI + y