BASIC SURVEYING UNIT-2

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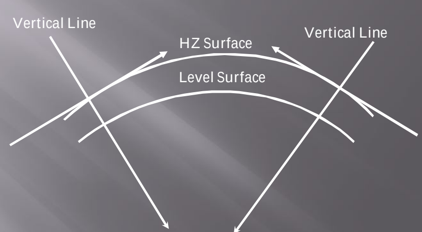
Vertical

- Direction of gravity
- Most fundamental direction
- Gravity as source of Energy
- Hydro power generation
- Continuously changing at any point
- Most Important application is gravitational Flow
- It is gravitational potential (gh) which governs flow not simply h

Vertical



Definitions

- Vertical line: A line that follows the local direction of gravity as indicated by a plumb line.
- Level surface: A curved surface that, at every point is perpendicular to the local plumb line (the direction in which gravity acts). Still Water surface
- Level line: A line in a level surface
- Horizontal plane: A plane perpendicular to the local direction of gravity. In plane surveying, it is a plane perpendicular to the local vertical line.

Definitions

- Horizontal line: A line in a horizontal plane. In plane surveying, it is a line perpendicular to the local vertical.
- Vertical datum: Any level surface to which elevations are referenced. This is the surface that is arbitrarily assigned an elevation of zero.
- Elevation: The distance measured along a vertical line from a vertical datum to a point or object
- Benchmark: relatively permanent object bearing a marked point whose elevation above or below an adopted datum

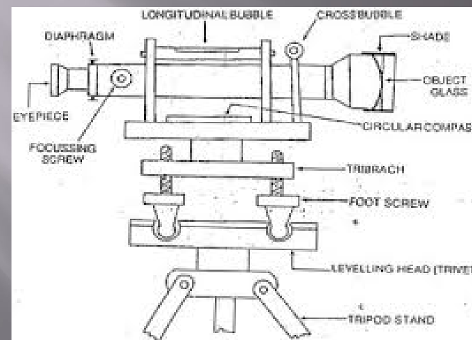
Bench Mark

- A point of Known elevation
  - GTS Bench mark (Great Triangulation Survey) :
    - These Bench marks are established by national agency like Survey of India. They are established with highest precision.
  - Permanent Bench Mark :
    - They are fixed points of reference establish with reference to GTS Bench mark. Usually established by CPWD, PWD, Railways etc.
  - Temporary Bench Mark
    - They are fixed points of reference establish with reference to Permanent Bench mark. Usually established at the construction sites
  - Arbitrary Bench mark :
    - These are reference points whose elevations are arbitrarily assumed.

Methods for Measuring Elevation

- Direct method
  - Uses Sprit level and telescope
  - Horizontal plane acts as reference
  - Long sights need curvature and refraction corrections
- Trignometric levelling
  - Vertical angles and distances are used for height determination
- Barometric Levelling
  - Atmospheric pressure reduces as height increases
  - Atmospheric pressure is measured to get height
- Hypsometry
  - Atmospheric Pressure and boiling point are related
  - Boiling point is measured thus atmospheric pressure and height

Levelling Instrument



Levelling Instruments

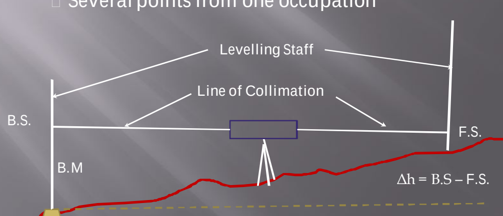
- Dumpy level
  - Base or levelling head
    - Tribrach (upper)
    - Trivet stage (Lower)
    - Foot screws
  - Telescope
  - Altitude bubble
- Tilting level (IOP level)
  - Same as dumpy level
  - Tilting screws
  - to tilt the telescope
    - Setting out constant slopes such as bed of a canal
- Automatic levels
- Digital levels

Levelling staff

- Graduated rod usually 5 mm thick b / w strips
- Solid staff
- Telescopic staff
- Folding Staff
- Target staff
- Aluminium staff

Basic Principle of Leveling

- Measures height differences between points
  - Assumes the Horizontal surface is Level Surface At the instruments axis, the *horizontal* surface is tangent to the *level* surface
  - Several points from one occupation



Definitions

- **Back sight (BS)**
  - The *first* reading from a new instrument station (i.e. fix the height of line of collimation)
- **Fore sight (FS)**
  - The *last* reading from the current instrument station (i.e. give the height to a benchmark)
- **Intermediate sight (IS)**
  - Any sight that is not a back sight or fore sight
- Change point
- Where we shift the instrument we take both FS and BS

Basic Rules for Leveling

- Always start and finish a leveling run on a Benchmark (BM) and close the loops
- Fore sight and back sight distances should be almost equal
- Use short line of sights (normally < 50m)
- Never read below 0.5m on a staff (refraction)
- Use well defined change points
- Beware of shadowing effects and crossing waters

Adjustment of Level

- Temporary Adjustment
  - adjustments which are made for every setting of a level
- Permanent adjustment
  - required if some error is there in instrument i.e. the axis relationship has disturbed

Temporary Adjustment

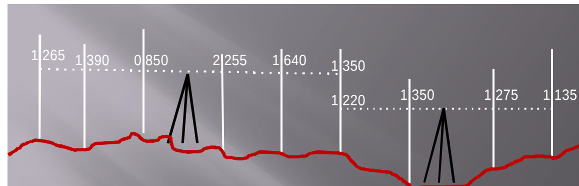
- setting up the level
  - fixing the instrument on the tripod and also approximate levelling by leg adjustment
- Levelling up
  - Accurate levelling is done with the help of foot screws and by using plate bubble.
  - The object of levelling up the instrument is to make its vertical axis truly vertical.
  - The level tube is brought parallel to any two of the foot screws, by rotating the upper part of the instrument
  - The bubble is brought to the centre of the leveltube by rotating both the foot screws either inward or outward
  - The level tube is then brought over the third footscrew again by rotating the upper part of the instrument.
  - The bubble is then again brought to the centre of the level tube by rotating the third foot screw either inward or outward
- Elimination of parallax
  - Focusing the eye piece for distinct vision of cross hairs
  - Focusing the objective so that image is formed in the plane of cross hairs

Simple levelling

- Place the instrument from where both points are visible and equidistant as far as possible
- Level the instrument correctly.
- Direct the telescope towards the staff held at B.M.
- Take the reading of Central, horizontal hair of the diaphram, where it appears to cut the staff ensuring that the bubble is central.
- Note down the reading in the column of Back sight
- Send the staff to next point (C) for which height difference is to be observed
- Direct the telescope towards C and focus it again
- Check up the bubble if central, if not bring it to the Central position by the foot screw nearest to the telescope.
- Take the reading of Central Horizontal cross hair
- Note down the reading in the column of Fore sight

Booking and reduction of the levels

- Rise and fall method
  - difference of staff readings between two consecutive points for each setting of the instrument is obtained
  - This difference indicates a rise if back sight is more than foresight and a fall if it is less than foresight
  - Rise and Fall worked out for all the points gives the vertical distances of each point relative to the preceding one.
  - RL of the following point is obtained by adding its rise or subtracting fall from the RL of preceding point
- Height of Collimation Method
  - Height of Instrument (H.I.) is calculated for each setting of the instrument by adding the back sight (B.S.) to the elevation of B.M.
  - Staff reading is subtracted from HI to obtain RL of the new point



- Computational Checks
- Rise and fall method
  - ΣBS - ΣFS = ΣRise – ΣFall = Last RL – First RL
- Height of Collimation Method
  - ΣBS - ΣFS = Last RL – First RL
  - Sum of all RL except first = (sum of each HI multiplied by the number of IS or FS taken from it) – (sum of IS and FS)

Rise and Fall Method

Stn.	Staff Reading			Rise	Fall	RL	Remarks
	BS	IS	FS				
BM	1.265					100.000	BM 100
		1.390			0.125	99.875	
		0.850		0.540		100.415	
		2.255			1.405	99.010	
		1.640		0.615		99.625	
CP	1.220		1.350	0.290		99.915	CP
		1.350			0.130	99.785	
		1.275		0.075		99.860	
			1.135	0.140		100.000	
Sum	**2.485**		**2.485**	**1.660**	**1.660**		
diff		**0.000**			**0.000**	**0.000**	

Height of Instrument Method

Stn	Reading			Height of Inst.	RL	Remarks
	BS	IS	FS			
BM	1.265			101.265	100.000	BM 100
		1.390			99.875	
		0.850			100.415	
		2.255			99.010	
		1.640			99.625	
CP1	1.220		1.350	101.135	99.915	CP
		1.350			99.785	
		1.275			99.860	
			1.135		100.000	
Sum	2.485		2.485			
diff		0.000			0.000	

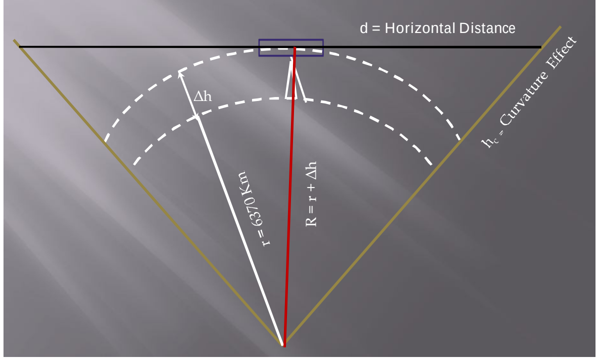
Check Height of Instrument method

- Sum of all RL except first = (sum of each HI multiplied by the number of IS or FS taken from it) − (sum of IS and FS)
- 798.485 = (101.265 X 5 + 101.135 X 3) – 11.245 = 798.485

Errors in Levelling

- Systematic Errors
  - Earth curvature
  - Refraction
  - Error in Collimation
- Accidental Errors and Mistakes
  - Change point / staff instability
  - Instrument or Benchmark instability
  - Un-calibrated staff or levels
  - Reading, booking, or computation errors
  - Fore- and back-sight distances different

Effect of Curvature



Curvature Correction

$(R + h_c)^2 = d^2 + R^2$

$R^2 + h_c^2 + 2. R. h_c = d^2 + R^2$

h_c^2 is negligible because very small in comparison to R^2

$d^2 = 2. R. h_c$

$h_c = d^2 / 2. R$

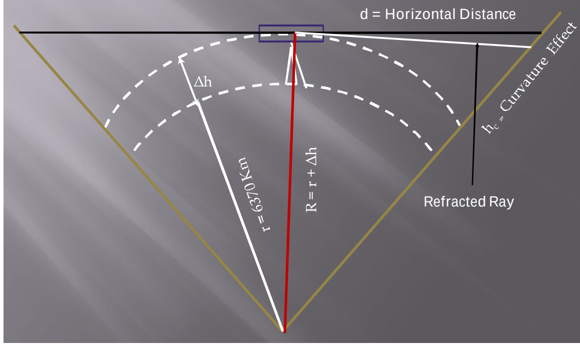
Since $R = r + \Delta h$ and Δh is very small in comparison to r therefore R = r (radius of Earth)

$h_c = d^2 / 2. r$

Refraction

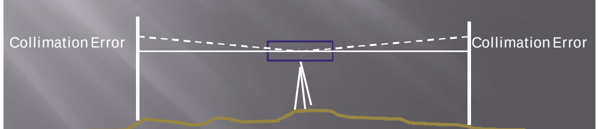
- The line of sight has to interact with different layers of atmosphere
- Refraction is largely a function of atmospheric density
- The density of atmosphere is a function of atmospheric pressure and temperature
- It normally bends down due to refraction
- The staff readings are a little lower than what should have been without refraction
- A positive correction of 1/7th of Curvature correction is applied for refraction
- Combined correction for curvature and refraction is (-ve) 6/7th of Curvature correction ($d^2/2.R$)

Curvature and refraction



Error due to collimation

- The line of collimation may be inclined upward or down ward to the true horizontal
- It inclined upward will make staff readings a little higher and vice versa
- Will be proportional to the distance
- Balancing of sights will cancel out its effect.



Reciprocal Levelling

- Instrument is set up very near to one of the points say A
- Staff readings for both stations A and B are taken as h_{A1} and h_{B1}
- h_{A1} is free from all systematic errors as distance is almost zero
- h_{B1} has an error of ΔE (Includes curvature refraction and Collimation)
- Level difference between A and B (Δh_{AB}) is $(h_{B1} + \Delta E) - h_{A1}$

Reciprocal Levelling

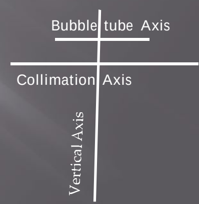
- Instrument is set up very near to one of the other point say B
- Staff readings for both stations A and B are taken as h_{A2} and h_{B2}
- h_{B2} is free from all systematic errors as distance is almost zero
- h_{A2} has an error of ΔE (Includes curvature refraction and Collimation)
- Level difference between A and B (Δh_{AB}) is $h_{B2} - (h_{A2} + \Delta E)$

Reciprocal Levelling

- Level difference between A and B
  $\Delta h_{AB} = h_{B2} - (h_{A2} + \Delta E)$
- Level difference between A and B
  $\Delta h_{AB} = (h_{B1} + \Delta E) - h_{A1}$
- Adding both
  $2.\ \Delta h_{AB} = h_{B2} - (h_{A2} + \Delta E) + (h_{B1} + \Delta E) - h_{A1}$
  $= (h_{B2} - h_{A2}) + (h_{B1} - h_{A1})$
  $\Delta h_{AB} = \{(h_{B2} - h_{A2}) + (h_{B1} - h_{A1})\}/2$
- Taking mean of both sided observations eliminates all kinds of systematic errors in reciprocal levelling
- Subtracting both gives the error (ΔE) (Includes curvature refraction and Collimation)
  $\Delta E = \{(h_{B2} - h_{A2}) - (h_{B1} - h_{A1})\}/2$

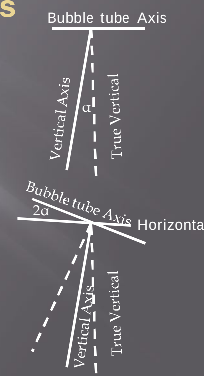
Permanent adjustment

- Resting and Adjusting the instrument to obtain desired axis relationship
  - The axis of bubble must be perpendicular to vertical axis
  - Horizontal cross hair should be perpendicular to vertical axis
  - Collimation axis must be parallel to bubble axis



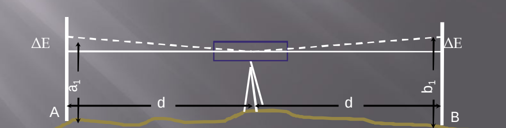
Bubble axis perpendicular to vertical axis

- Set up and level the Dumpy level with foot screws.
- Rotate 180^o if bubble remains in centre the axes are perpendicular
- If not, The error is double of actual error
- Correct half of the error by adjusting capstan screw at one end of bubble tube



Line of Collimation parallel to bubble axis

- Principle: when instrument is exactly midway the collimation error cancels out
- Test and adjustment is done by TWO-Peg test
- Let staff readings are a_1 and b_1 corresponding to A and B respectively when instrument is exactly midway
- Difference of a_1 and b_1 is the true level difference between A and B

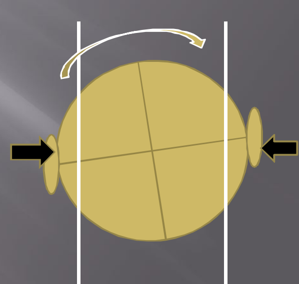


Two- Peg test

- Shift the instrument to one end either A or B
- Staff readings taken as a_2 and b_2 corresponding to A and B respectively
- Difference of a_2 and b_2 is the apparent level difference between A and B i.e. this includes double the error.
- Find out the error and compute the correct staff reading for B
- Adjust the diaphragm by loosening and tightening opposite vertical screws of the diaphragm for correct staff reading

Horizontal cross hair Perpendicular to vertical axis

- Set up and level the Dumpy level with foot screws.
- Take staff reading at one edge of cross hair
- Rotate slightly so that staff is other edge of cross hair
- Compare both edge readings
- If same there is no error
- If different adjust half by loosening and rotating the cross hair in such a way that half error is adjusted
- Tighten the screws
- Recheck and correct till difference is zero



Methods of relief representations

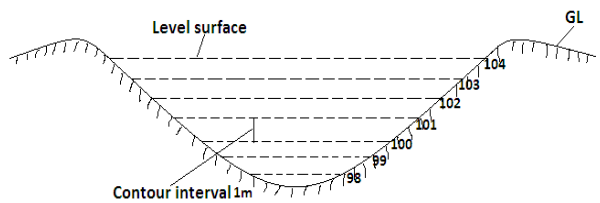
- **HACHURING**
  - small lines drawn to represent slopes. The lines are drawn thicker to represent steeper slopes and thinner for gentle slope. The slopes above 45° is depicted completely in black colour.
- **RELIEF SHADING**
  - uses '*light and shadows*' to highlight the three-dimensional appearance of terrain
  - the slope is darkened according to its steepness (i.e. The steeper the slope, the darker the shade), whereas, on the illuminated parts of the relief, the slope is shown by progressively lightening the shades.
- **LAYER TINTING**
  - *Layer tinting*, also known as *layer coloring* or *hypsometric coloring* is a method used to represent relief by using various shades of colors.
- **SPOT HEIGHTS**
  - Spot heights are depicted by using a dot together with a number which indicates the exact elevation of the given point on the map
- **CONTOURING**
  - Contour lines are the lines drawn on the map connecting all points on the earth's surface with equal elevations above a fixed datum line

Contour Line

- *A contour is an imaginary line joining points of equal elevation*
- A contour line is a line on the map representing a contour.

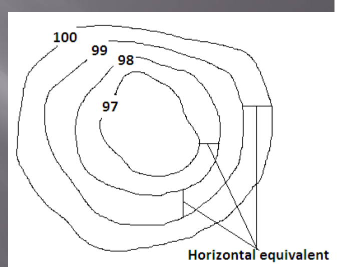
Contour Interval

- The vertical distance between two successive contours is known as 'Contour interval'. It remains constant for a given map. The difference in R.L.'s of two contour gives contour interval.



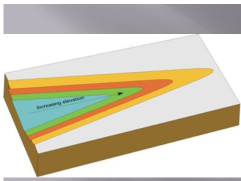
Horizontal Equivalent

- The horizontal distance between two successive contours is known as 'Horizontal equivalent'. It is not constant for a given map, it varies according to the steepness of the ground

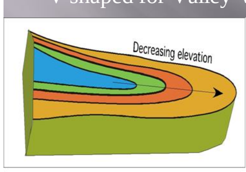


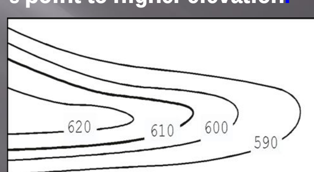
Characteristics of Contours

- **Contour lines are continuous**
- **Contours must either close or extend from boundary to boundary.**
- **A series of V-shape indicates a valley and the V's point to higher elevation**
- **A series U shape indicates a ridge. The U shapes will point to lower elevation**
- **Evenly spaced lines indicate an area of uniform slope**
- **The distance between contour lines indicates the steepness of the slope. The greater the distance between two contours the less the slope. The opposite is also true.**
- **Contours are perpendicular to the maximum slope**



V shaped for Valley **V's point to higher elevation.**

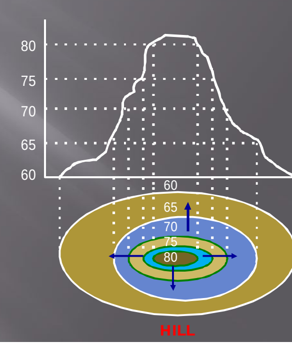




U shaped for Ridge **U's point to lower elevation.**

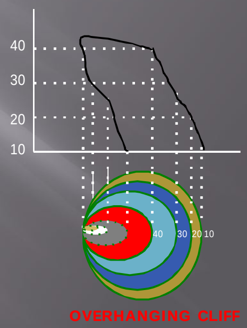
Characteristics of Contours

- A series of closed contour lines on the map represent **a hill** , if the higher values are inside
- A series of closed contour lines on the map indicate **a depression** if the higher values are outside



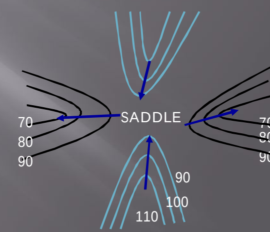
Characteristics of Contours

- Contour lines cannot merge or cross one another on map except in the case of **an overhanging cliff.**



Characteristics of Contours

- Depressions between summits is called **a saddle.** It is represented by four sets of contours as shown. It represents a dip in a ridge or the junction of two ridges.



Purposes of Contouring

- Contour survey is carried out at the starting of any engineering project such as a road, a railway, a canal, a dam, a building etc.
- For preparing contour maps in order to select the most economical or suitable site.
- To locate the alignment of a canal so that it should follow a ridge line.
- To mark the alignment of roads and railways so that the quantity of earthwork both in cutting and filling should be minimum.
- For getting information about the ground whether it is flat, undulating or mountainous.
- To locate the physical features of the ground such as a pond depression, hill, steep or small slopes.

Methods of Contouring

- **Two Step Process**
  - **Vertical Control**
  - **Horizontal Control**
- **Direct Method**
  - **Locates points of equal elevation first then those points are located (vertical First)**
- **Indirect Method.**
  - **Locates horizontal positions then their elevations are recorded, Interpolation to locate points of equal elevation (Horizontal first)**
  - **by squares or grids method**
  - **by cross sections**
  - **By radial lines**

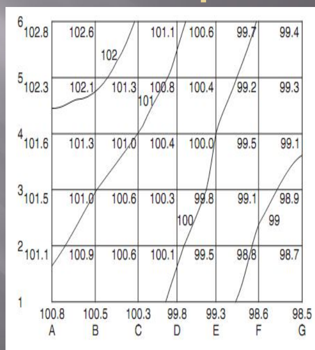
Direct method

- First of all we locate points of desired elevation and mark them with peg
  - The height of instrument is determined by taking a back sight on the B.M. and adding it to the R.L. of bench mark
  - Subtract the RL of desired contour from HI and locate the points where we get desired staff reading and put a peg
- Locate those pegs with any of the surveying techniques such as tape and compass, theodolite and tape, plane tabling etc.
- This is suitable for small area and where great accuracy is required
- Very accurate but highly time consuming so not much popular

Indirect methods

- the spot levels are taken along the series of lines laid out over the area
- The series of lines may form a regular pattern so that horizontal positions can be easily plotted
- The RL of intersection points is measured with levelling instrument
- The positions are plotted on the plan and the contours drawn by interpolation
- also known as contouring by spot levels

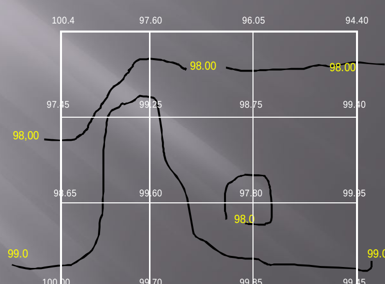
Method of Squares



Method of Squares

- the whole area is divided into number of squares/ rectangles
- the side of which may vary from 5m to 30m depending upon the nature of the ground and the contour interval.
- The corners of the squares are pegged out and the reduced levels of these points are determined with a level
- Interpolation are carried out to join contours

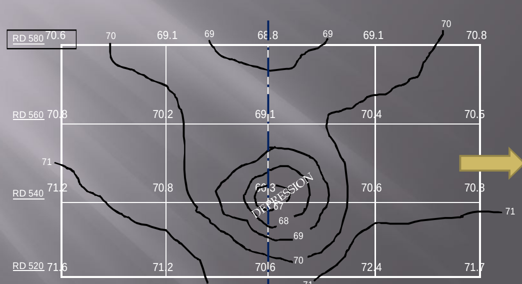
Contour lines



By Cross sections

- most suitable for the surveys of long narrow strips such as a road, railway or canal etc
- Cross sections are run transverse to the centre line of the work and representative points are marked along the lines of cross-section
- spacing of the cross-sections depends upon the topography of the country and the nature of the survey
- levels of the points along the section lines are plotted on the plan and the contours are then interpolated

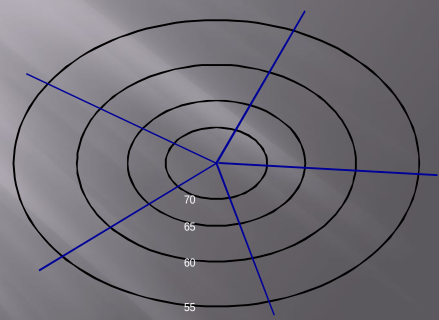
By Cross sections



By Radial Lines

- number of Radial lines are laid out at a *known angular interval* from the common centre by theodolite or compass
- representative points are marked by pegs along these radial lines
- their positions are fixed up by horizontal angles and bearings
- Alternatively a tacheometer or total station can be used
- *elevations and distances* are then *calculated and plotted* on the plan
- *contour lines* are then *interpolated and plotted*

By Radial Lines



Interpolation

- Interpolation is required because contour lines are lines of constant elevation and the station elevations that are measured in the field seldom fall on the desired contour elevation
- Interpolating is finding the proportional distance from the grid points to the contour line elevation
- by estimation
  - for low precision maps.
- by calculation and measurement
  - for higher precision maps.
- A combination of methods can also be used,
  - depending on the use of the map

By Estimation

- points of desired elevation are estimated roughly and the contours are then drawn through these points
- Assumes Constant slope between the points

calculation and measurement

- Proportional distance is calculated using an equation

$$\text{Proporiton} = \frac{\text{High elevation - Contour elevation}}{\text{High elevation - Low elevation}}$$

- For the previous example this would result in

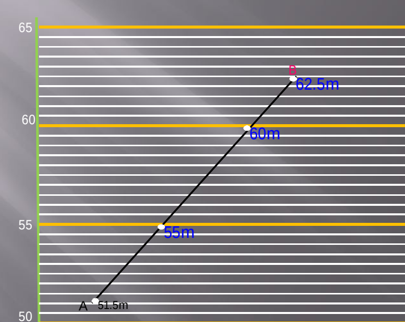
$$\text{Proporiton} = \frac{102.300 - 102.0}{102.300 - 101.450} = \frac{0.300}{0.85} = 0.353$$

- The 102 m contour line would be located 0.353 or 1 / 3 of the distance between the two stations from 102.30 m point towards 101.45 m point

Graphical Method

- on a piece of tracing cloth, a number of *parallel lines spaced* (usually 1/10th of the contour interval)
- *Every tenth line* being made *thick*.
- interpolate contours between two points A and B of elevation 51.5m and 62.5m respectively.
- If the *bottom line* represents an elevation of 50m. Then *the successive thick lines* will represent 55m, 60m and 65m
- Place the tracing cloth so that the point A is on the *third* line from the bottom, now move and rotate the tracing cloth until B is on the *fifth* line *above* the 60m thick line
- The intersection of the thick lines 1 and 2 representing elevations of 55m and 60 m and the line AB gives the position of the points on the 55m and 60m contours respectively and are pricked through on the plan with a *pin*

Graphical Method



Drawing the contour lines

- Contour lines are drawn as fine and smooth free hand curved lines by joining points of equal elevation
- They are inked in either in black or brown colour.
- Every fifth contour is made *thicker* than the rest.
- elevation of contours must be written in a uniform manner, either on the higher side or in a gap left in the line

Uses of Contour maps

- A contour map furnishes information regarding the features of the ground , whether it is flat, undulating or mountainous.
- From a contour map , sections may be easily drawn in any direction
- Intervisibility between two ground points plotted on map can be ascertained
- It enables an engineer to approximately select the most economical or suitable site for an engineering project such as a road, a railway, a canal or a pipe line etc.
- A route of a given grade can be traced on the map.
- Catchment area and capacity of a reservoir may be determined from the contour map.
- Contour map may be used to determine the quantities of earth work.

Reciprocal Levelling Numerical

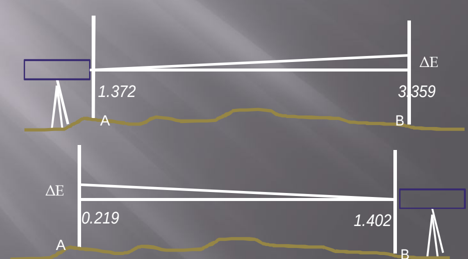
A and B are 2400 m apart. Observations with a level gave:

A, height of instrument 1.372 m, reading at B 3.359 m

B, height of instrument 1.402 m, reading at A 0.219 m

Calculate the difference of level and the error of the instrument if refraction correction is one seventh that of curvature.

- Solution



Instrument at *A, B is lower by* $(3.359 - 1.372) = 1.987\ m$

Instrument at *B, B is lower by* $(1.402 - 0.219) = 1.183\ m$

True height of B below A $= 0.5 \times 3.170\ m = 1.585\ m$

Combined error due to curvature and refraction $= 0.0673D^2\ m = 0.0673 \times 2.4^2 = 0.388\ m$

Instrument at $A = 1.372$, *thus true reading at* $B = (1.372 + 1.585) = 2.957$ m Actual reading at $B = 3.359\ m$

Actual reading at *B too high by* $+ 0.402\ m\ (3.359-2.957)$

Thus: $(c - r) + e = +0.402\ m$

$e = +0.402 - 0.388 = +0.014\ m$ in 2400 m

Collimation error $e = +0.001$ m up in 100 m