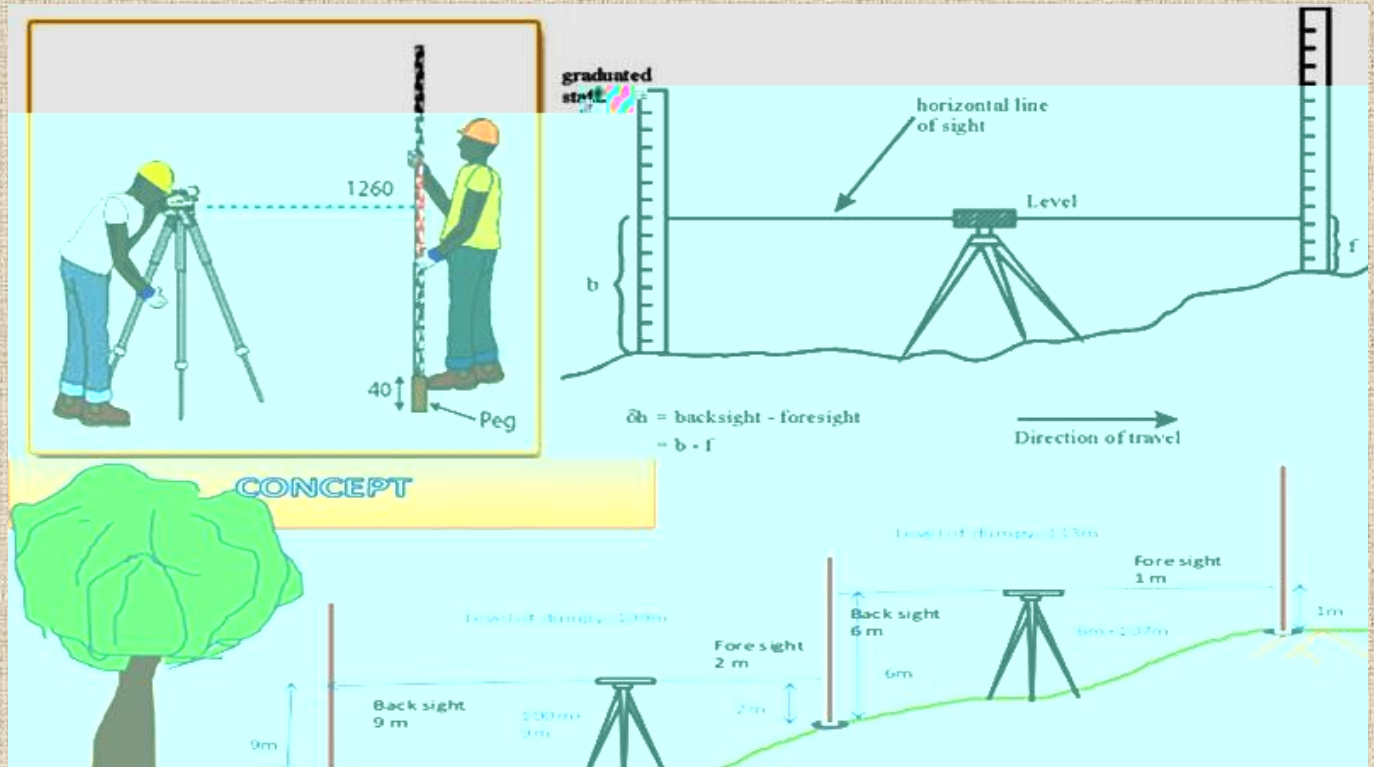


Chapter 4: Leveling



Dr. Maher A. El-Hallaq
Associate Professor of Geomatics
The Islamic University of Gaza

Contents

- General definitions
- Methods of leveling
- Differential leveling equipment
- Basic principle in Diff. leveling
- Diff. leveling definitions
- General procedure
- Booking and calculations
- Leveling applications

Definitions

Point Elevation:

Vertical distance above or below a certain datum (MSL).

+ve if above datum (e.g. Jerusalem)

–ve if below datum (e.g. Jericho)

Leveling:

Determination of elevation or difference in elevation

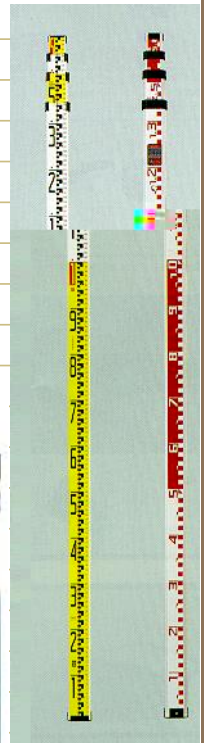


Methods of leveling

Leveling can be done in several ways:

- Tape leveling
- Barometric leveling
- Trigonometric leveling
- GPS leveling
- Photogrammetric leveling
- Differential leveling

Differential leveling equipment



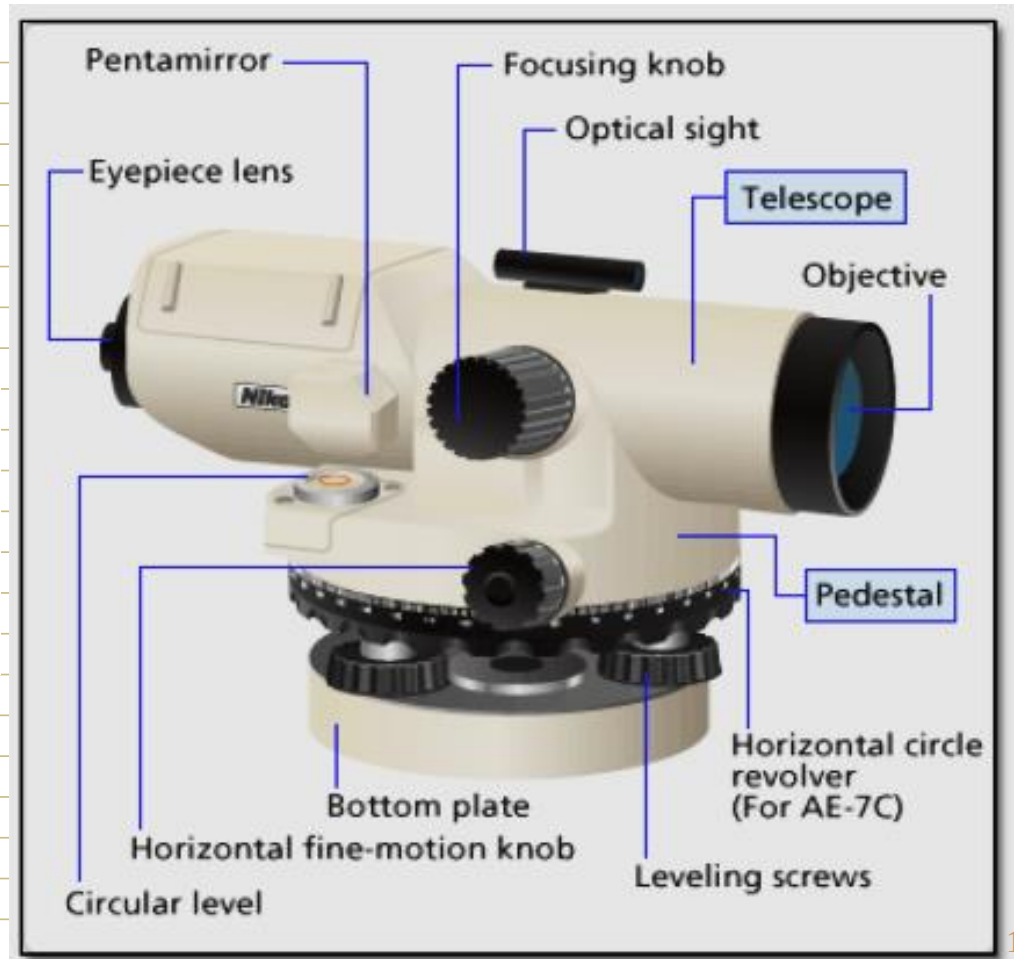
Level Instrument



Differential leveling equipment

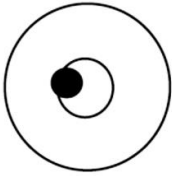


Differential leveling equipment

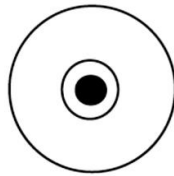


Basic Principle in Diff. Leveling

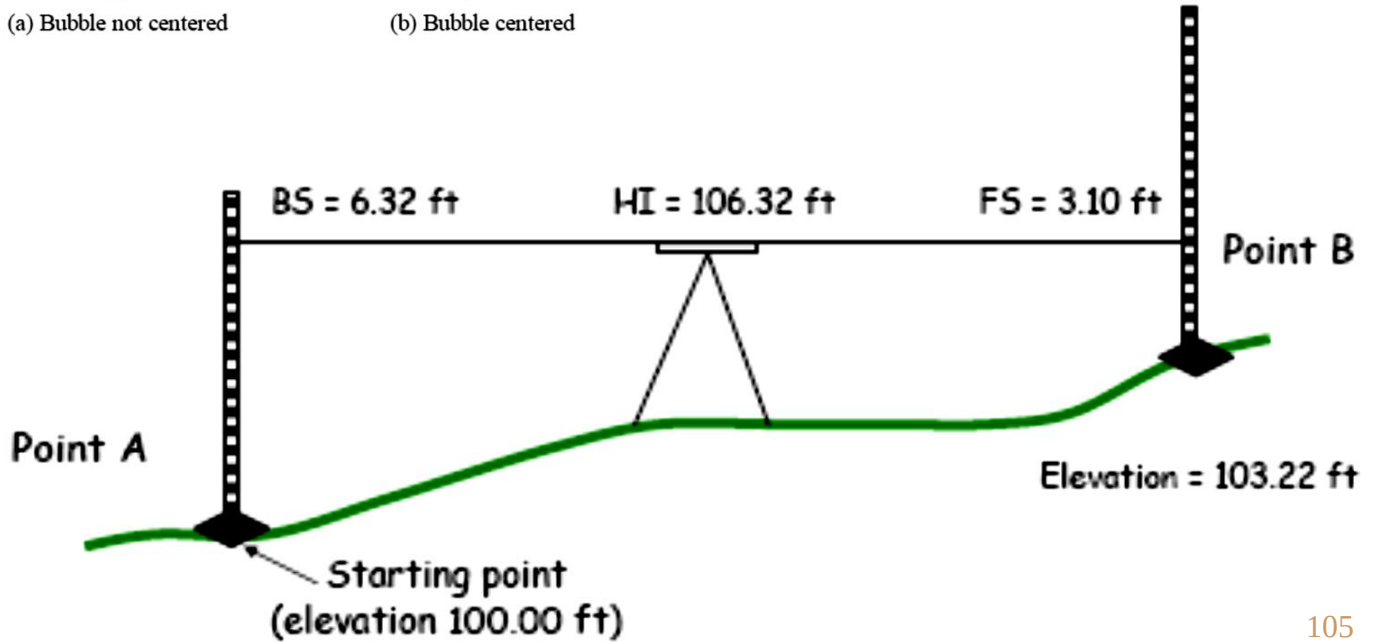
The line of sight must be in a horizontal plane



(a) Bubble not centered

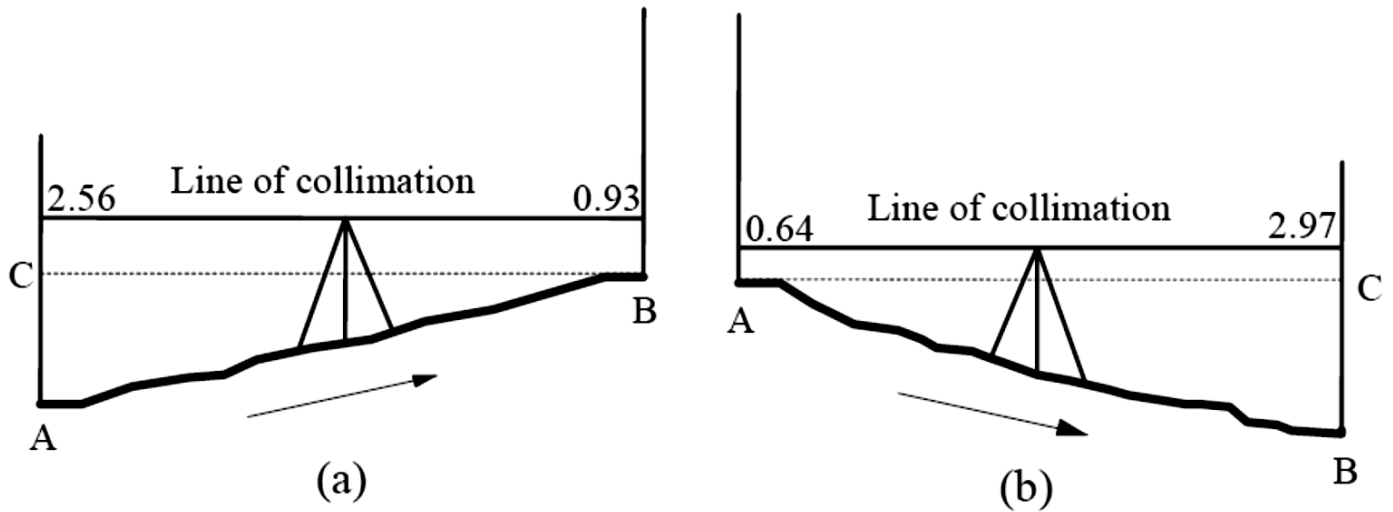


(b) Bubble centered



Basic Theory in Diff. Leveling

Elevation difference = first reading at A - second reading at B

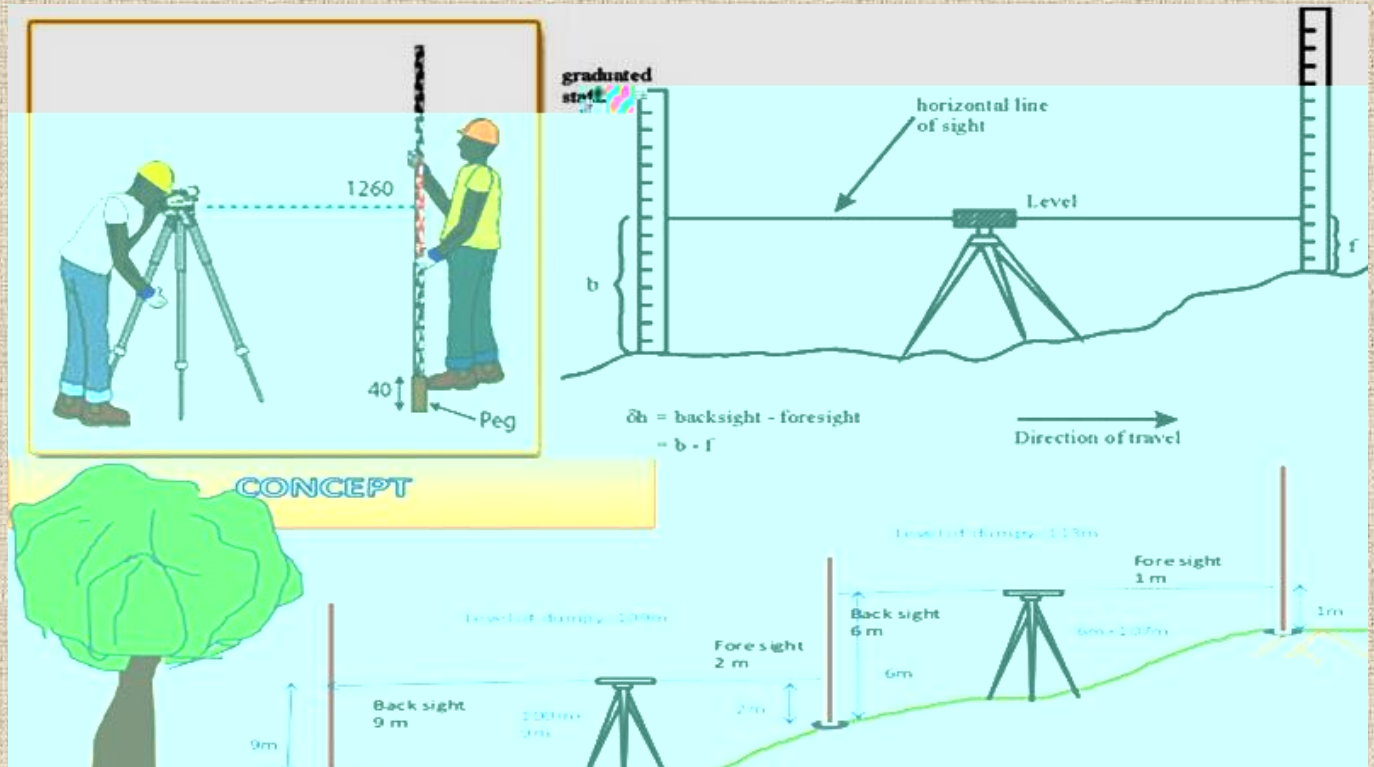




THANK YOU

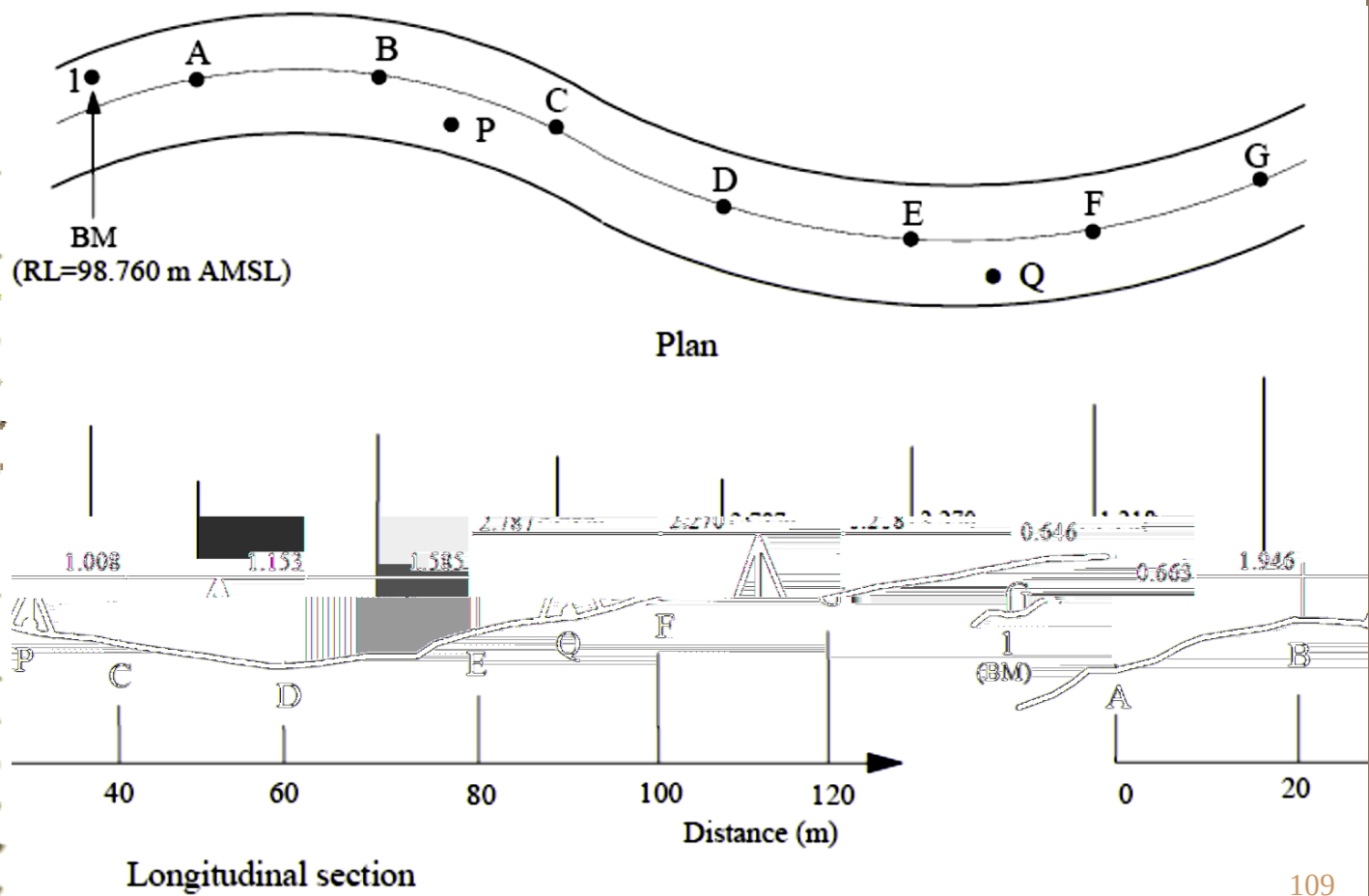
Questions

Chapter 4: Leveling



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General Procedure



Diff. Leveling Definitions

BM: relatively permanent point of known elevation.

HI: elevation of the line of sight of the level.
= elevation of BM + staff reading at BM

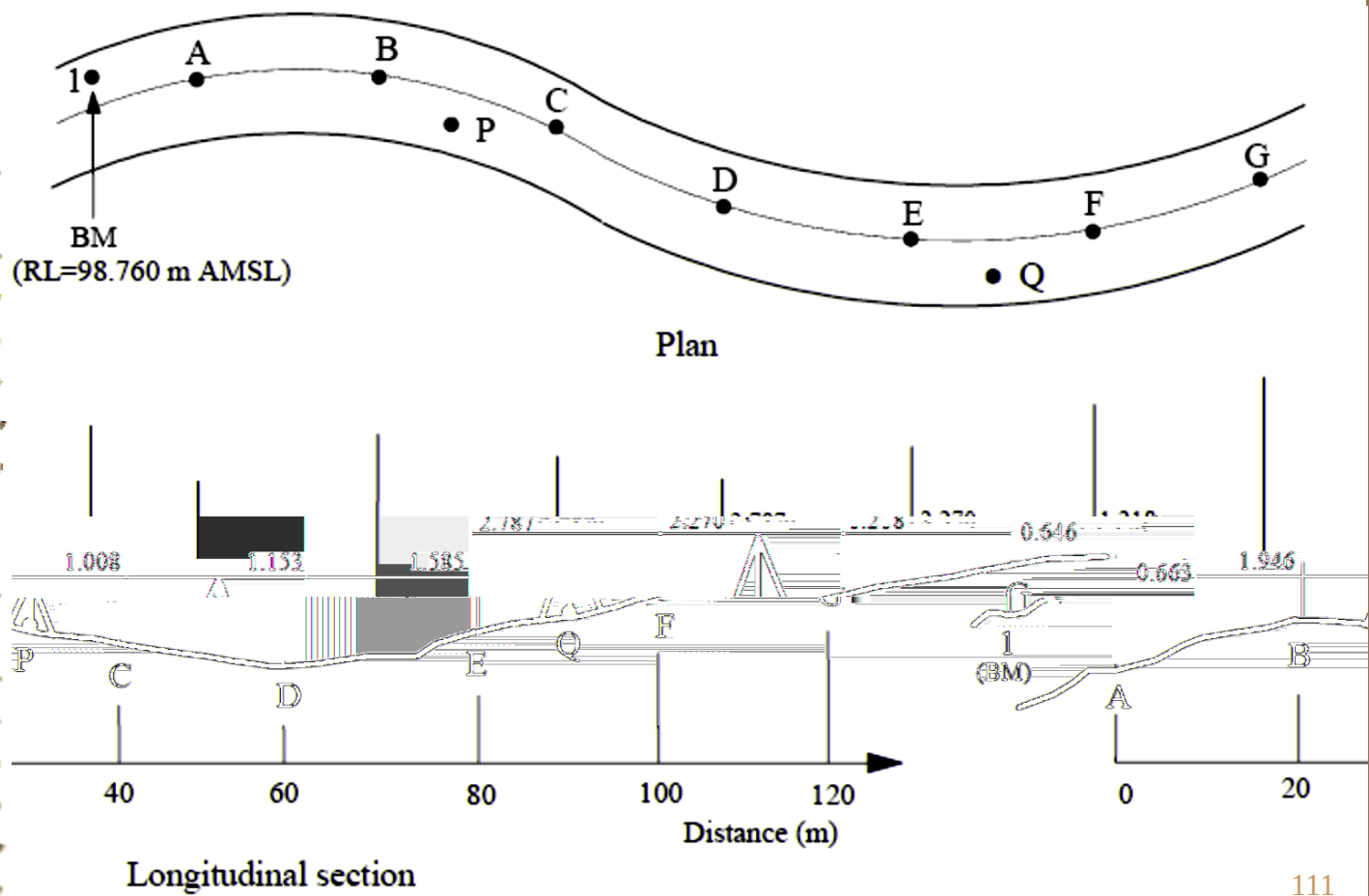
BS: the first staff reading after setting up the level.

FS: the last staff reading before moving the level.

IS: reading(s) between BS and FS.

TP: point that has FS and BS readings.

General Procedure



Booking and Calculations

Height of Instrument method

Point	BS	IS	FS	HI	RL	Distance (m)	Notes
1	0.663			99.423	98.760	-	BM
A		1.946			97.477	0	Beginning of project
B		1.008			98.415	20	
C		1.153			98.270	40	
D	2.787		1.585	100.625	97.838	60	TP
E		2.270			98.355	80	
F		1.218			99.407	100	
G			0.646		99.979	120	
SUM	3.450	7.595	2.231				

→ Number of BS readings = number of FS readings

→ $\Sigma BS - \Sigma FS = RL \text{ of last point} - RL \text{ of first point}$

Booking and Calculations

Height of Instrument method

Point	BS	IS	FS	HI	RL	Distance (m)	Notes
1	0.663			99.423	98.760	-	BM
A		1.946			97.477	0	Beginning of project
B		1.008			98.415	20	
C		1.153			98.270	40	
D	2.787		1.585	100.625	97.838	60	TP
E		2.270			98.355	80	
F		1.218			99.407	100	
G			0.646		99.979	120	
SUM	3.450	7.595	2.231				

→ ~~Number of BS readings = number of FS readings~~

→ $\Sigma BS - \Sigma FS = RL \text{ of last point} - RL \text{ of first point}$

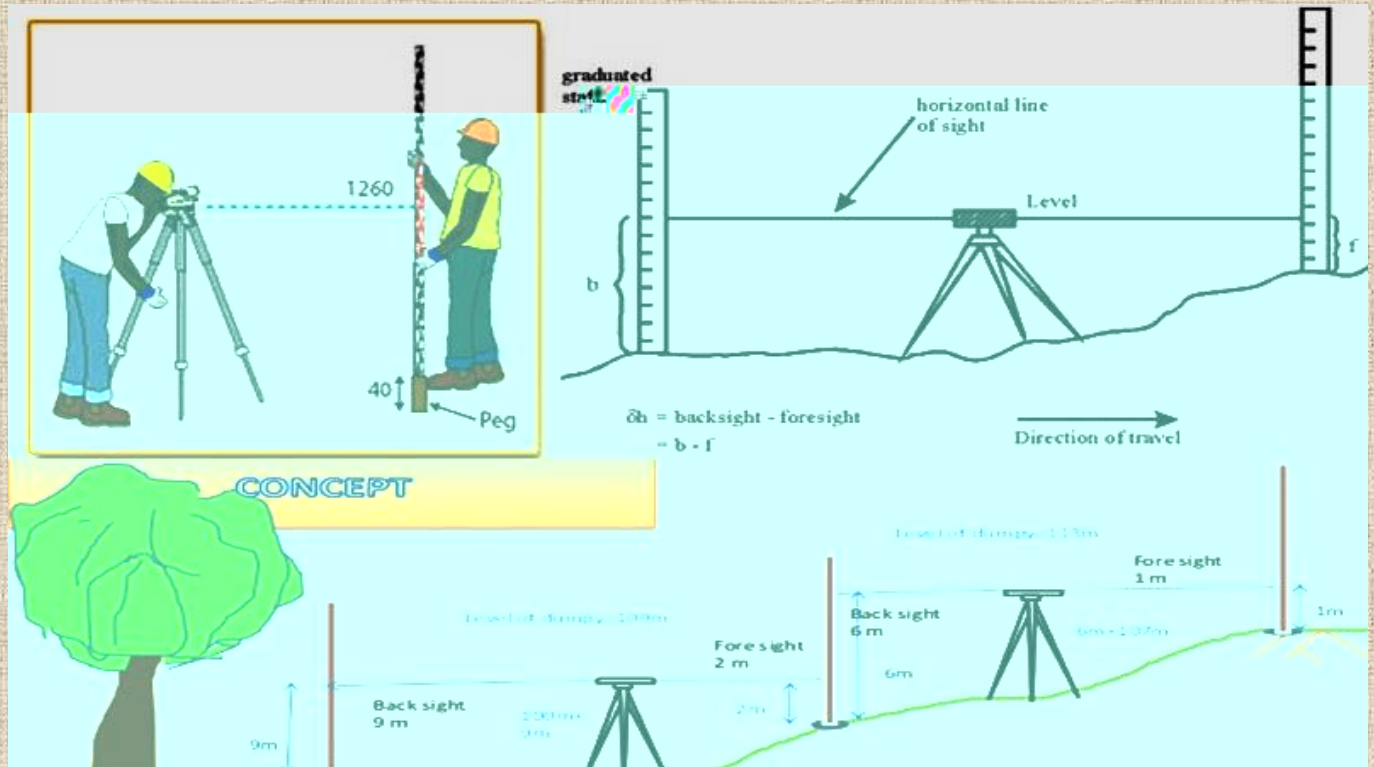
→ All RLs except the first = $(\Sigma \text{ of each HI value} * \Sigma (\text{related \# of IS \& FS})) - \Sigma IS - \Sigma FS$



THANK YOU

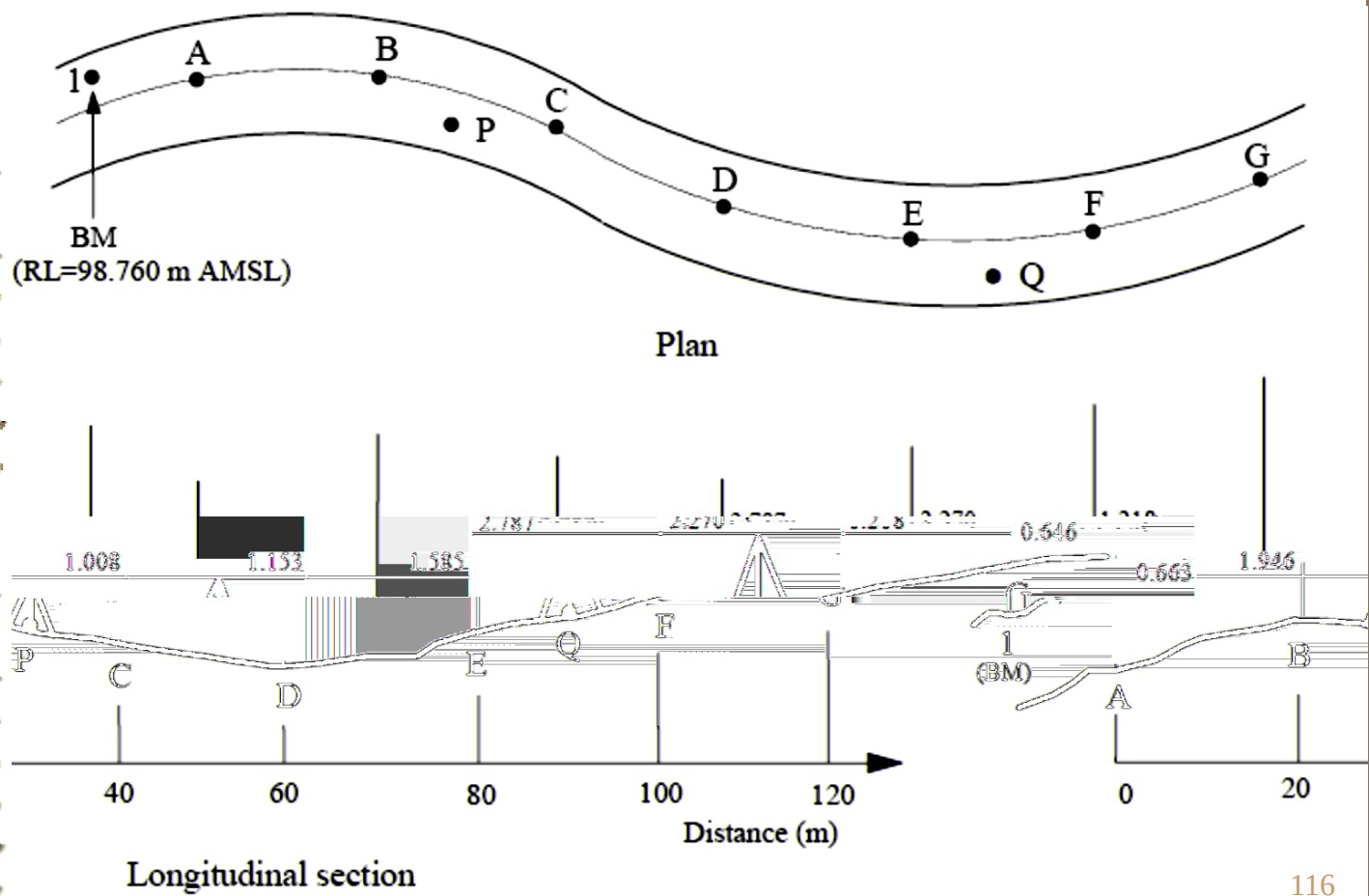
Questions

Chapter 4: Leveling



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General Procedure



Booking and Calculations

Rise and Fall method

Point	BS	IS	FS	Rise	Fall	RL	Distance (m)	Notes
1	0.663					98.760	-	BM
A		1.040			1.088	97.672	20	Beginning of project
B		1.008		0.938		98.415	20	
C			1.153				0.145	98.270 40
TP			D 2.787		1.585		0.432	97.838 60
			E	2.270		0.517		98.355 80
			F	1.218		1.052		99.407 100
			G		0.646	0.572		99.979 120
		SUM	3.450	7.595	2.231	3.079	1.860	

→ Number of BS readings = number of FS readings

→ $\Sigma BS - \Sigma FS = RL \text{ of last point} - RL \text{ of first point} = \Sigma Rise - \Sigma Fall$

Booking and Calculations

Rise and Fall method

Point	BS	IS	FS	Rise	Fall	RL	Distance (m)	Notes
1	0.663					98.760	-	BM
A		1.946			1.283	97.477	0	Beginning of project
B		1.008		0.938		98.415	20	
C		1.153			0.145	98.270	40	
D	2.787		1.585		0.432	97.838	60	TP
E		2.270		0.517		98.355	80	
F		1.218		1.052		99.407	100	
G			0.646	0.572		99.979	120	
SUM	3.450	7.585	2.231	3.079	1.860			

→ Number of BS readings = number of FS readings

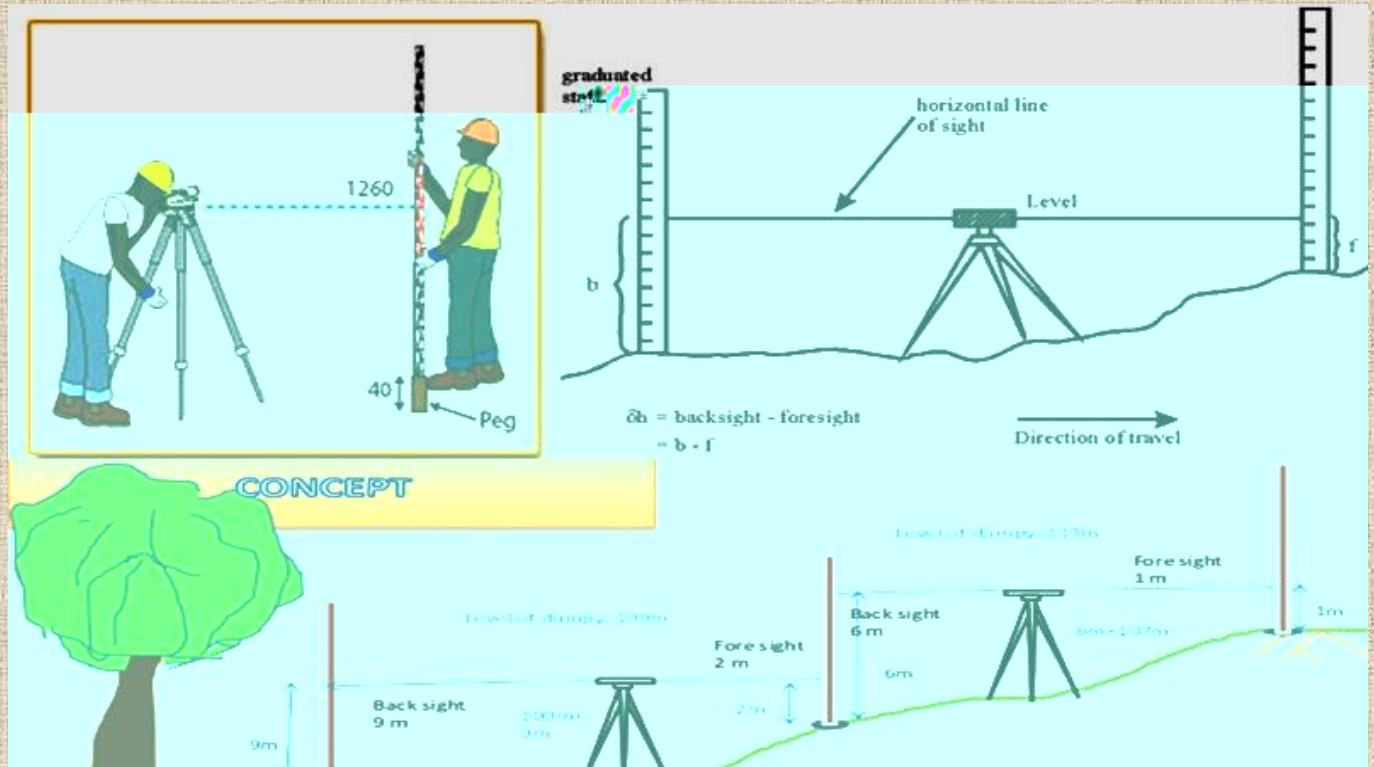
→ $\Sigma BS - \Sigma FS = RL \text{ of last point} - RL \text{ of first point} = \Sigma Rise - \Sigma Fall$

A spiral-bound notebook with a brown cover is shown. The notebook is open to a white page with horizontal yellow lines. The words "THANK YOU" are written in a large, bold, grey sans-serif font. Below them, the word "Questions" is written in a smaller, bold, grey serif font. The spiral binding is visible on the left side of the page.

THANK YOU

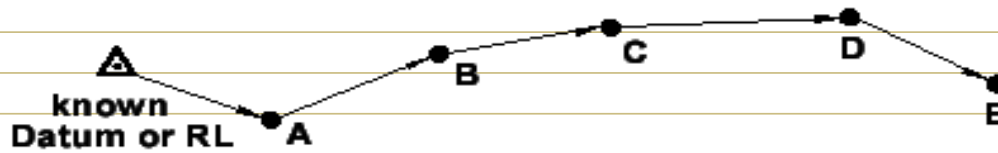
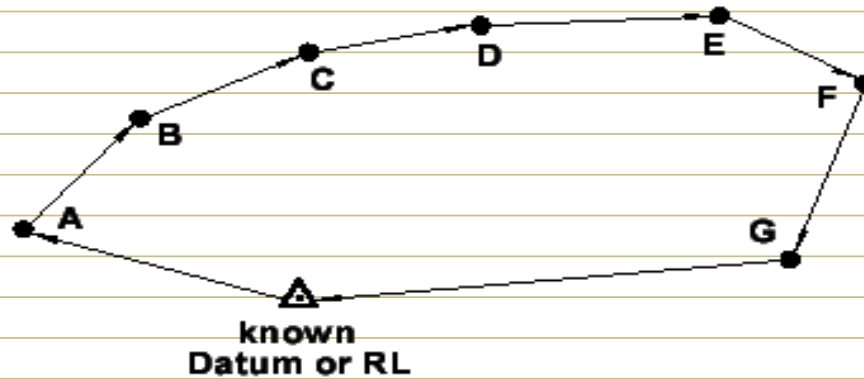
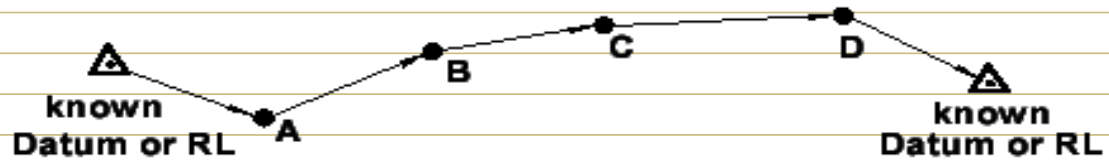
Questions

Chapter 4: Leveling

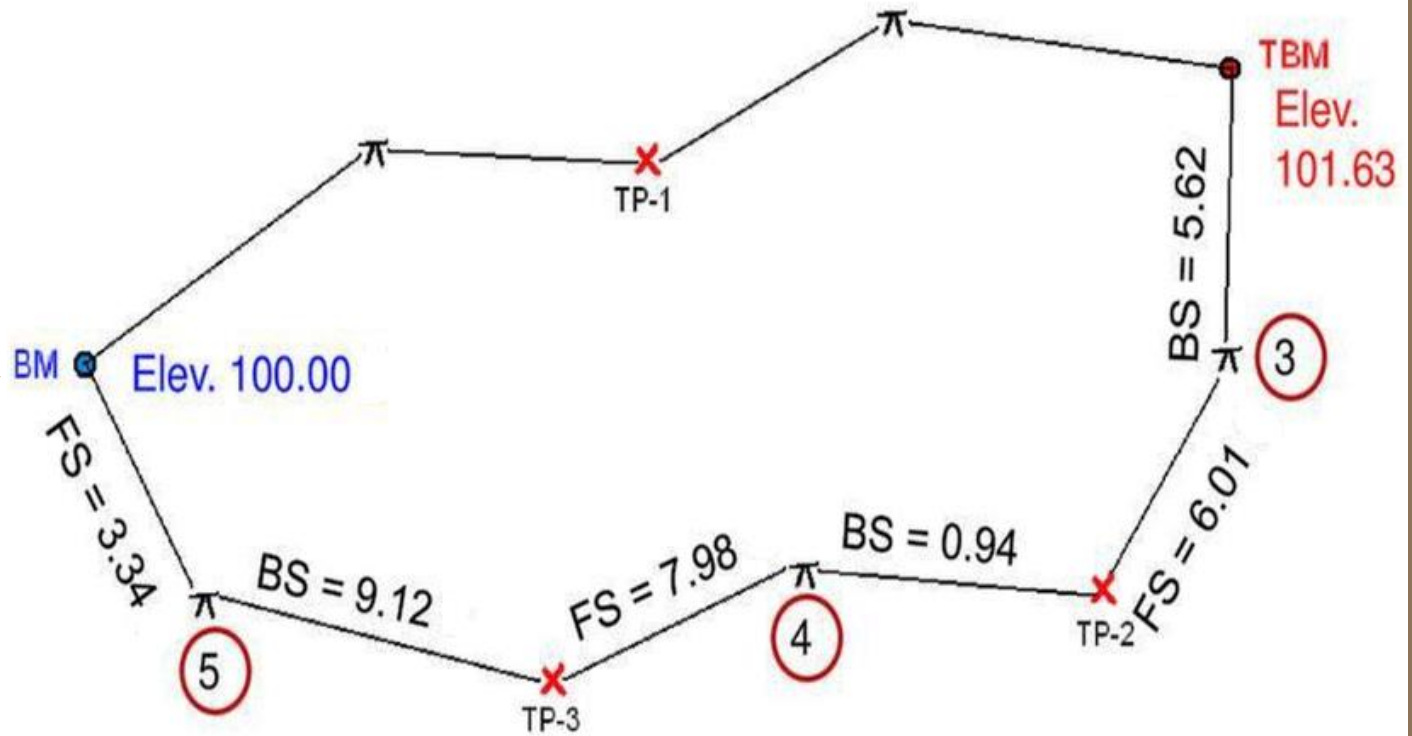


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Closure Error



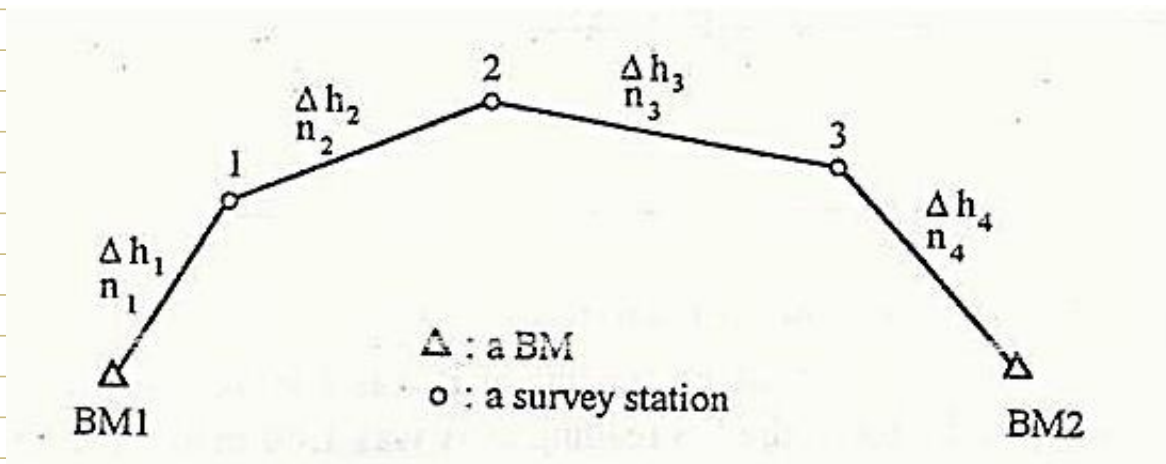
Closure Error



Closure Error

AUTO LEVEL READINGS						
					STADIA	
PT	(+) BS	HI	(-) FS	ELEV	TOP/BOT STADIA	DIST /Angle
BM	7.13	107.13	X	100.00		
TP-1	1.75	104.62	4.26	102.87		
TBM	5.62	107.25	2.99	101.63		
TP-2	0.94	102.18	6.01	101.24		
TP-3	9.12	103.32	7.98	94.20		
BM			3.34	99.98		
				- 100.00		
CLOSURE ERROR				- 0.02		

Closure Error



Closure correction for $\Delta h_i = (- n_i / \sum n_i) \times (\epsilon)$

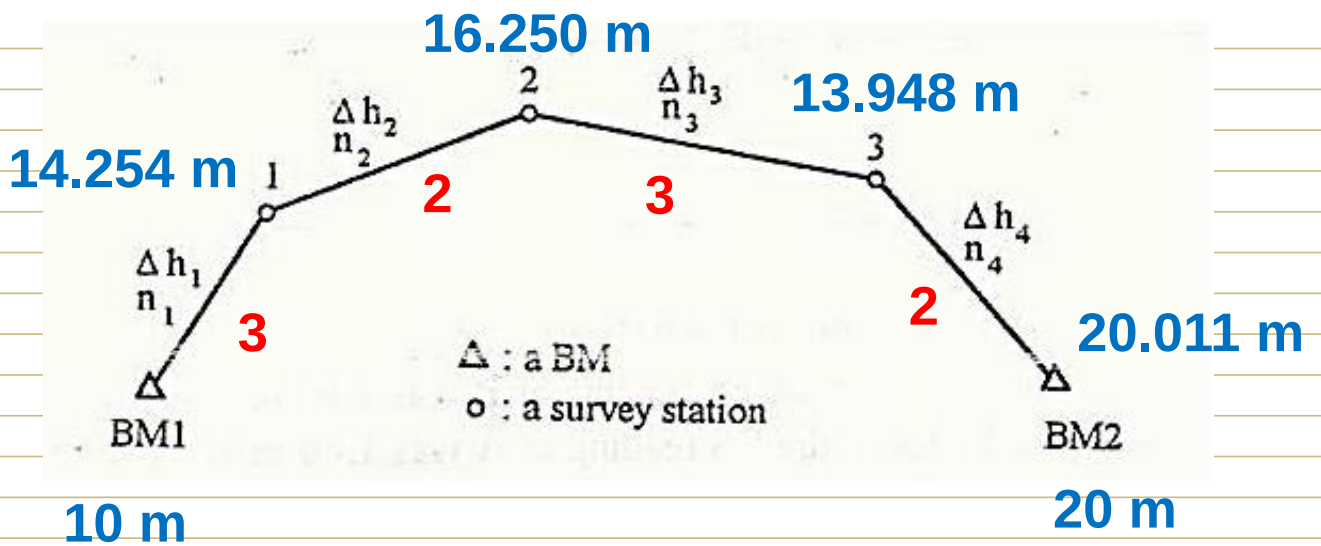
Corrected Δh_i = measured Δh_i + closure correction for Δh_i

ϵ (closure error) = h' (calculated elevation) – h (known elevation)

n_i refers to the number of level setups

& Δh_i refers to the elevation difference between consecutive stations.

Closure Error



Closure error = 20.011 - 20 = + 0.011 m ~ (11 mm)

Allowable error = $\pm (2 \text{ to } 5 \text{ km}) = \pm 15 \text{ mm}$

Since {C. error (11 mm) < A. error (15 mm) **Accepted**

Leveling classes and accuracy

1. Ordinary Leveling

- doesn't require very high accuracy
- suitable for small engineering projects, topographic mapping

$$\varepsilon = \pm k\sqrt{D}$$

2. Precise Leveling

- very accurate
- used for the establishment of BM points and high accuracy projects
- require high precision levels and staves.

K = 2 - 5 mm for precise leveling

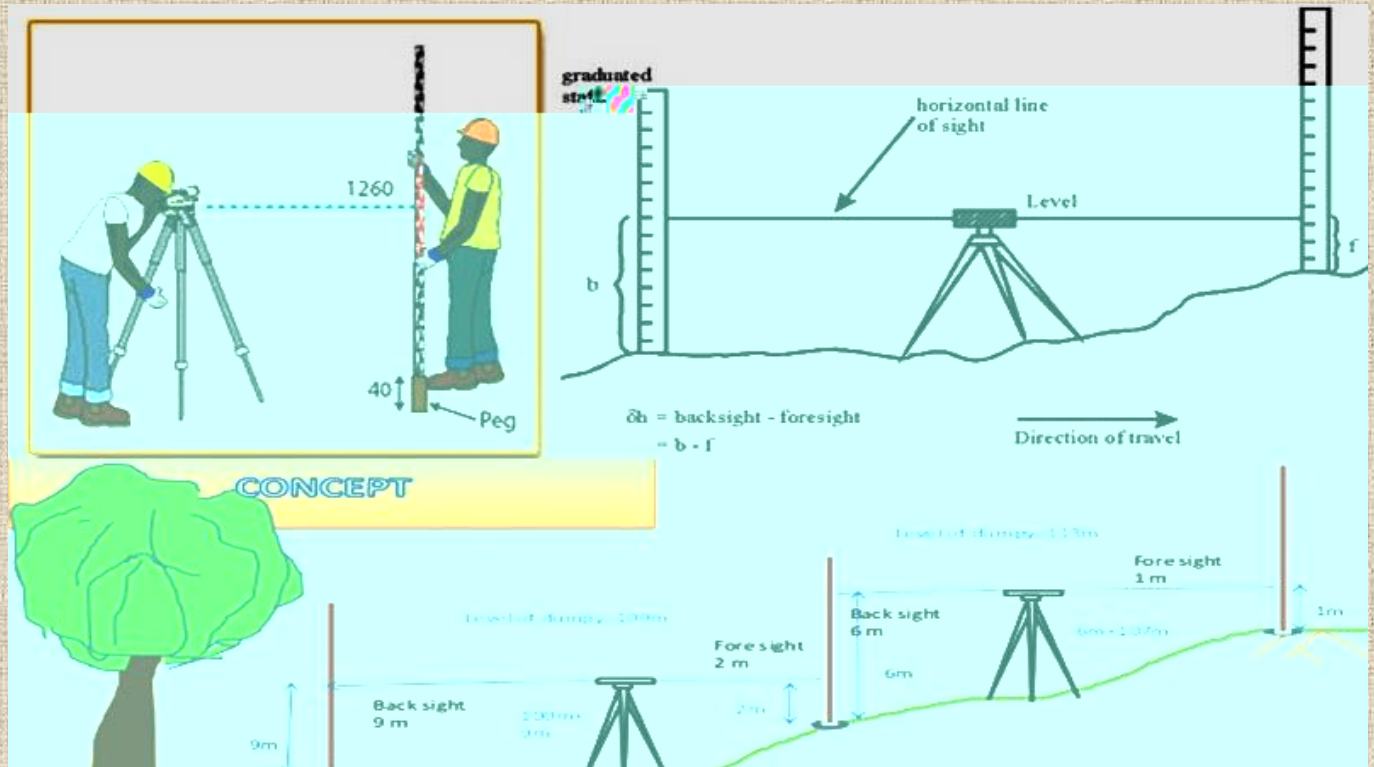
K = 10 - 30 mm for ordinary leveling



THANK YOU

Questions

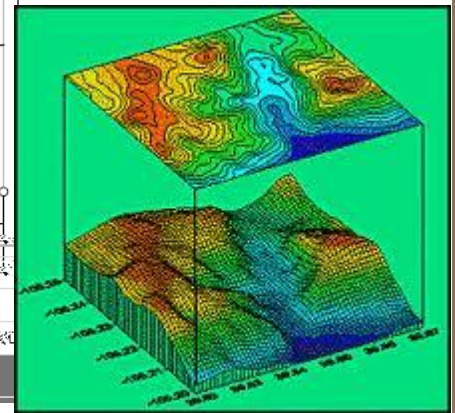
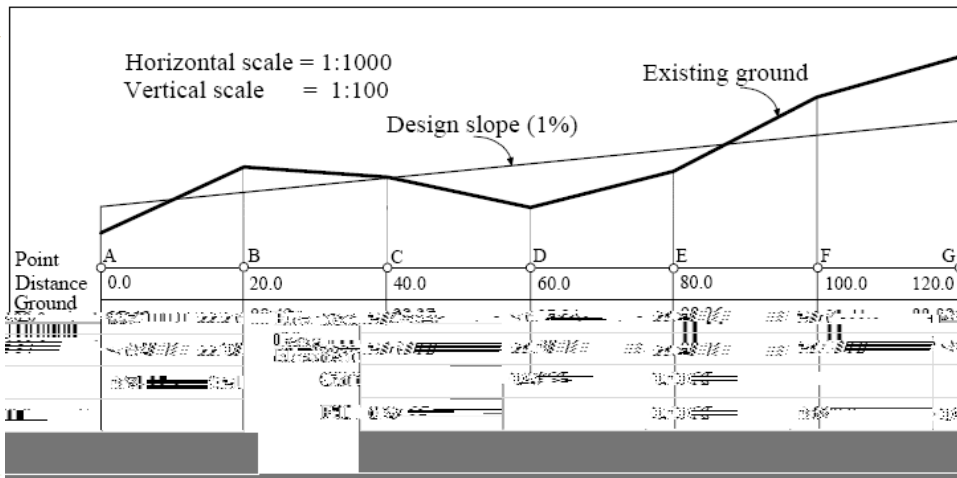
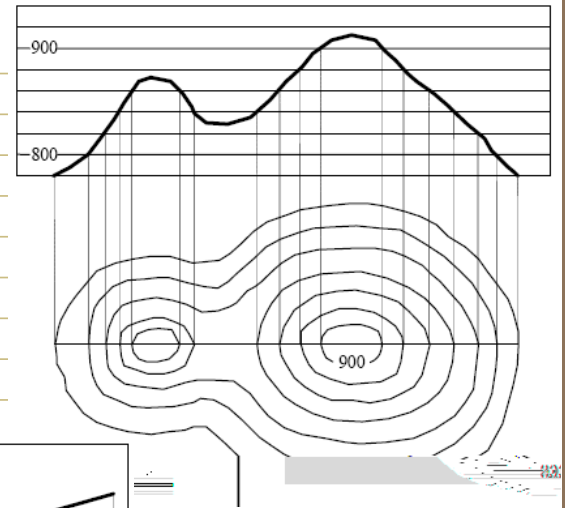
Chapter 4: Leveling



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Leveling Applications

- Longitudinal sections (profiles)
- Cross sections
- Contour maps
- Setting out elevations

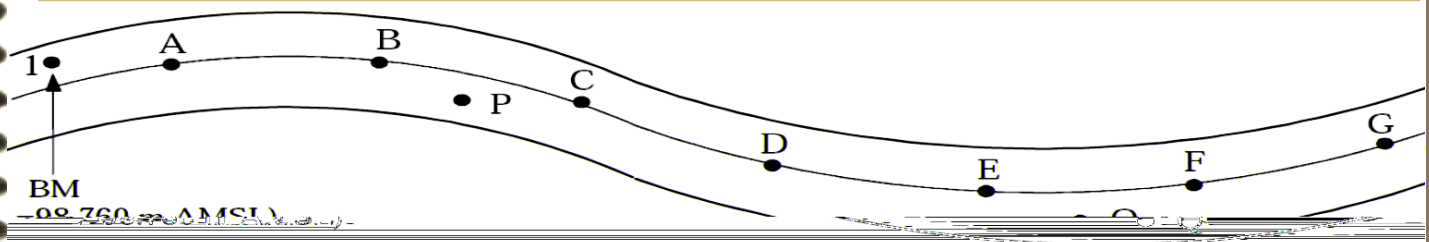


Leveling Applications



Leveling Applications

- Longitudinal sections (profiles)



Horizontal scale = 1:1000

Vertical scale = 1:100

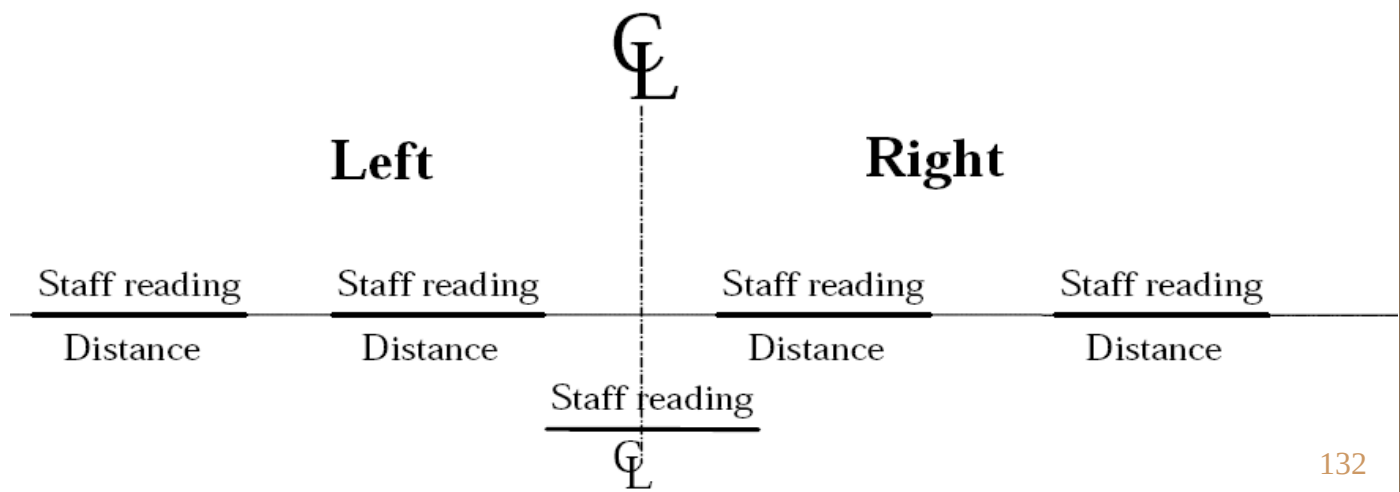
Existing ground

Design slope (1%)

Point	A	B	C	D	E	F	G
Distance	0.0	20.0	40.0	60.0	80.0	100.0	120.0
Ground Elevation	97.48	98.42	98.27	97.84	98.36	99.41	99.98
Design Elevation	97.87	98.07	98.27	98.47	98.67	98.87	99.07
Cut		0.35	0.00			0.54	0.91
Fill	0.39		0.00	0.63	0.31		131

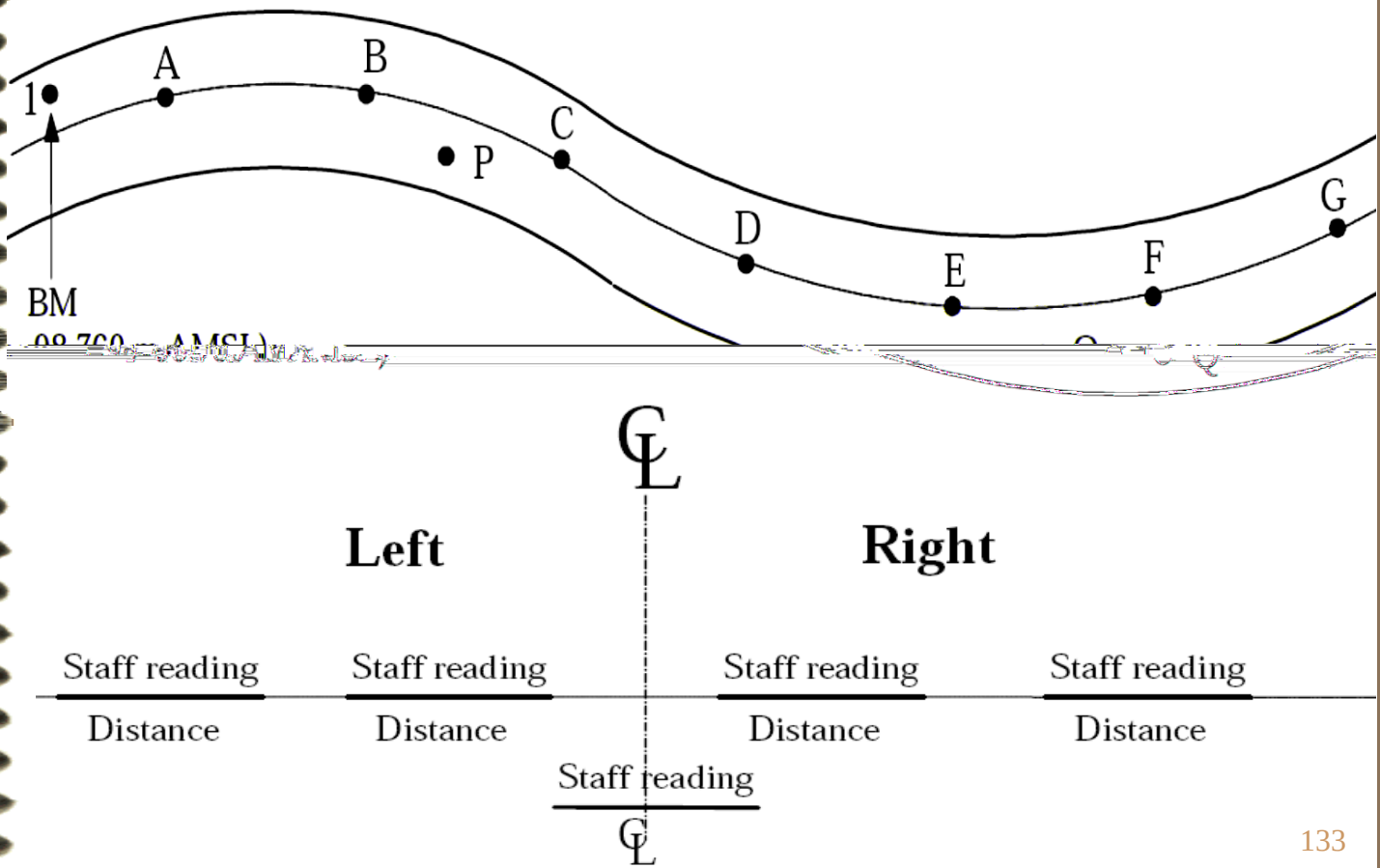
Leveling Applications

- Cross sections



Leveling Applications

- Cross sections

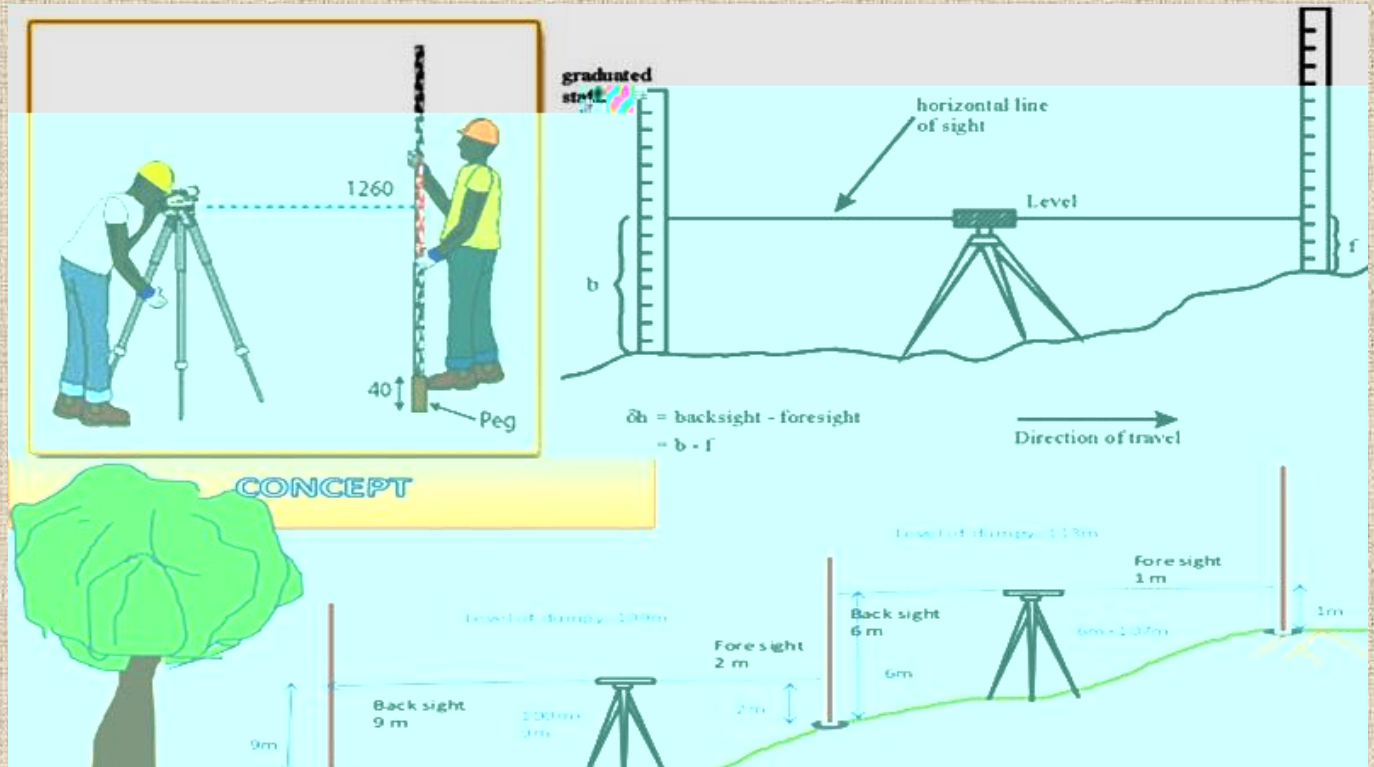




THANK YOU

Questions

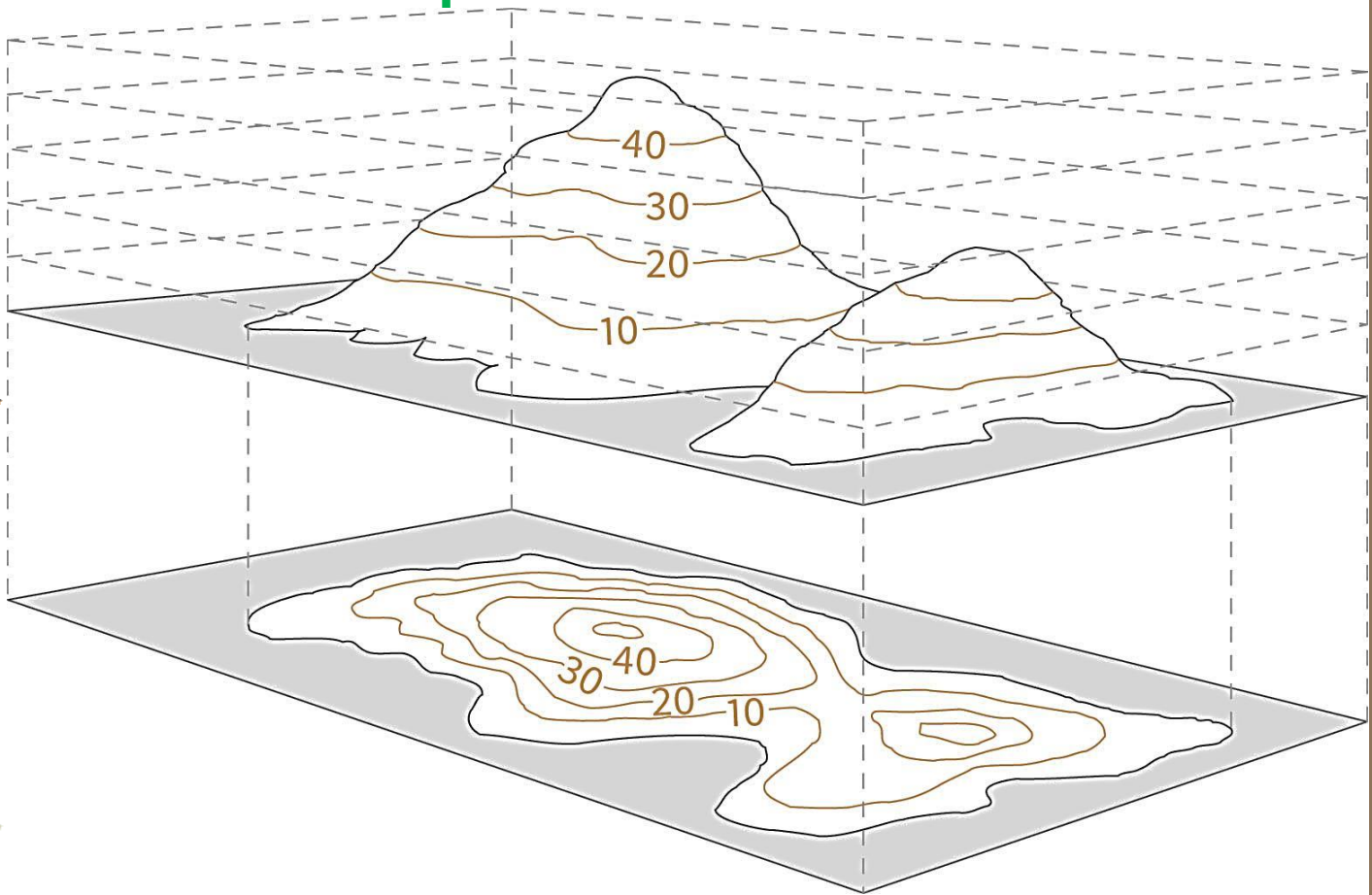
Chapter 4: Leveling



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The Islamic University of Gaza

Leveling Applications

- Contour maps



Leveling Applications

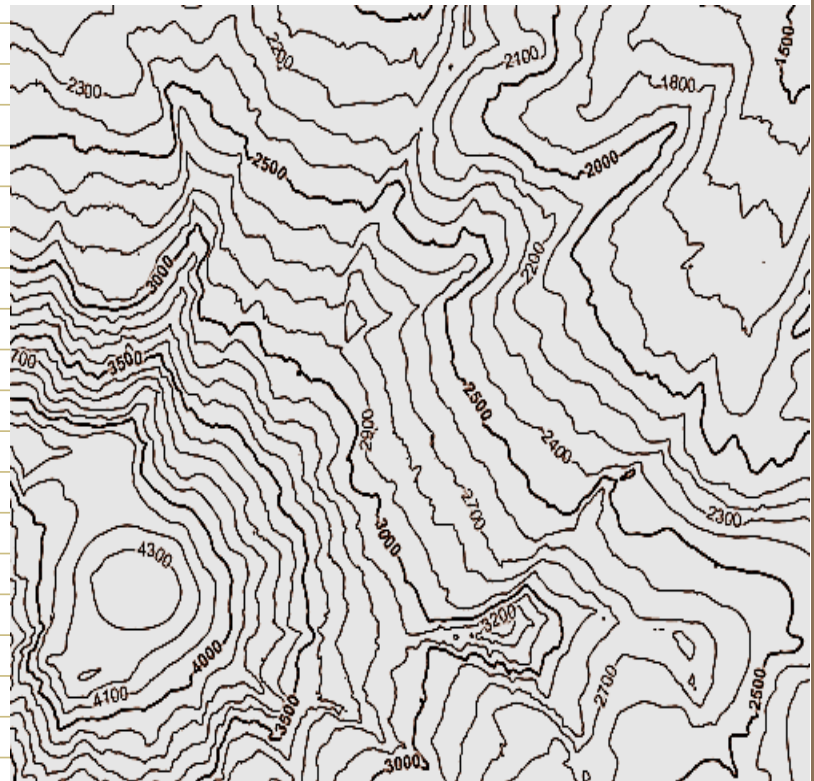
- **Contour maps**

A contour line:

An imaginary line that
Connects points on the
Ground of the same
Elevation.

A contour interval:

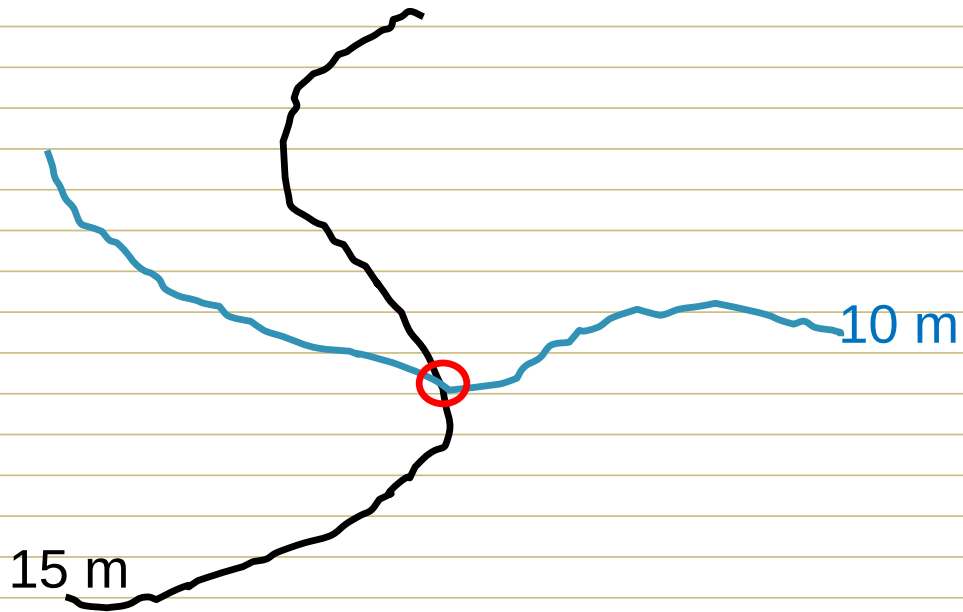
The vertical distance
between two successive
contours.



Leveling Applications

Contour characteristics:

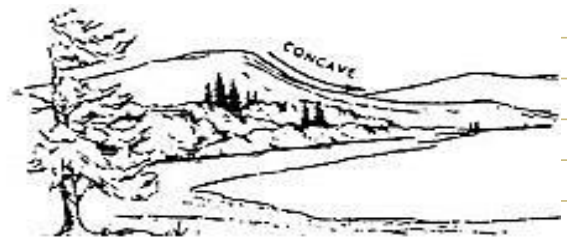
Contours of different values do not cross each other nor do they merge except in rare situations where there is a cave or a vertically standing



Leveling Applications

Contour characteristics:

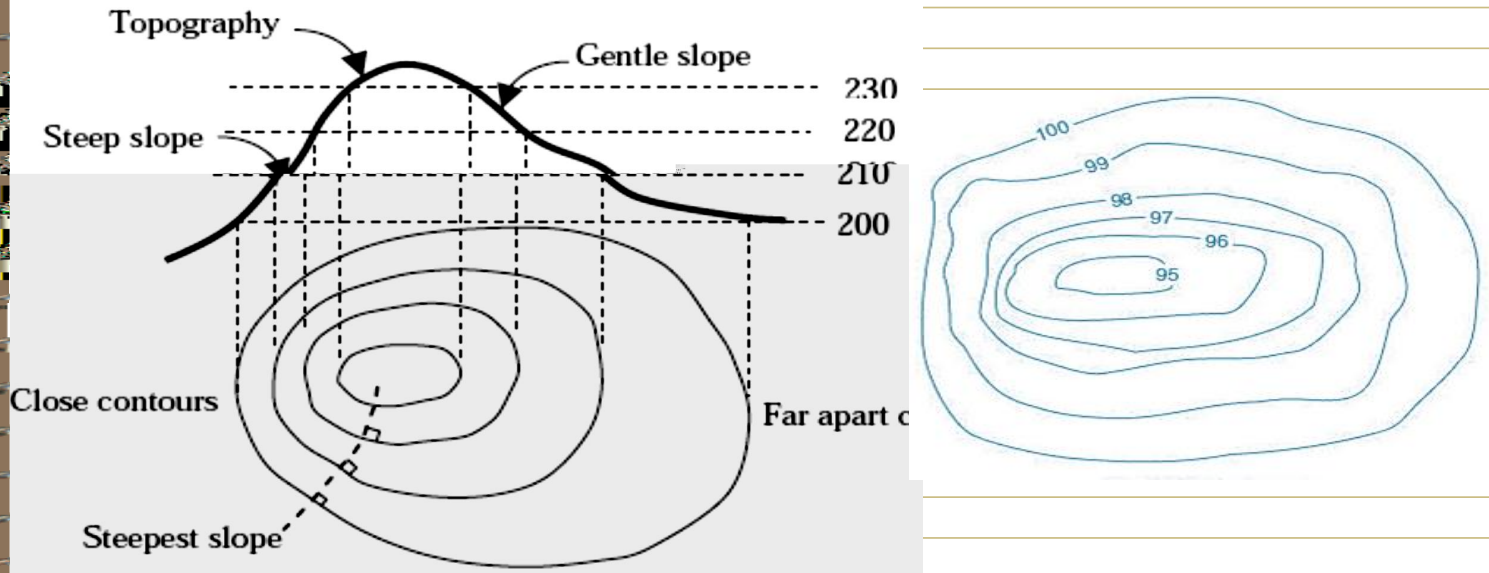
Contours spaced closely together represent a steep slope. When spaced far apart, they indicate a flat slope (Figure 4.20).



Leveling Applications

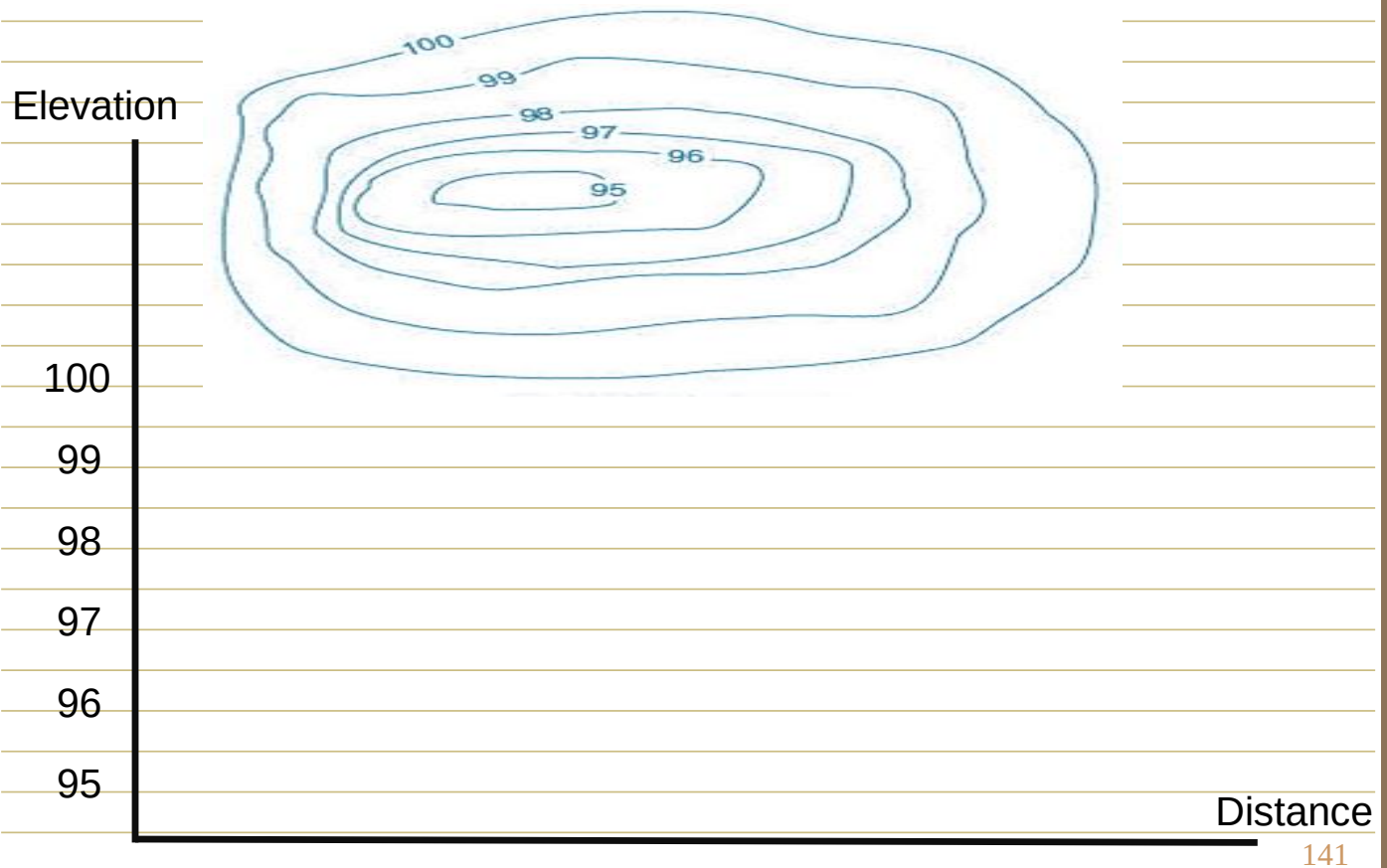
Contour characteristics:

Contours that portray summits (such as a hill) or depressions (such as a bottom of a lake) are closed lines.



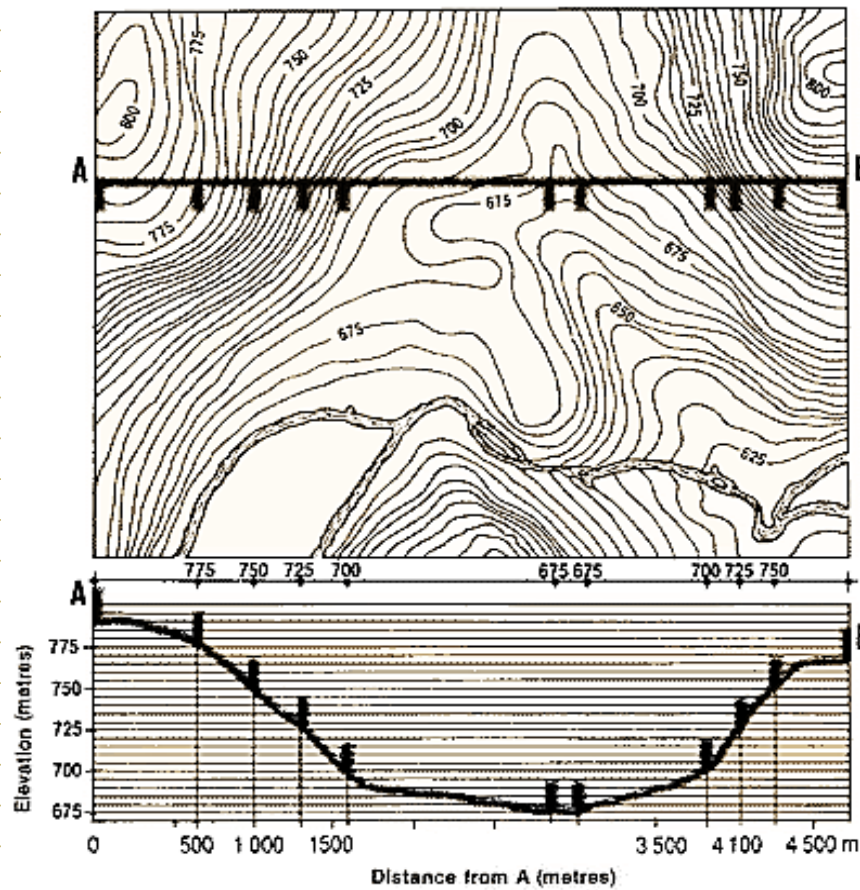
Leveling Applications

Contour characteristics:



Leveling Applications

Contour characteristics:



Leveling Applications

Contour interval choice:

The scale of the contour plan. As the scale of the contour map becomes smaller, the distance between the contours becomes also smaller, and as a result, the map becomes crowded with lines and difficult to read.

The importance and purpose for which the plan is to be used. When more details are needed in the contour plan for computation of earth volumes and for design purposes, a smaller contour interval should be used. However, if the contour plan aims merely to give an idea about the

Accuracy, time and cost of the contour plan. As higher accuracy is required, a smaller contour interval should be chosen. As a result, the project will be more costly and will require longer time to complete.

The topography of the ground. Steep ground requires a larger contour interval to increase the distance between contours, while a small contour interval can be used for flat terrain.

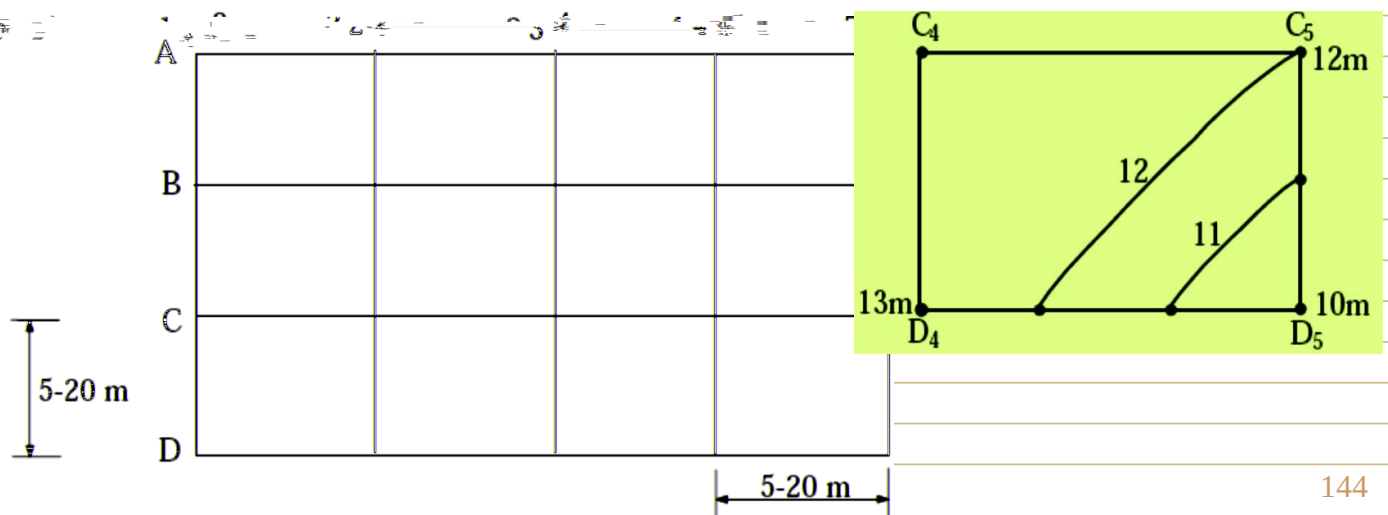
The area for which the contour plan is to be made. As the area to be covered becomes larger, a smaller scale is usually chosen to draw the map. As a result, a larger contour interval is used.

Leveling Applications

Contouring methods:

1. Grid Method

Griding. This method is most suitable for flat terrain, especially on comparatively small sites. Rectangles or squares of 5 to 20 m a side are usually set out on the ground in the form of a grid, and levels (staff readings) are taken at the corners (Figure 4.23).



Leveling Applications

1. Grid Method

Field

	1	2	3	4
A	19	17	16.5	16.8
B	21	18	16	16.9
C	21	19	17	16.5
D	19	18	17.5	17

20 m

	1	2	3	4
A				
B				
C				
D				

4 cm

4 cm

20 m

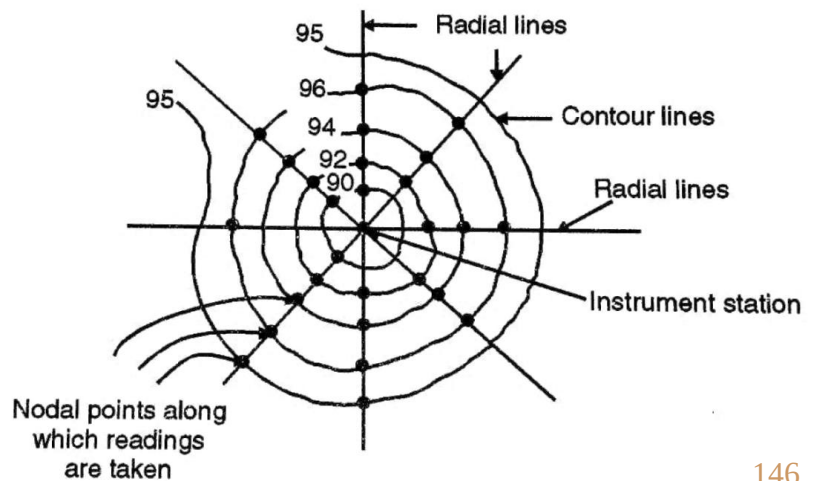
Map

Leveling Applications

Contouring methods:

2. Radiating lines method

Radiating Lines. Rays are set out on the ground from a central point such as the top of a small hill, the directions of these rays being known. Levels are taken along these rays at measured distances from the center (Figure 4.26). Again, linear interpolation is used to give the contour lines.

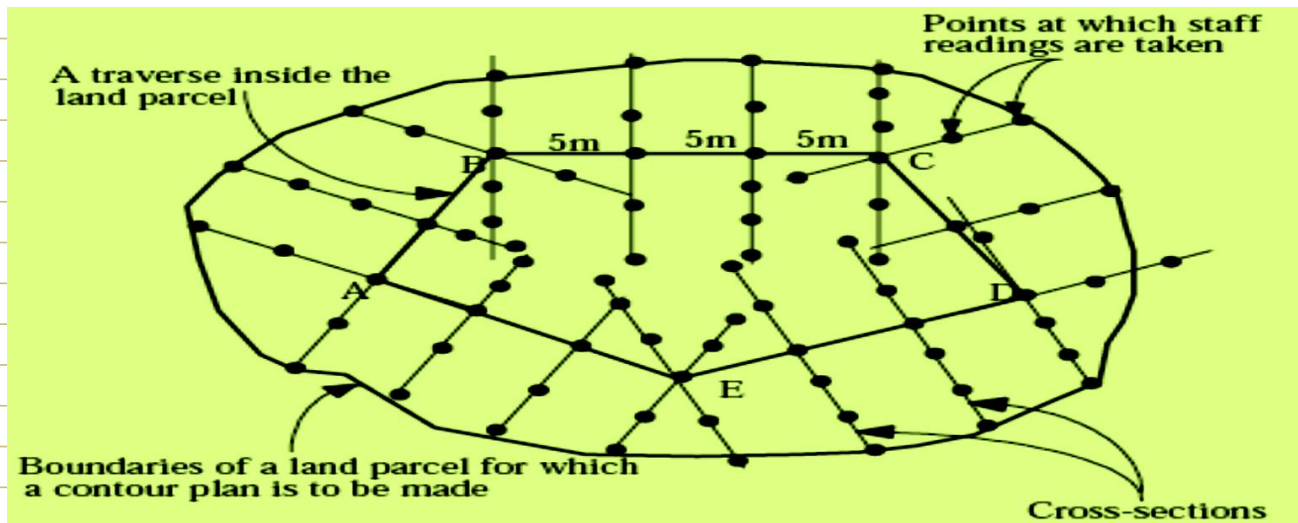


Leveling Applications

Contouring methods:

3. Cross sections method

Cross-Sections Method. In this method, cross-sections are made on a line or a traverse inside the area for which the contour plan is to be made (Figure 4.27). Levels are then taken at points on the cross-sections where the topography changes. Again contour lines are drawn section by section using the method of linear interpolation as explained earlier.

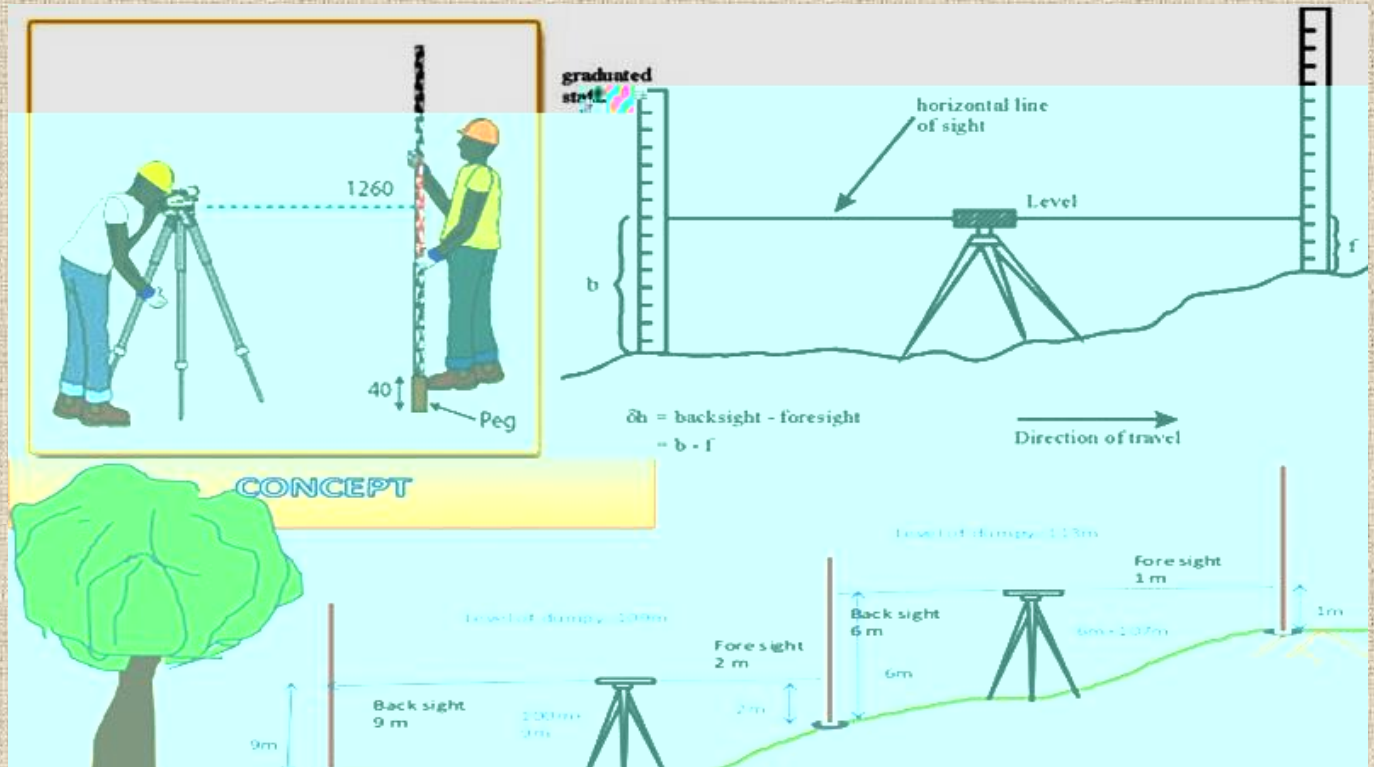




THANK YOU

Questions

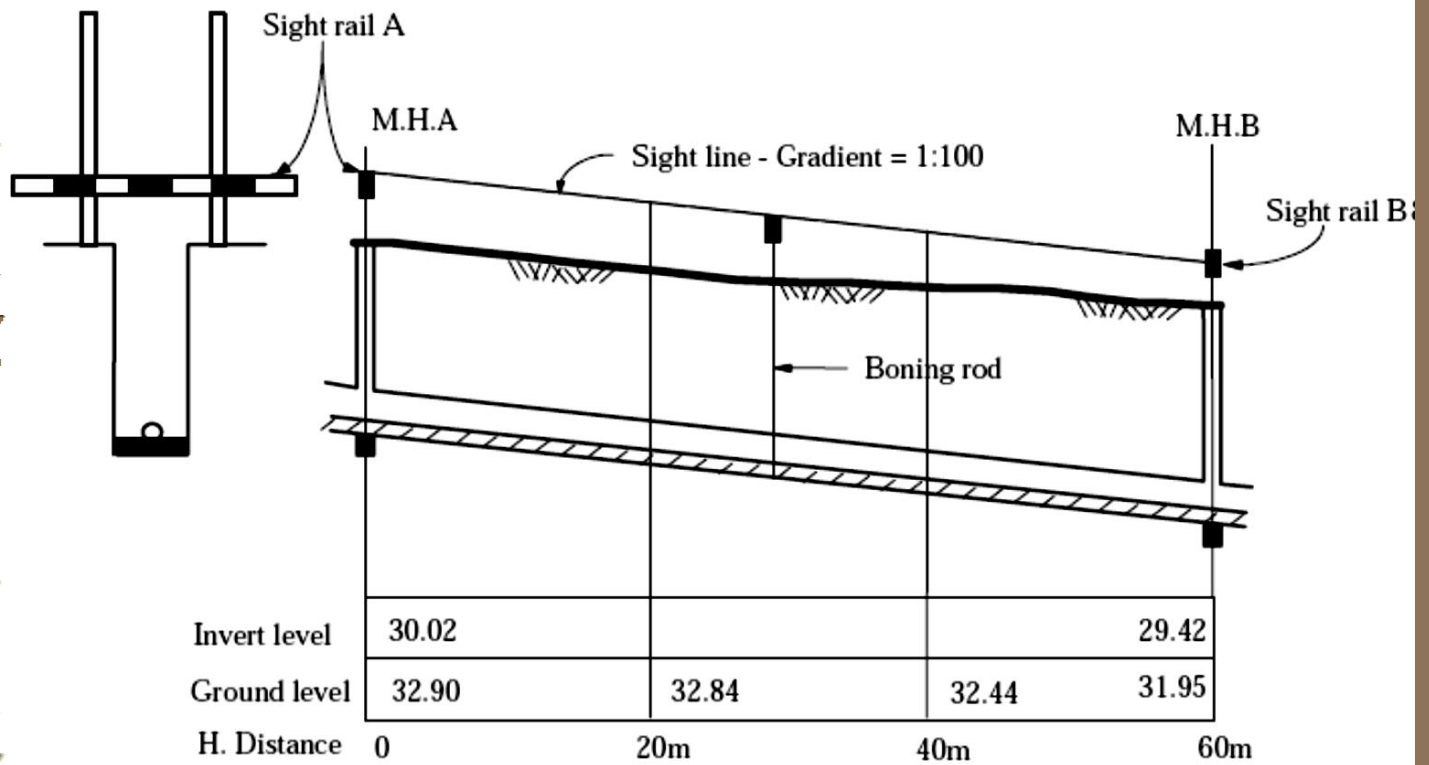
Chapter 4: Leveling



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Leveling Applications

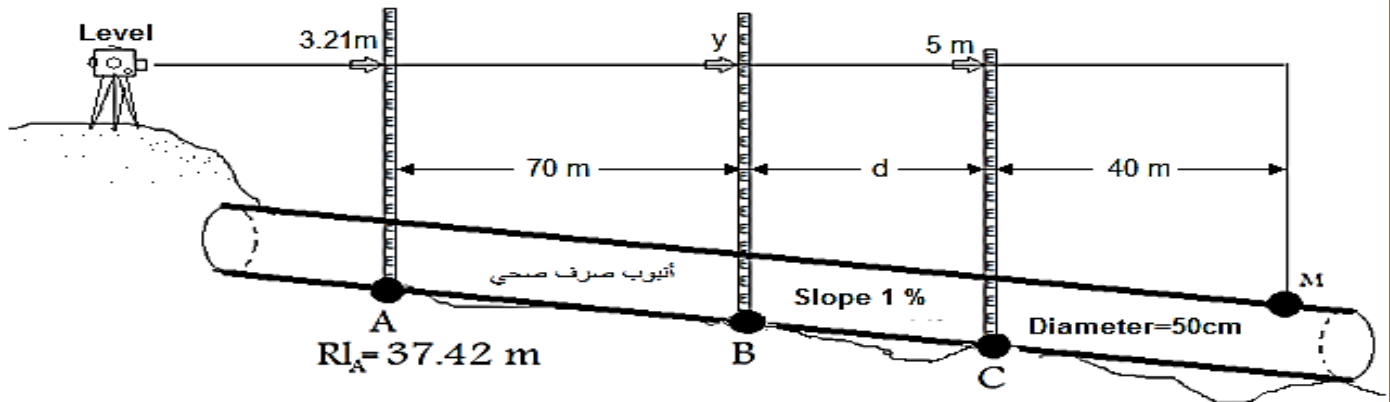
- Setting out elevations





• Example:

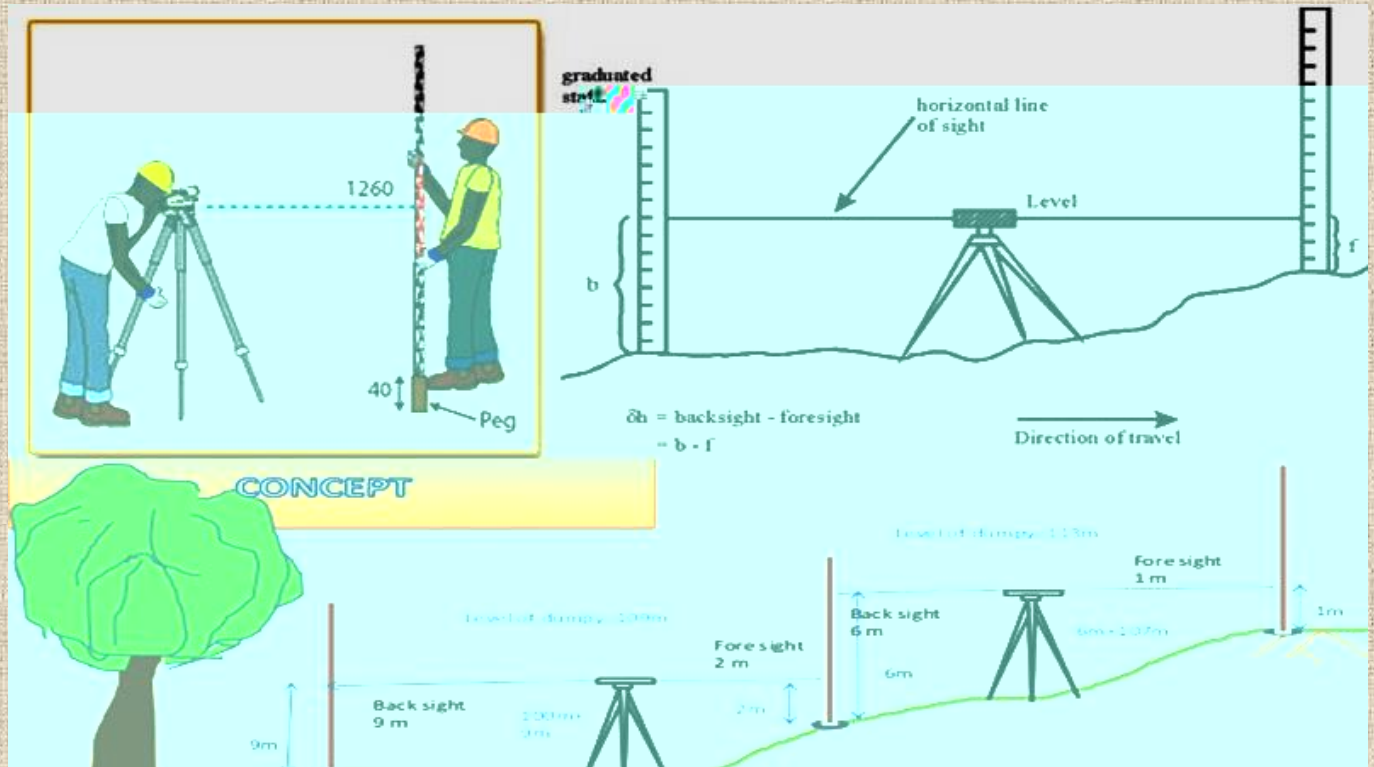
A sewage pipe with 1% slope and 50 cm diameter was set out in a project where the staff readings at soil under the pipe of A, B and C were (3.21, y , 5) m. The elevation of point A is 37.42 m. Determine: a) Staff reading at B(y), b) the distance d between B and C, c) the elevation of M



Thank you



Chapter 4: Leveling



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Leveling Errors

- Blunder errors
- Random errors
- Systematic errors

Leveling Errors

- **Blunder errors**

Misreading the staff especially when the marks on the staff are obscured by a tree, fence and so on.

Not setting the staff on the same point for a FS and the subsequent BS readings.

Recording or booking of data. Examples of this kind of error will be reading 2.58 m as 2.85 m, or booking a FS in the BS column and vice

Leveling Errors

- **Random errors**

The staff not held plumb

The bubble of the level not perfectly centered

The incorrect reading of the staff

The instability of turning points

Wind. Wind may vibrate the level and the staff and make it difficult to keep the bubble centered and to read the staff correctly.

Leveling Errors

- **Systematic errors**

1. Inclination of the line of sight due to the earth's curvature and atmospheric refraction, and
2. Inclination of the line of sight due to maladjustment of the level.

Leveling Errors

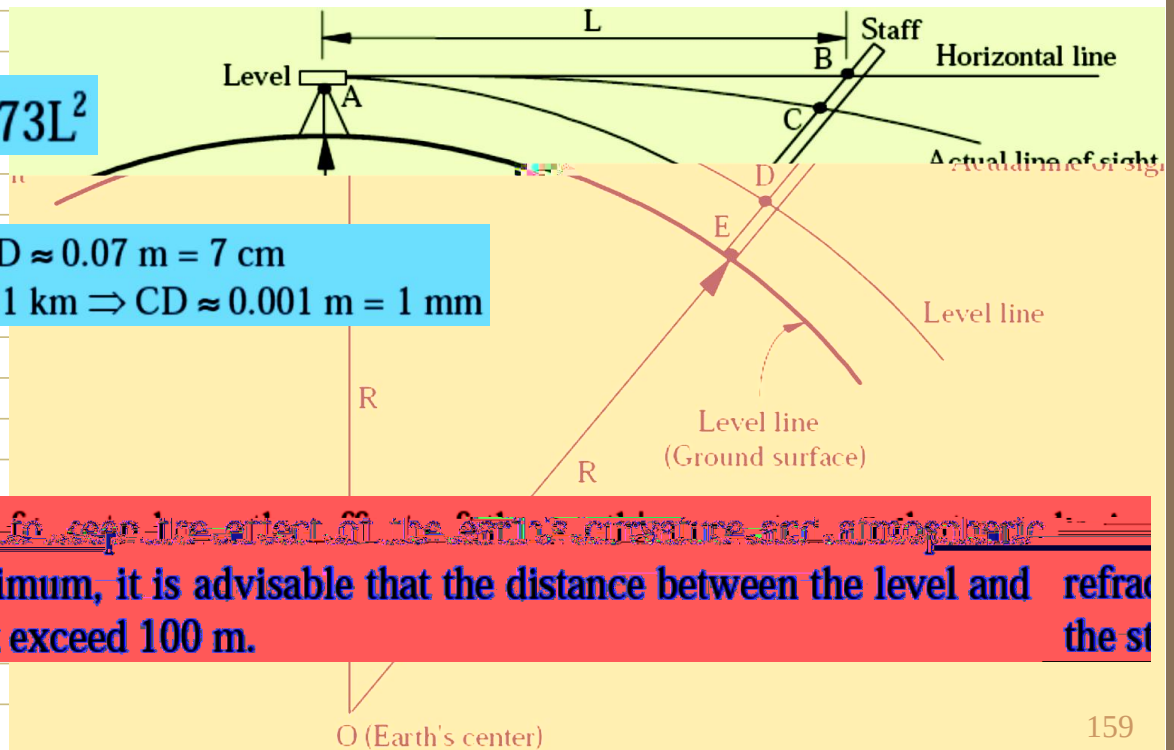
- Systematic errors

1. Inclination of the line of sight due to the earth's curvature and atmospheric refraction, and

$$CD = 0.0673L^2$$

$$L = 1 \text{ km} \Rightarrow CD \approx 0.07 \text{ m} = 7 \text{ cm}$$

$$L = 100 \text{ m} = 0.1 \text{ km} \Rightarrow CD \approx 0.001 \text{ m} = 1 \text{ mm}$$

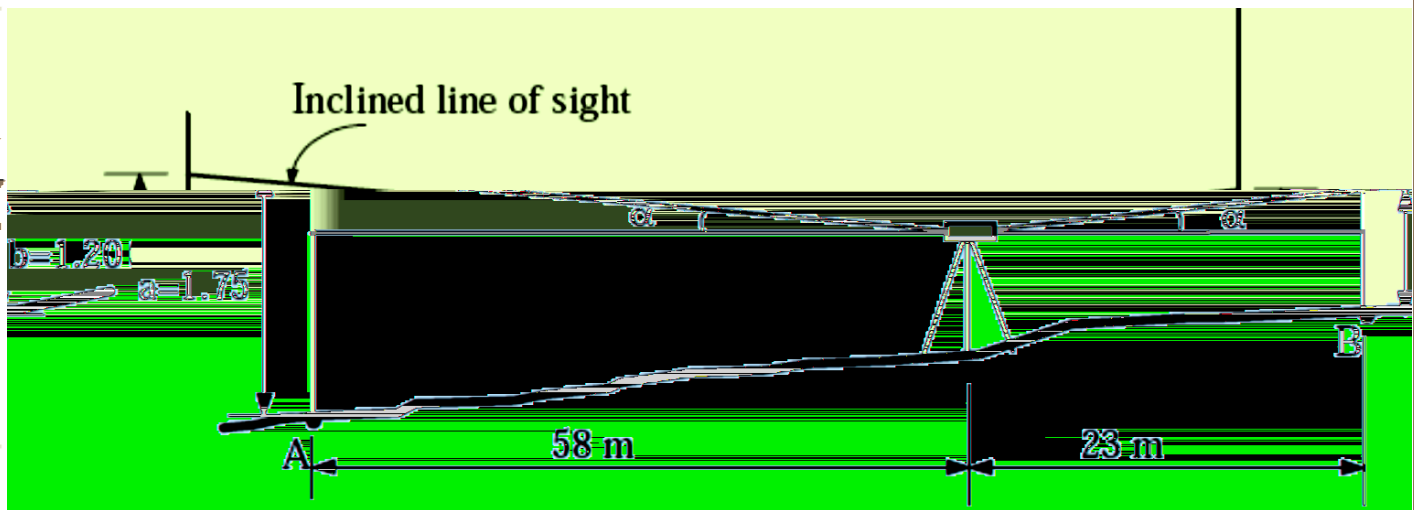


Therefore, to keep the effect of the earth's curvature and atmospheric refraction to a minimum, it is advisable that the distance between the level and staff should not exceed 100 m.

Leveling Errors

- Systematic errors

2. Inclination of the line of sight due to maladjustment of the level.

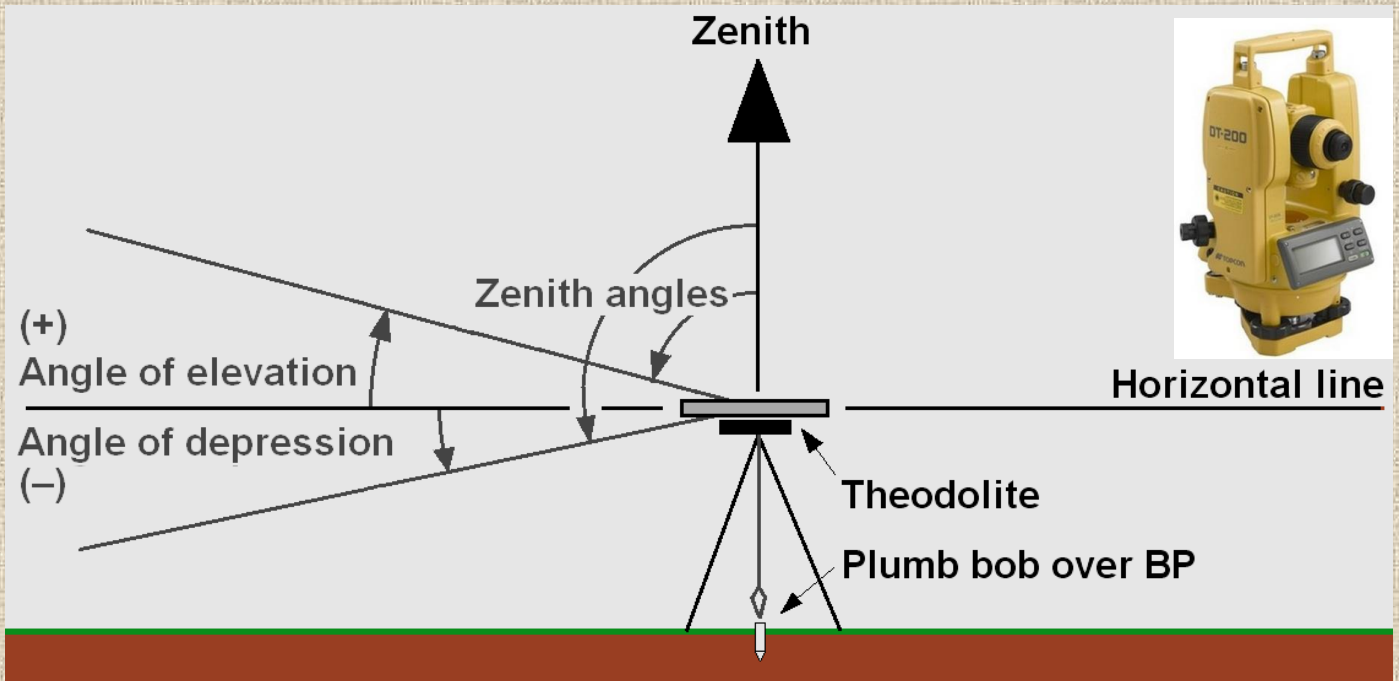


$$\Delta h = (a - b) - \tan \alpha (L_1 - L_2)$$

Thank you



Chapter 5: Angle Measurement



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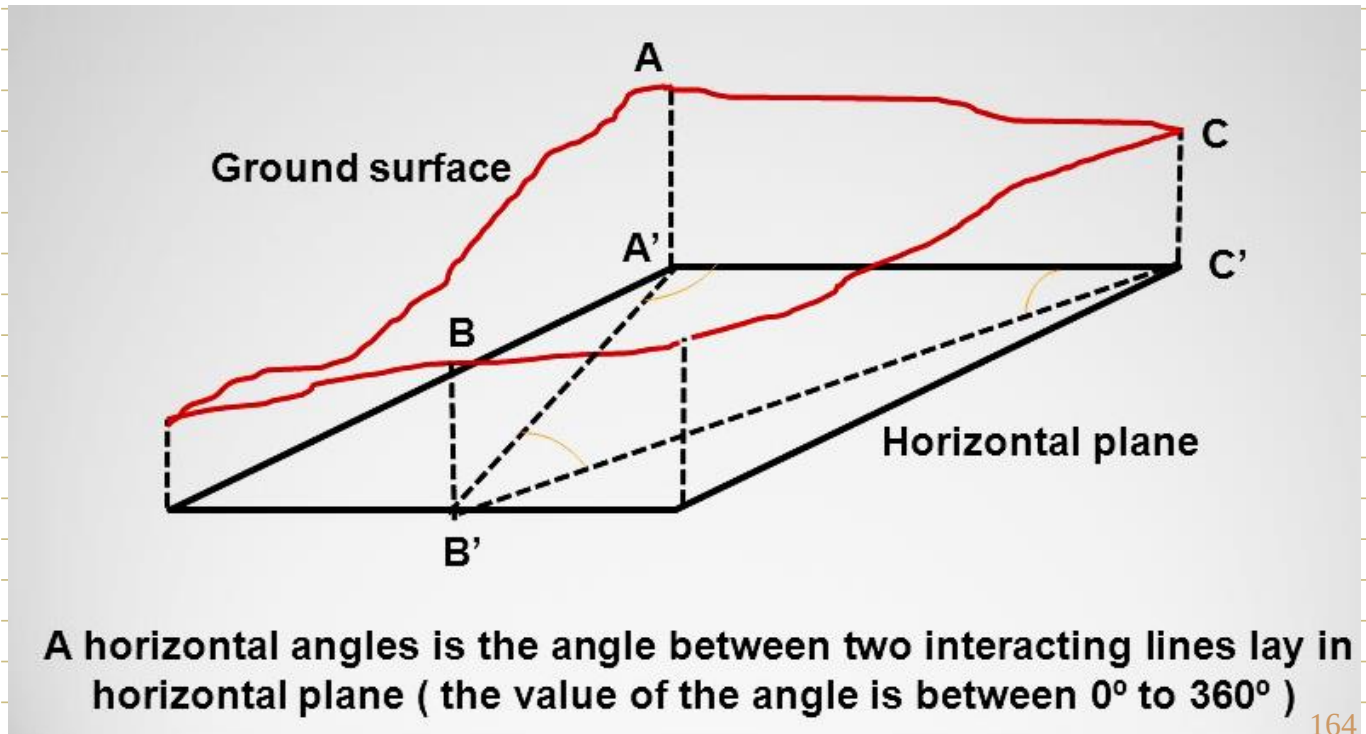
Contents

- **Definitions.**
- **Theodolite equipment.**
- **Theodolite setting up.**
- **Theodolite applications.**
- **Practice**

Definitions

Horizontal Angle: Angle in a horizontal plane.

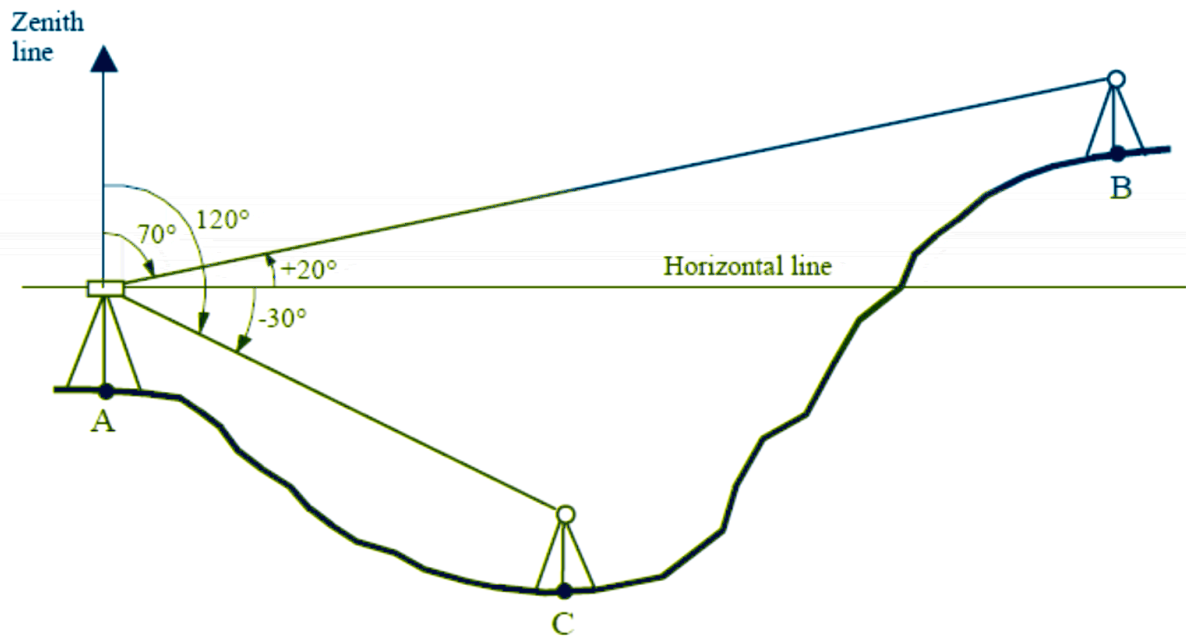
Angle between the projections of lines in a horizontal plane.



Definitions

Vertical Angle: Angle in a vertical plane.

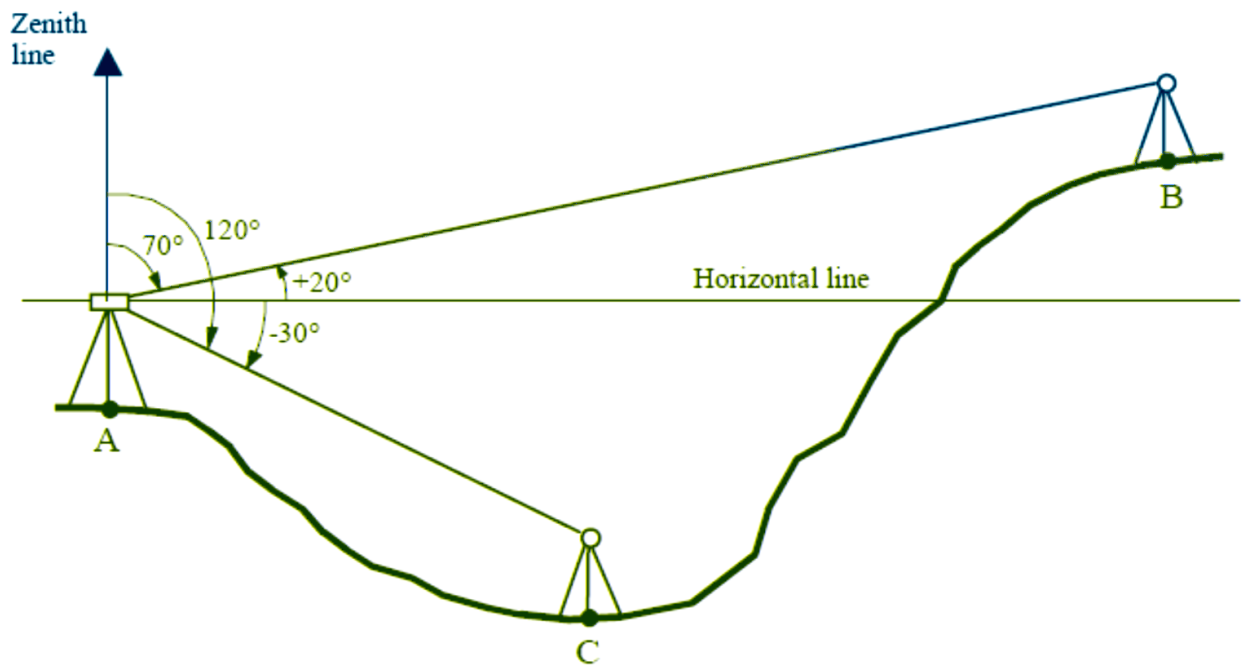
Angle between the line of sight and a reference horizontal plane. Either angle of elevation (+) or of depression (-).



Definitions

Zenith Angle: Angle between a line of sight and Zenith direction.

$$Z = 90 - V \quad \text{or,} \quad \underline{V = 90 - Z}$$

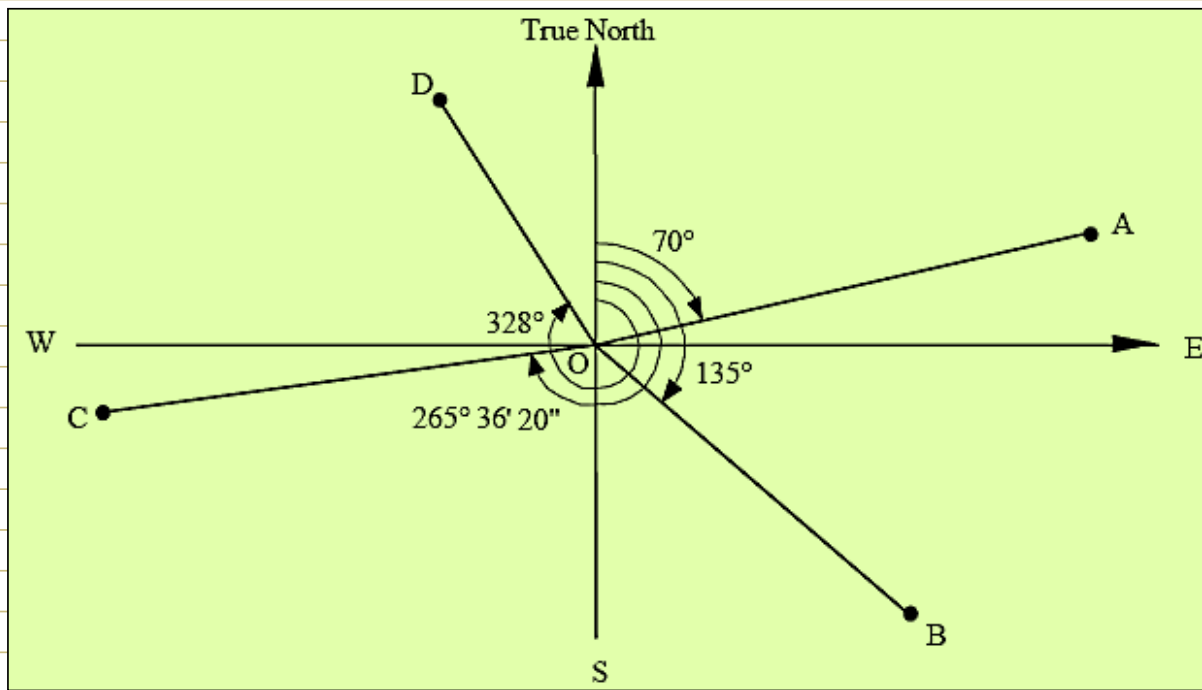


Definitions

Direction Angles: Reference angles express the direction of a line. *Always referred to the North direction*

A. Azimuth Angle

مستوى أفقي

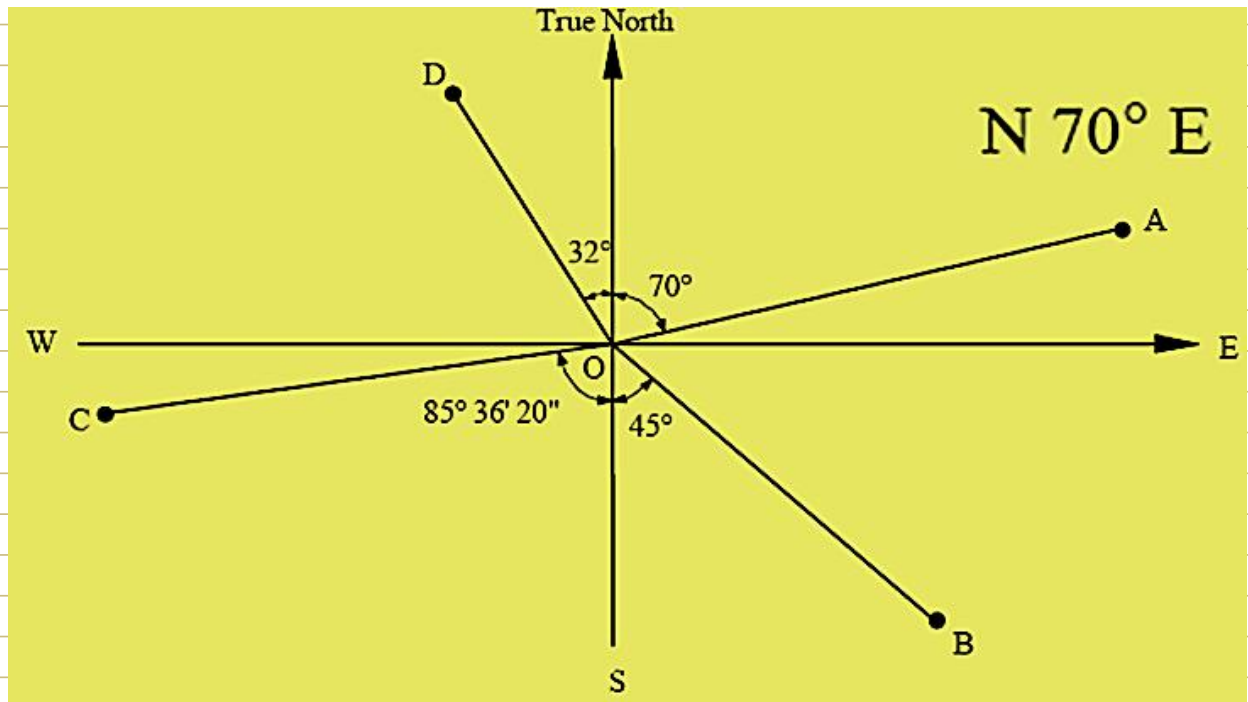


Definitions

Direction Angles: Reference angles express the direction of a line. *Always referred to the North direction*

B. Reduced or True Bearing

مستوى أفقي

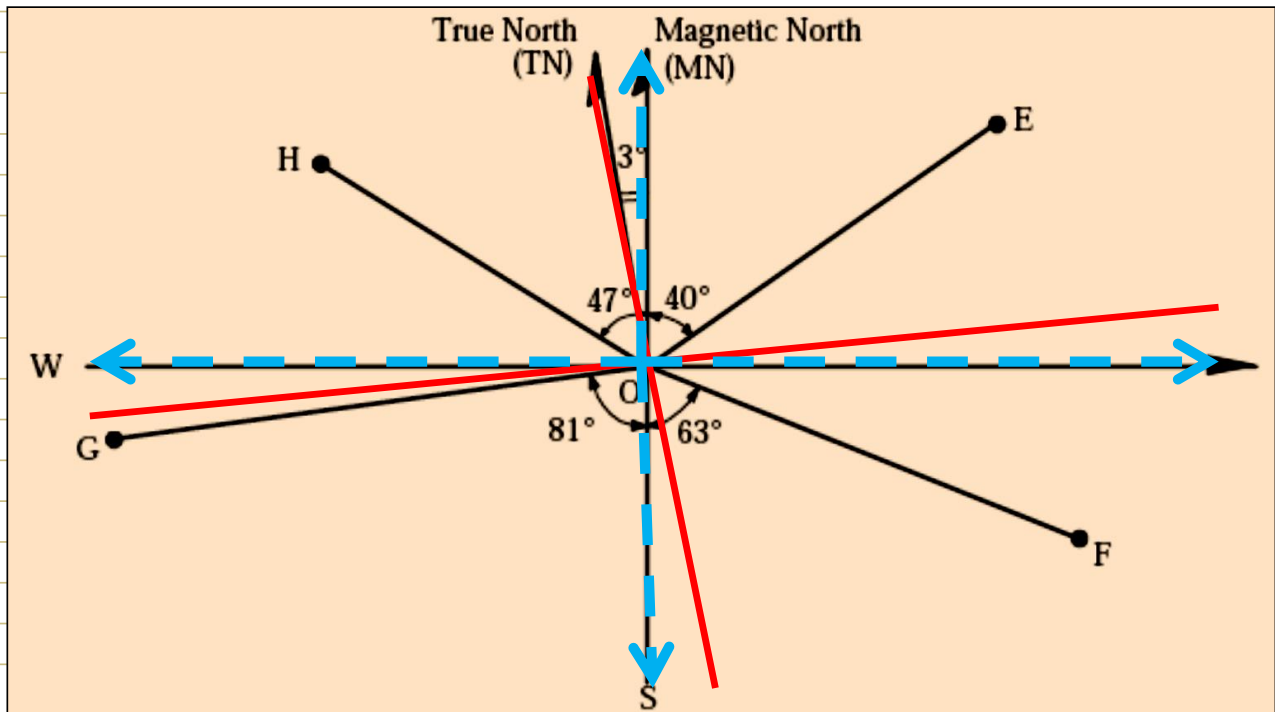


Definitions

Declination Angle: Angle between true north and magnetic north. *It varies from time to time and from location to another.*

C. Magnetic Bearing

مستوى أفقي



Definitions

Back Bearing and Back Azimuth

Back Bearing

Bearing of AB = N 60° E

Back Bearing of AB = Bearing of BA
= S 60° W

Back Azimuth

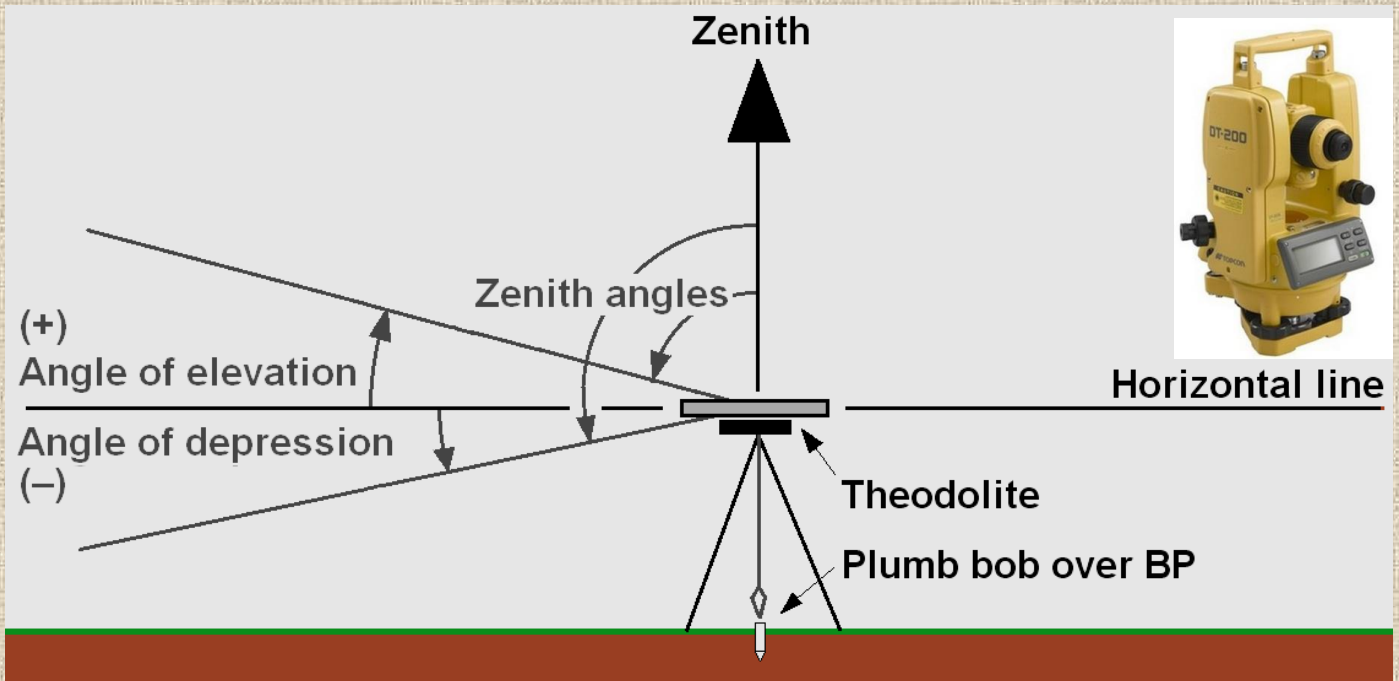
$$\alpha_{BA} = \alpha_{AB} \pm 180^\circ$$



THANK YOU

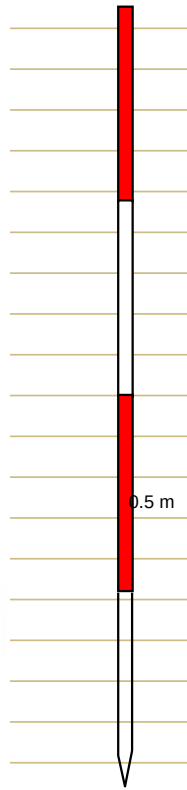
Questions

Chapter 5: Angle Measurement

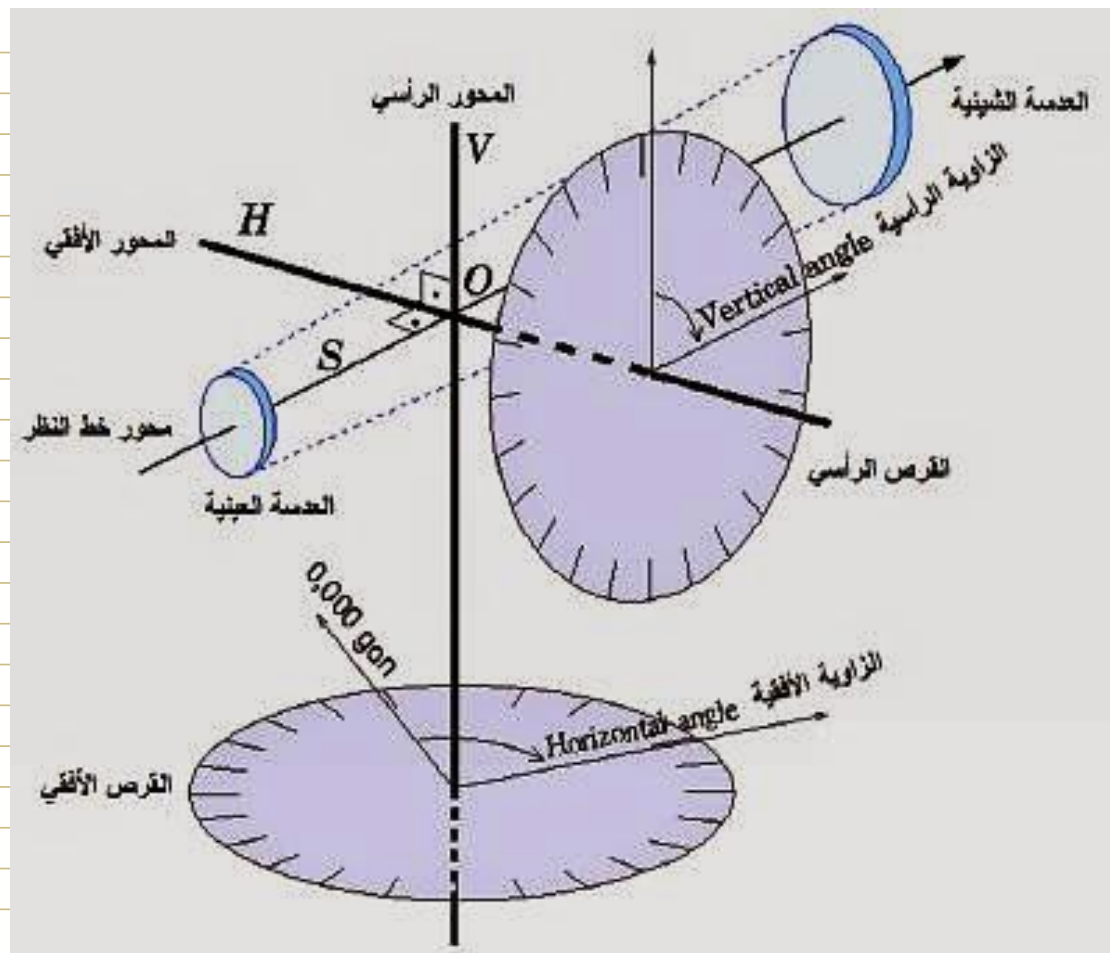


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The Theodolite Equipment



The Theodolite Equipment



The Theodolite Equipment

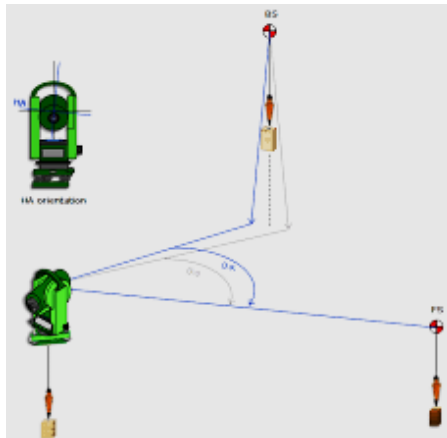


Theodolite setting up

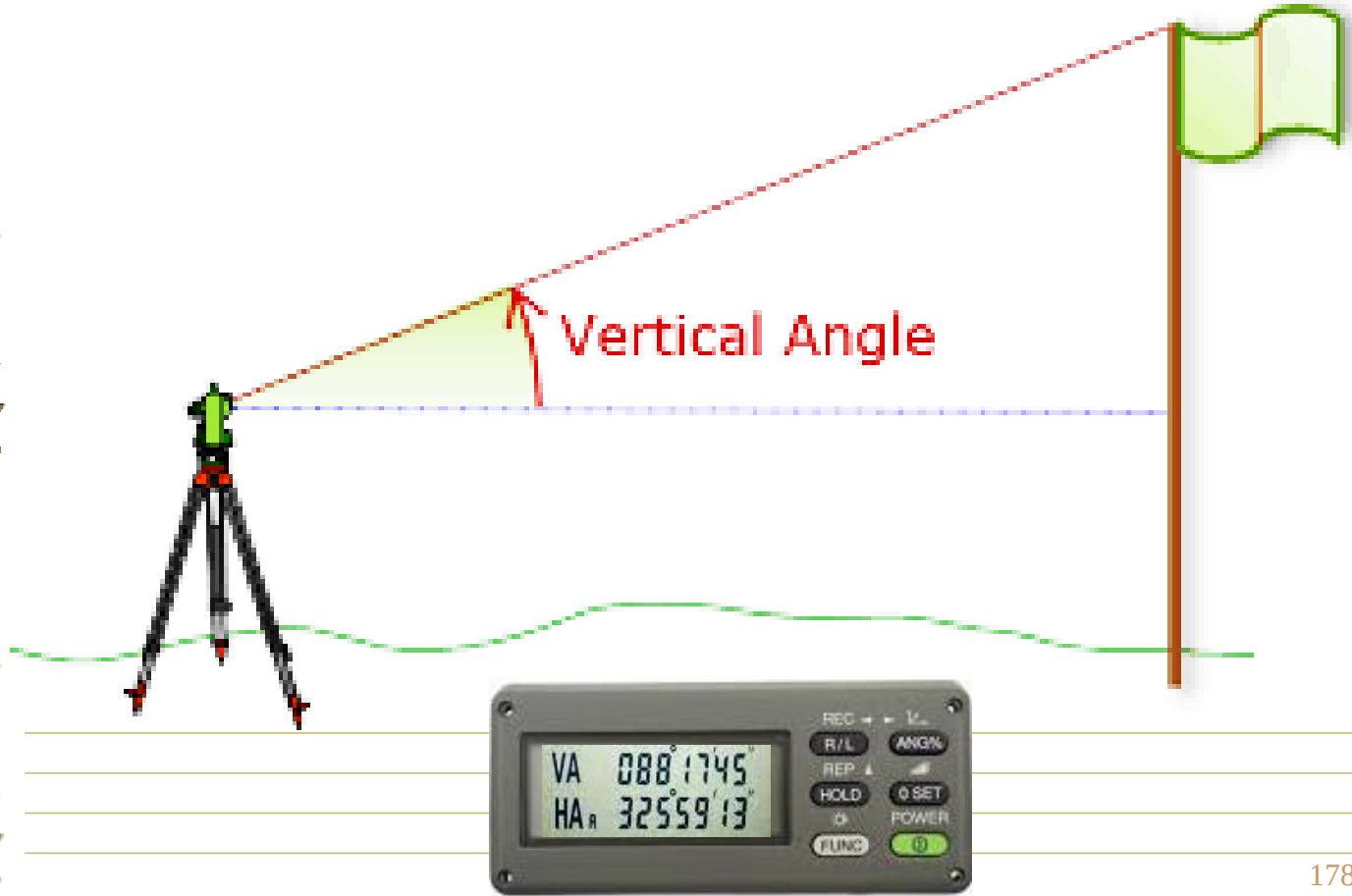
- ✓ Should be **centered** over the survey point.
- ✓ Should be **leveled**.
 - bull's-eye bubble for preliminary leveling
 - one plate bubble for precise leveling



Horizontal Angle Measuring



Vertical Angle Measuring

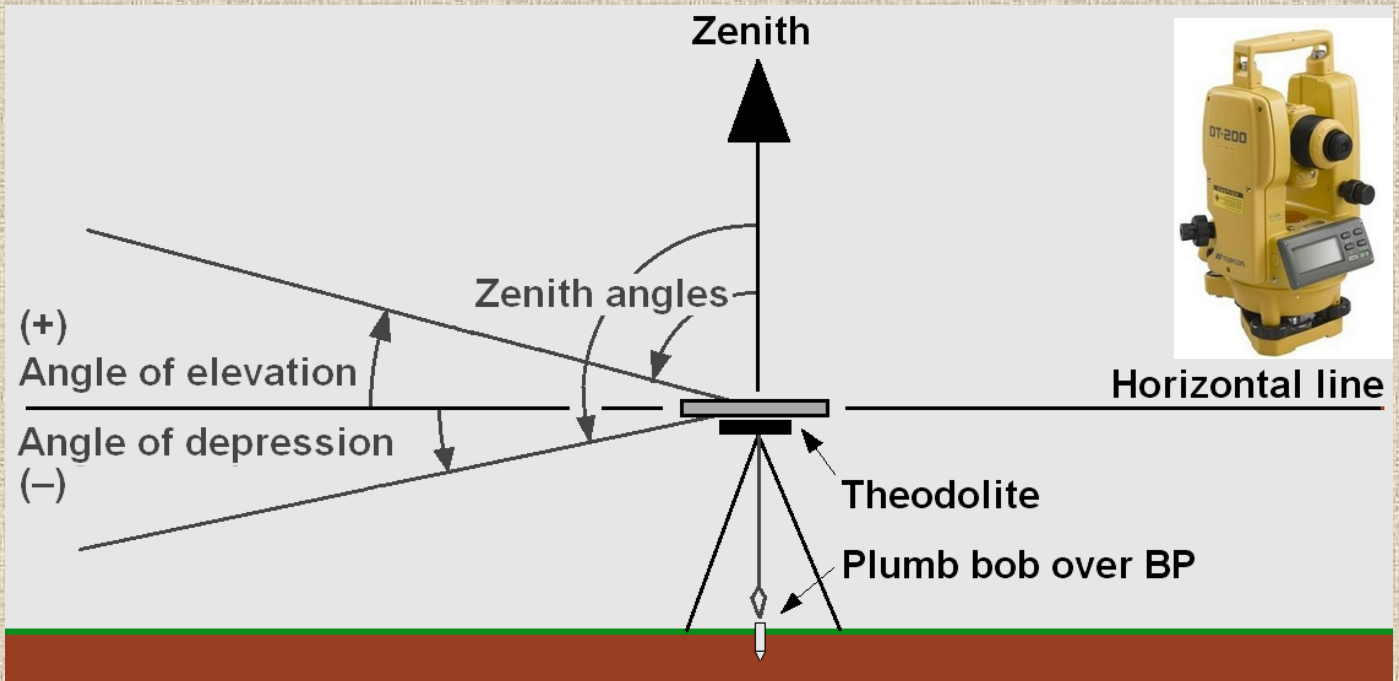




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Questions

Chapter 5: Angle Measurement



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Applications

1. measuring heights

2. measuring horizontal distances

a. tangential method طريقة الظل

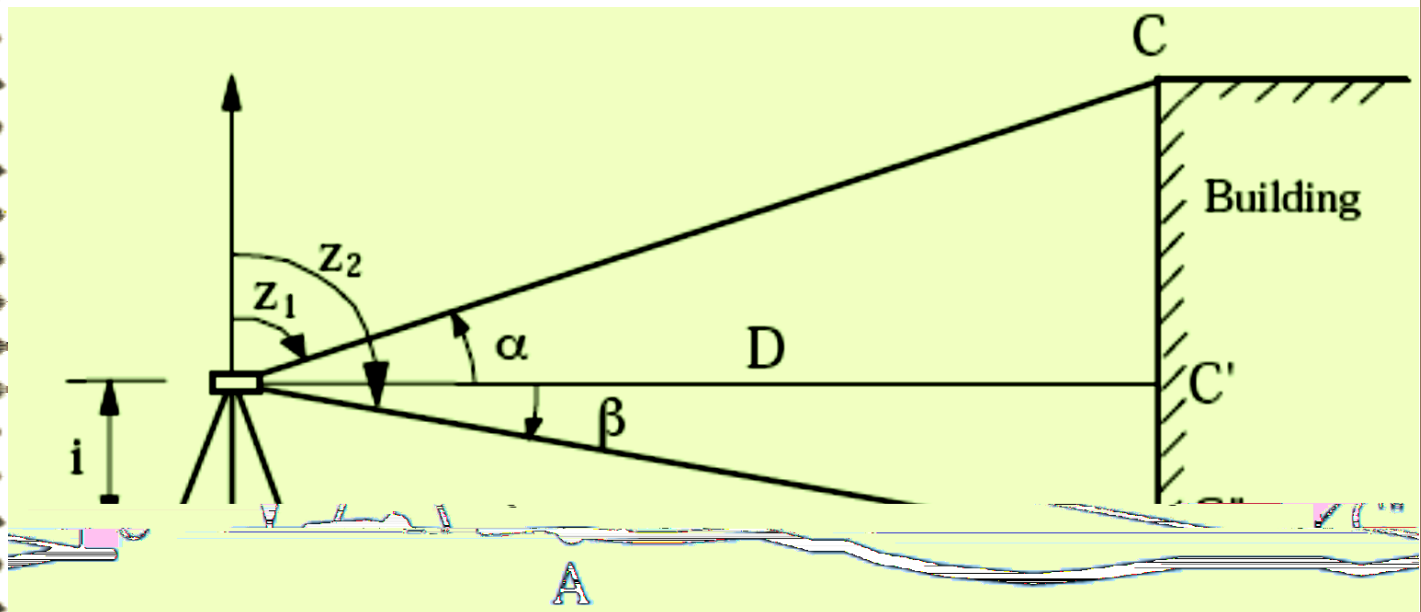
b. stadia method طريقة الشعيرات

- horizontal telescope

- inclined telescope

Applications

Measuring heights

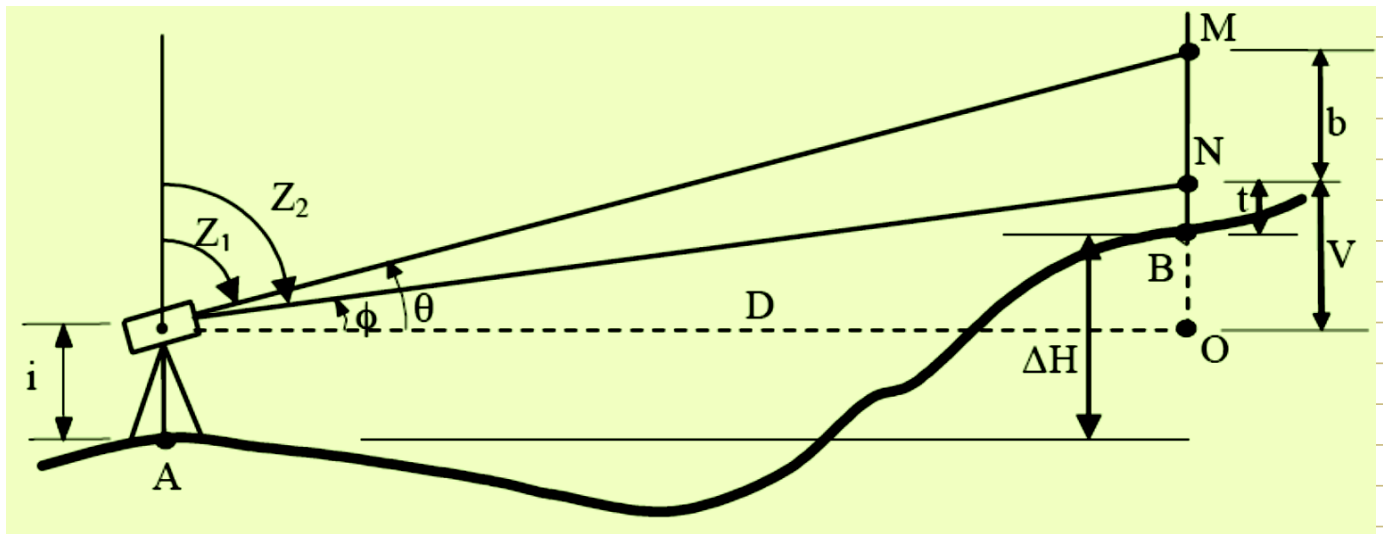


$$H = D(\tan \alpha - \tan \beta)$$

Applications

Tachometry: Tangential method

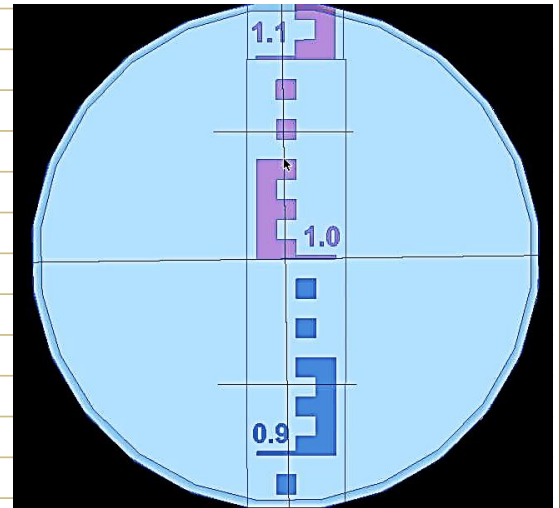
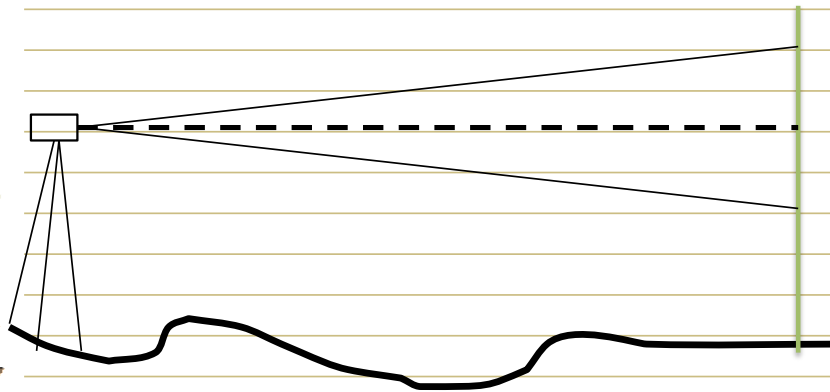
$$D = \frac{b}{(\tan \theta - \tan \phi)}$$





Applications

Example:



Soln:

$$k = 100$$

$$r = \{upper\ stadia\ reading - lower\ stadia\ reading\}$$

$$D = kr = 100(1.062 - 0.938) = 12.40\ m$$

Applications

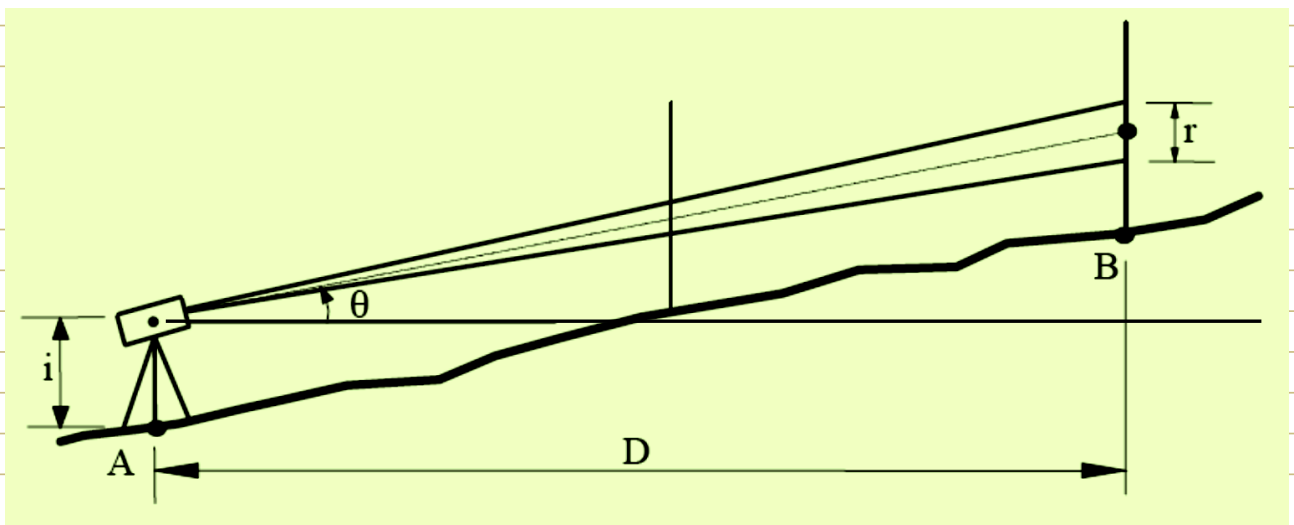
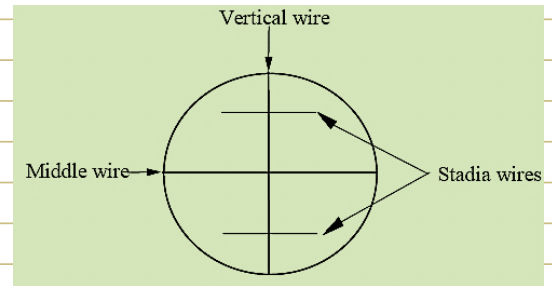
Tachometry: Stadia method

$$D = kr \cos^2 \theta$$

$$k = 100$$

$$V = \frac{1}{2} kr \sin 2\theta$$

r = upper stadia reading lower stadia reading

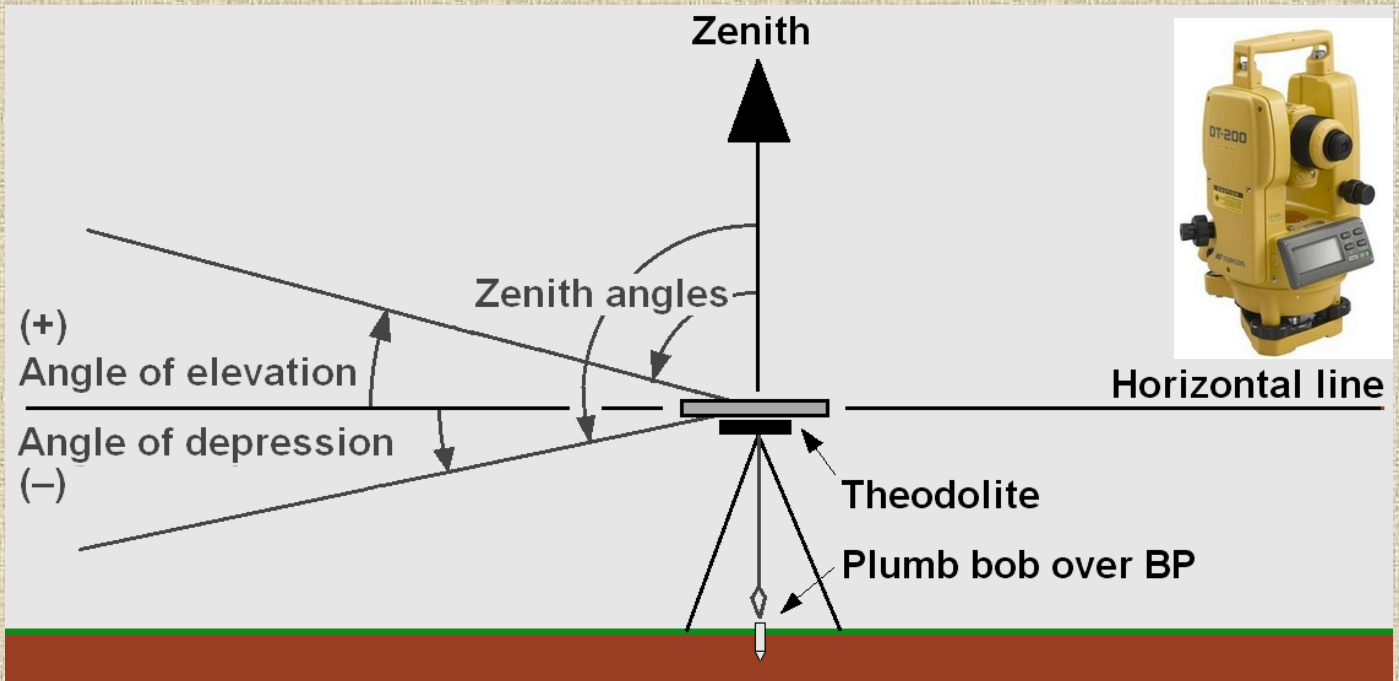




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Questions

Chapter 5: Angle Measurement



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Applications

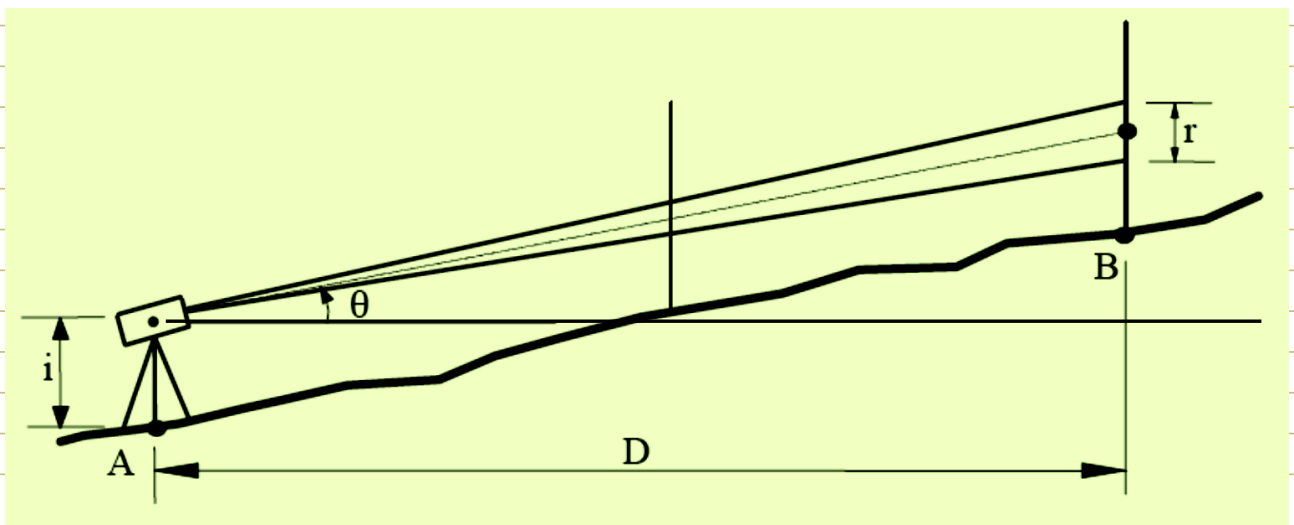
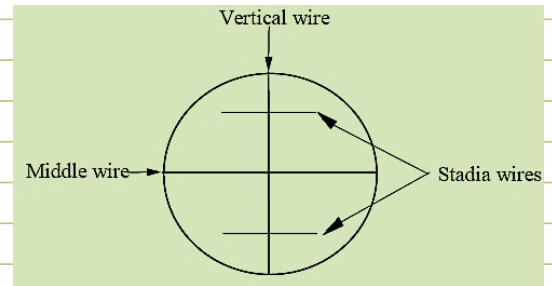
Tachometry: Stadia method

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$$k = 100$$

$$V = \frac{1}{2} kr \sin 2\theta$$

r = upper stadia reading lower stadia reading

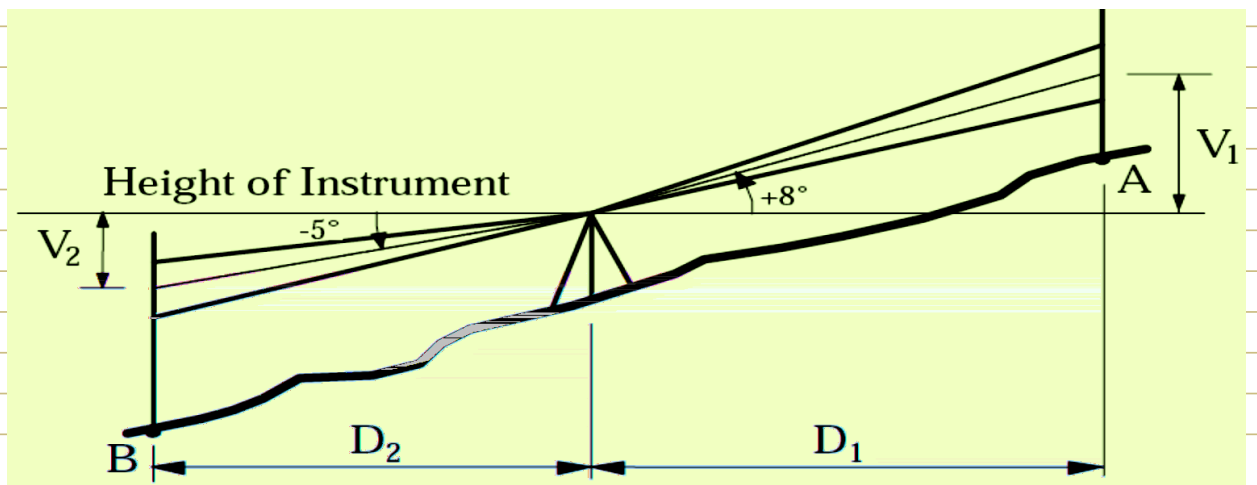
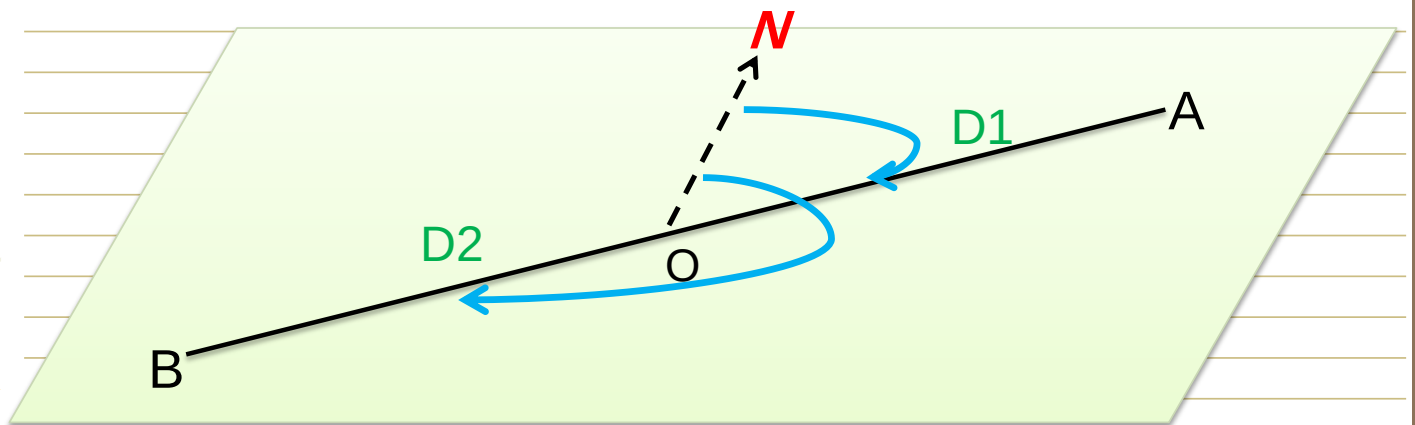


Example

The following readings were taken on a vertical staff with a theodolite having a constant $k = 100$ and $F + C = 0$.

Staff	Azimuth	Staff Readings	Vertical Angle
A	$27^{\circ} 30'$	1.000 1.515 2.025	$+ 8^{\circ} 00'$
B	$207^{\circ} 30'$	1.000 2.055 3.110	$- 5^{\circ} 00'$

Station	Azimuth	Sine	Readings	Vertical Angle	Sta
A	27° 30'	1.000	1.515 2.025	+8° 00'	
B	207° 30'	1.000	2.055 3.110	-5° 00'	



Example

Staff Station	Azimuth	Stadia Readings	Vertical Angle
A	27° 30'	1.000 1.515 2.025	+ 8° 00'
B	207° 30'	1.000 2.055 3.110	- 5° 00'

(1) Staff at Station A:

Staff intercept $r = 2.025 - 1.000 = 1.025$ m

Mid-reading = 1.515 m

$$D = kr \cos^2 \theta$$

$$V = \frac{1}{2} kr \sin 2\theta$$

$$\Rightarrow D_1 = 100 \times 1.025 \times \cos^2 (8^\circ) = 100.515 \text{ m}$$

$$V_1 = \frac{1}{2} \times 100 \times 1.025 \times \sin (16^\circ) = 14.126 \text{ m}$$

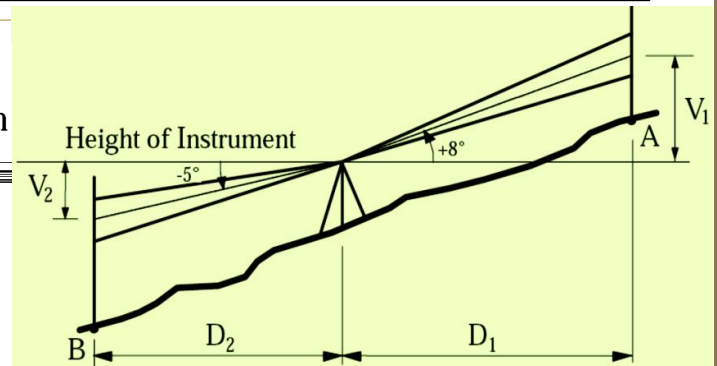
(2) Staff at Station B:

Staff intercept $r = 3.110 - 1.000 = 2.110$ m

Mid-reading = 2.055 m

$$\Rightarrow D_2 = 100 \times 2.110 \times \cos^2 (-5^\circ) = 209.397 \text{ m}$$

$$V_2 = \frac{1}{2} \times 100 \times 2.110 \times \sin (-10^\circ) = -18.320 \text{ m}$$



$$\text{Elevation of point A} = h + 14.126 - 1.515 = h + 12.611$$

$$\text{Elevation of point B} = h - 18.320 - 2.055 = h - 20.375$$

Elevation difference between B and A (ΔH_{BA}):

$$(\Delta H_{BA}) = (h + 12.611) - (h - 20.375) = 32.986 \text{ m}$$

$$\text{slope} = \frac{\text{Elevation difference}}{D_1 + D_2}$$

$$= 0.1064 = 10.64\%$$

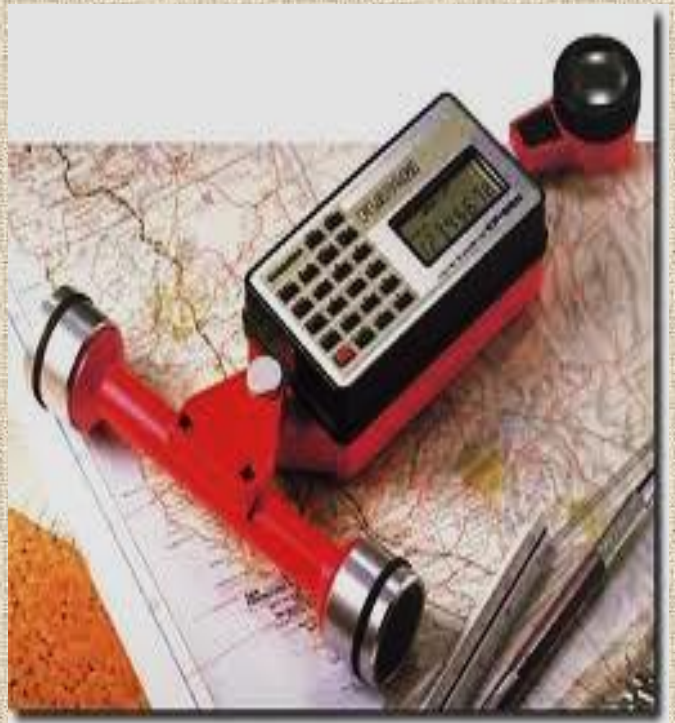
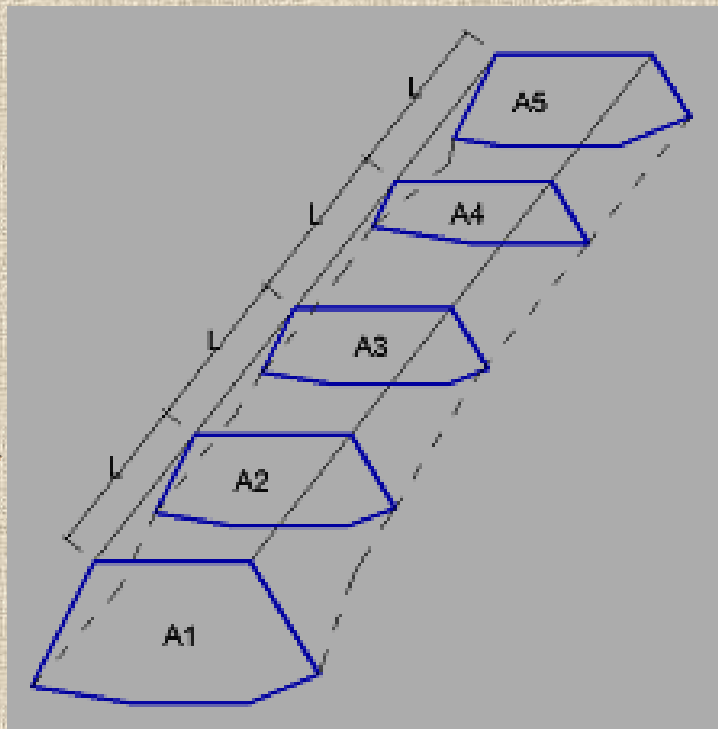
Other applications

- Building width.
- Building verticality.
- Drawing building elevations.
- Traversing and triangulation networks.
- Mapping details. (angle + distance or two angles)
- Setting out works.
 - angles (right angles)
 - horizontal curves (circular and spiral)
 - engineering drawings.
- Others as extending lines, projection of elevated points.



THANK YOU

Chapter 8: Areas and Volumes



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Contents

- **Areas**

- I. Areas by a planimeter
- II. Areas of regular figures
- III. Areas of irregular figures

- **Volumes**

- I. Volumes by AEA method
- II. Volumes by prismoidal method
- III. Volumes from contour maps
- IV. Volumes from spot levels

Areas

Part One: Areas

- I. Areas by a planimeter
- II. Areas of regular figures
- III. Areas of irregular figures

Areas

I. Areas by a planimeter

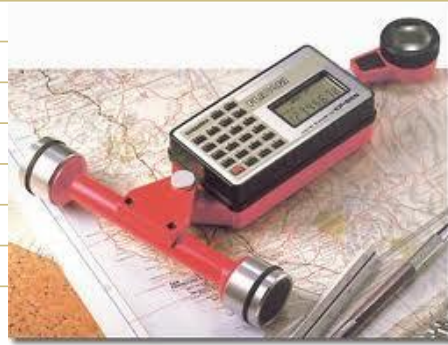
The planimeter is an instrument by means of which the area of a known scale plotted, closed figure (regular or irregular) can be determined.

Planimeter Types:

- Polar type (Old)



- Digital type



Areas



I. Areas by a planimeter

- Polar type (Old)

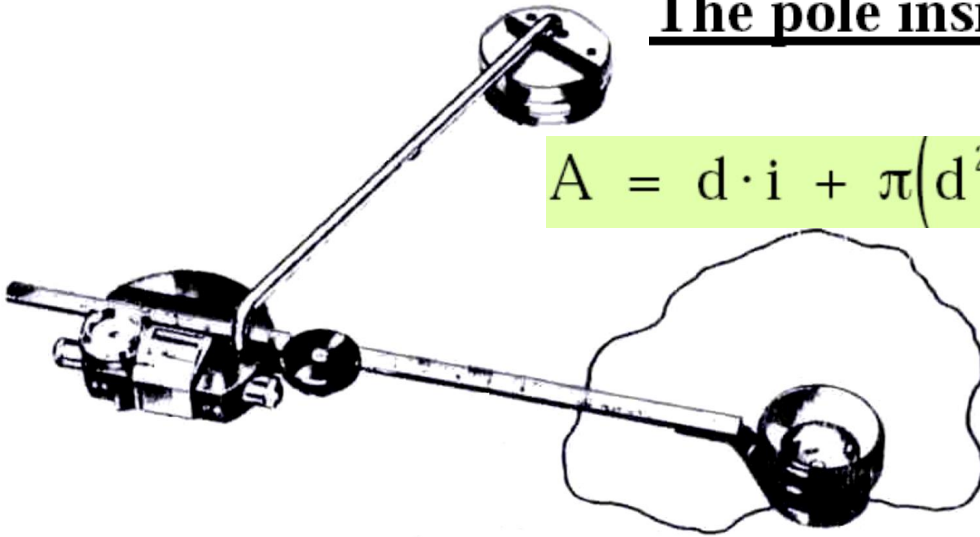
The pole outside the figure:

Map Scale	Length of Tracing Arm	Vernier Unit Equivalent
1:500	17.85 cm	4 m ²
1:1000	.	.
1:2000	.	.
1:5000	.	.

$$A = J \cdot i$$

The pole inside the figure:

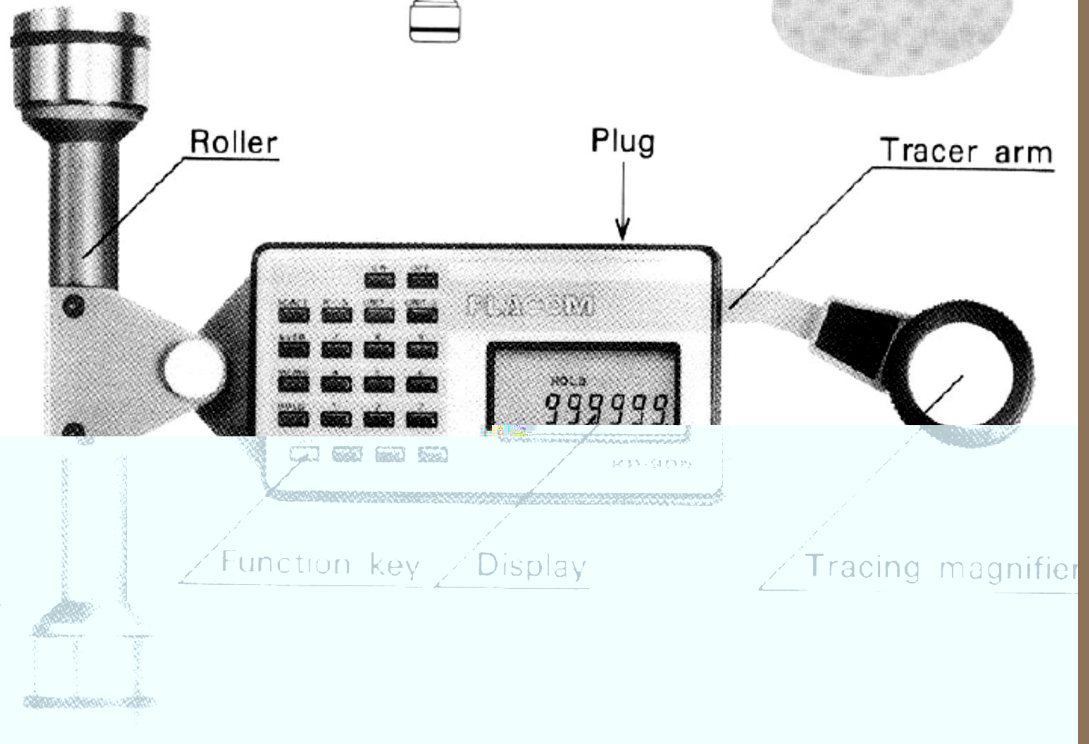
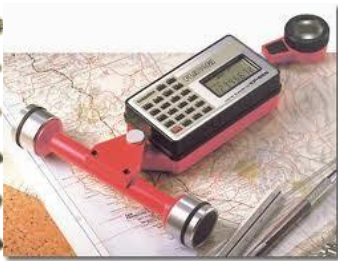
$$A = d \cdot i + \pi(d^2 \pm 2d^2k + r^2)$$



Areas

I. Areas by a planimeter

- Digital type



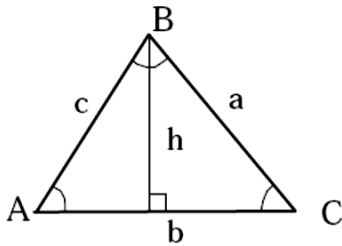
Areas

II. Areas of regular figures

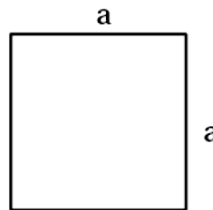
1. Basic Figures

2. Method of coordinates

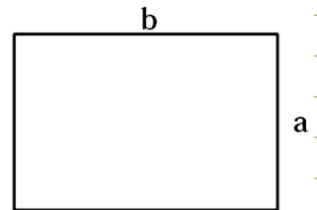
1. Basic Figures



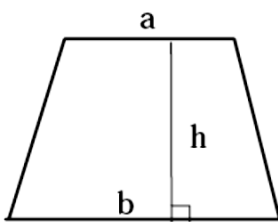
(a) Triangle



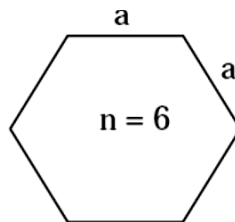
(b) Square



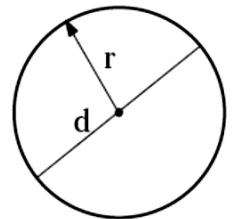
(c) Rectangle



(d) Trapezoid



(e) Regular polygon

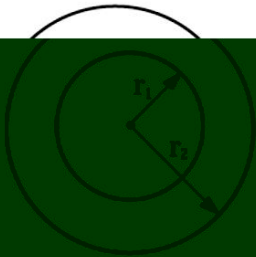


(f) Circle

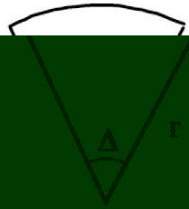
Areas

II. Areas of regular figures

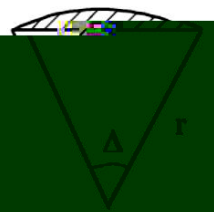
1. Basic Figures



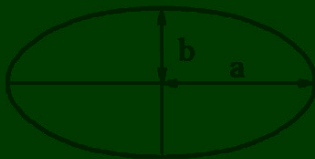
(g) Circular ring



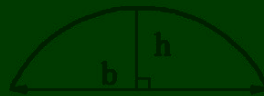
(h) Circular sector



(i) Circular segment



(j) Ellipse

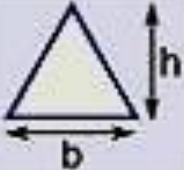
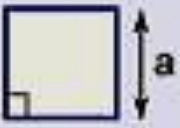
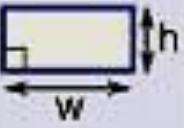
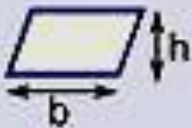
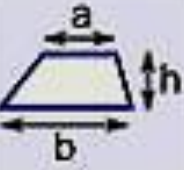


(k) Parabola

Areas

II. Areas of regular figures

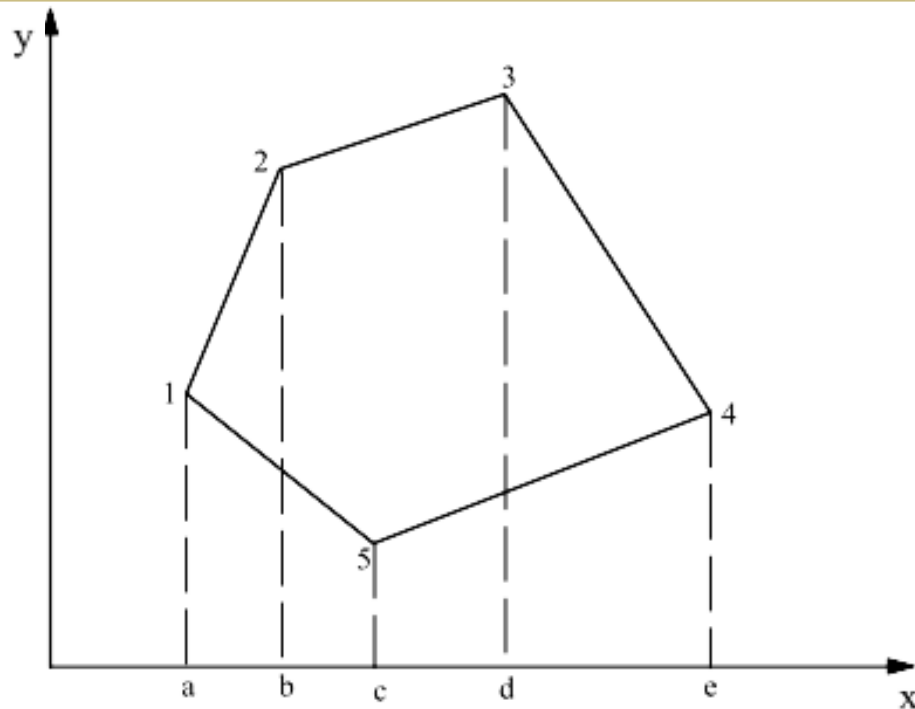
1. Basic Figures

	● <u>Triangle</u> Area = $\frac{1}{2}b \times h$ b = base h = vertical height		○ <u>Square</u> Area = a^2 a = length of side
	○ <u>Rectangle</u> Area = $w \times h$ w = width h = height		○ <u>Parallelogram</u> Area = $b \times h$ b = base h = vertical height
	○ <u>Trapezoid (US)</u> <u>Trapezium (UK)</u> Area = $\frac{1}{2}(a+b) \times h$ h = vertical height		○ <u>Circle</u> Area = πr^2 Circumference = $2\pi r$ r = radius
	○ <u>Ellipse</u> Area = πab		○ <u>Sector</u> Area = $\frac{1}{2}r^2\theta$ r = radius θ = angle in radians

Areas

II. Areas of regular figures

2. Method of coordinates



Areas

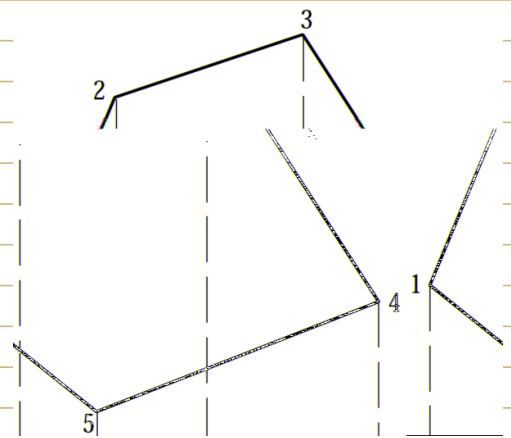
II. Areas of regular figures

2. Method of Coordinates

$$\text{Area} = \frac{1}{2} (|\text{Sum1} - \text{Sum 2}|)$$

Point	x	y	Positive product (Solid product)	Negative product (Dashed product)
1	-57.41	-231.66		
2	-311.26	-79.49	72,106.49	4,563.52
3	-31.66	123.48	2,516.65	-38,434.38
4	62.35	309.11	7,698.98	-9,786.42
5	172.76	-19.44	53,401.84	-1,212.08
1	-57.41	-231.66	1,116.05	-40,021.58
			136,840.01	-84,890.94

$$\begin{aligned} \text{Area} &= \frac{1}{2} \left[136840.01 - (-84890.94) \right] \\ &= 110865.48 \text{ ft}^2 = \frac{110865.48}{43560} = 2.545 \text{ acres} \end{aligned}$$

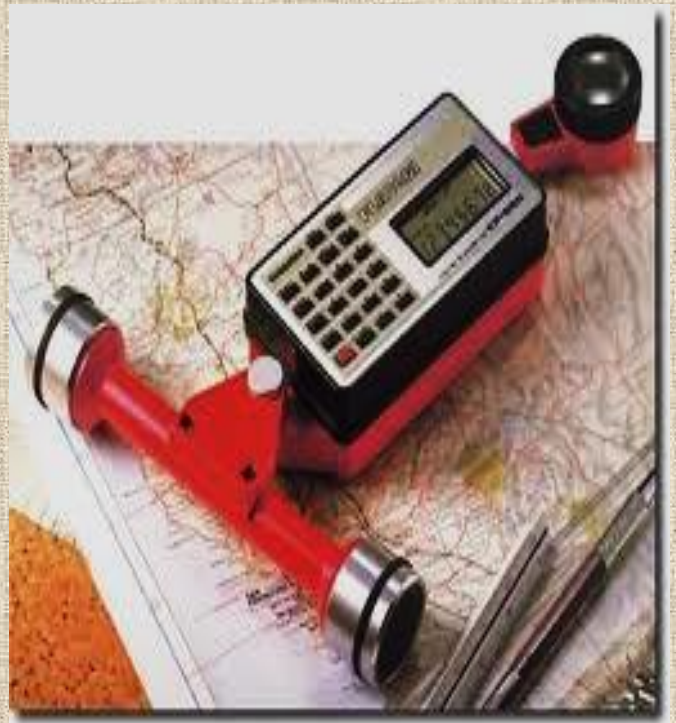
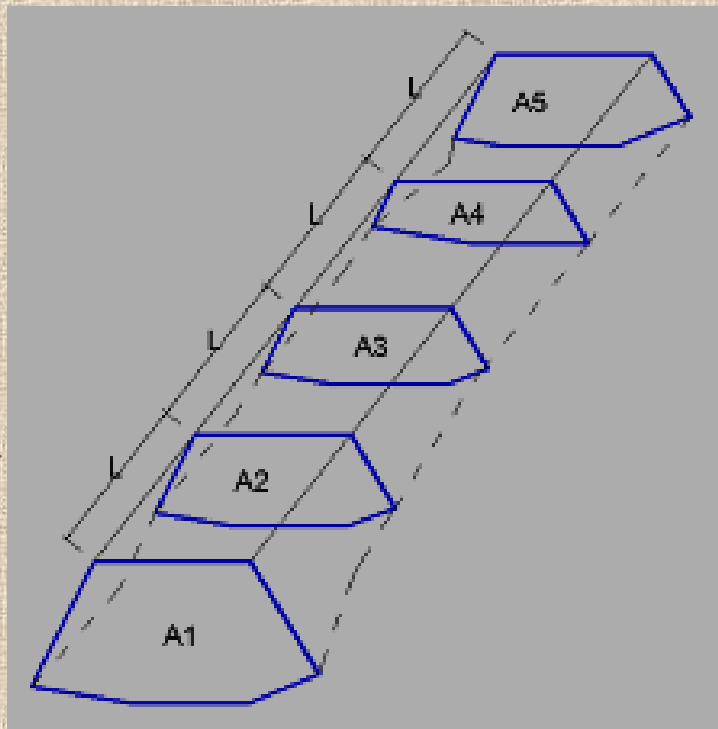


Station	x (ft)	y (ft)
A	-57.41	-231.66
B	-311.26	-79.49
C	-31.66	123.48
D	62.35	309.11
E	172.76	-19.44



THANK YOU

Chapter 8: Areas and Volumes



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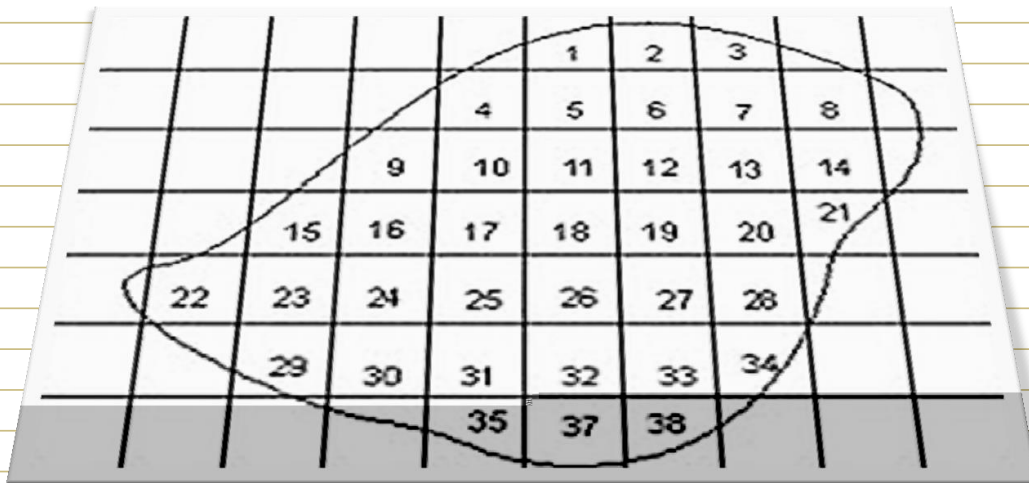
III. Areas of irregular figures

1. Give and take method

Areas

III. Areas of irregular figures

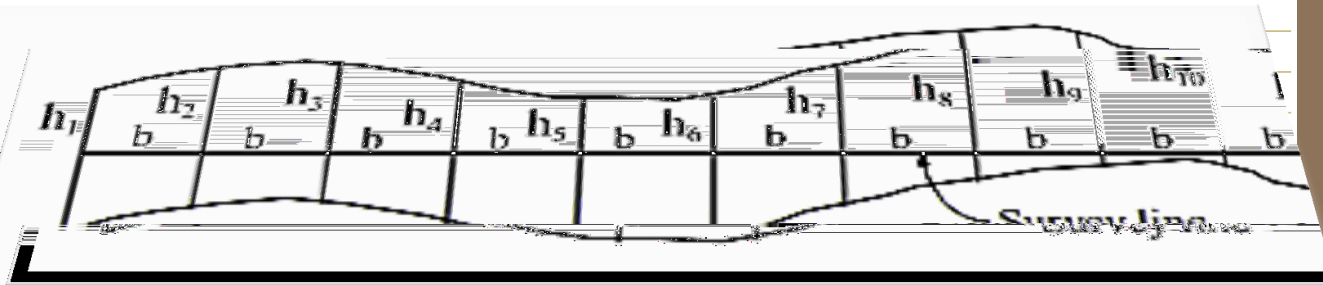
2. Graphical method



Areas

III. Areas of irregular figures

3. Trapezoidal method

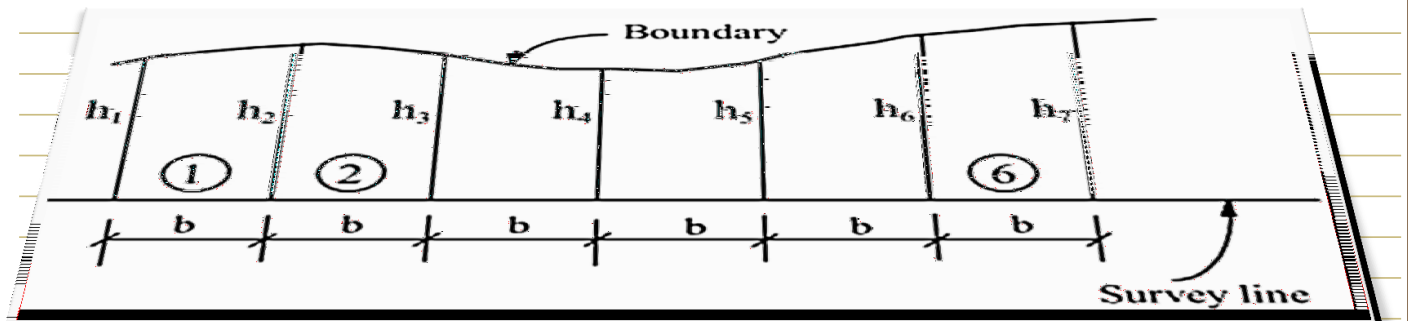


$$\text{Area} = \frac{b}{2} \left[h_1 + h_n + 2(h_2 + h_3 + \dots + h_{n-1}) \right]$$

Areas

III. Areas of irregular figures

4. Simpson's one third method



$$\text{Area} = \frac{b}{3} (X + 2O + 4E)$$

Where X = sum of first and last offsets

O = sum of the remaining odd offsets

E = sum of the even offsets

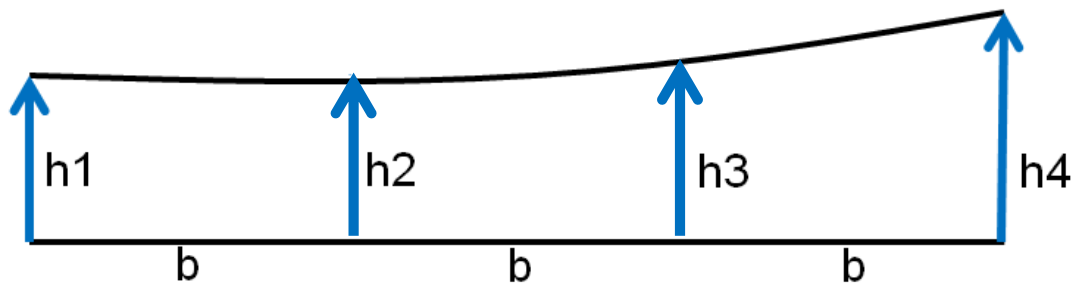
Example

For n = 8:

$$A = \frac{b}{3}[h1 + 2(h3 + h5) + 4(h2 + h4 + h6) + h7] + \left[\frac{(h7+h8)}{2}\right] \times b$$

For n = 4:

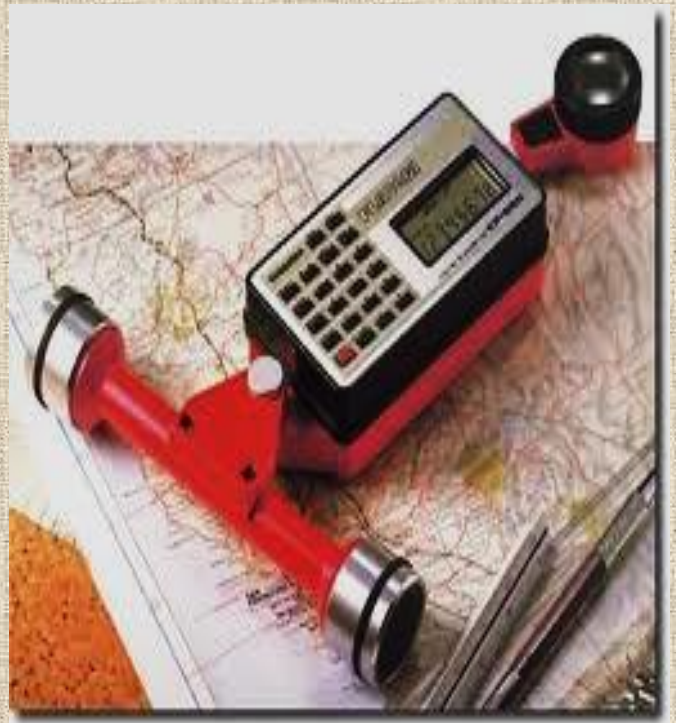
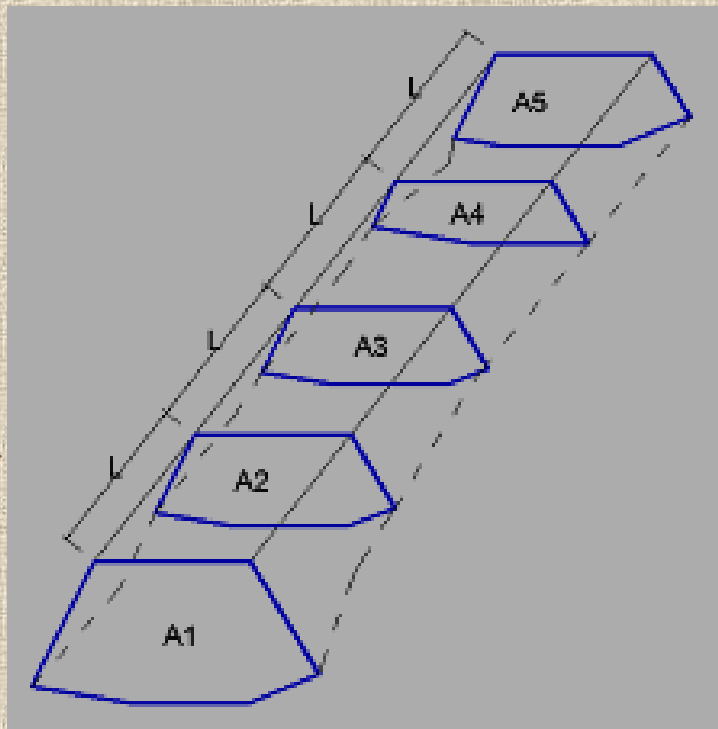
$$A = \frac{b}{3}[h1 + 4(h2) + h3] + \left[\frac{(h3+h4)}{2}\right] \times b$$





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Chapter 8: Areas and Volumes



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Volumes

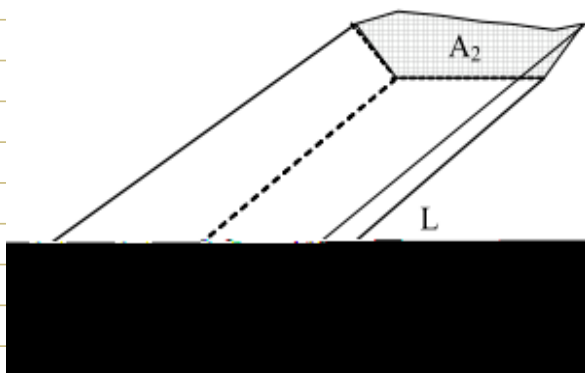
Part Two: Volumes

- I. Volumes by AEA method
- II. Volumes by prismoidal method
- III. Volumes from contour maps
- IV. Volumes from spot levels

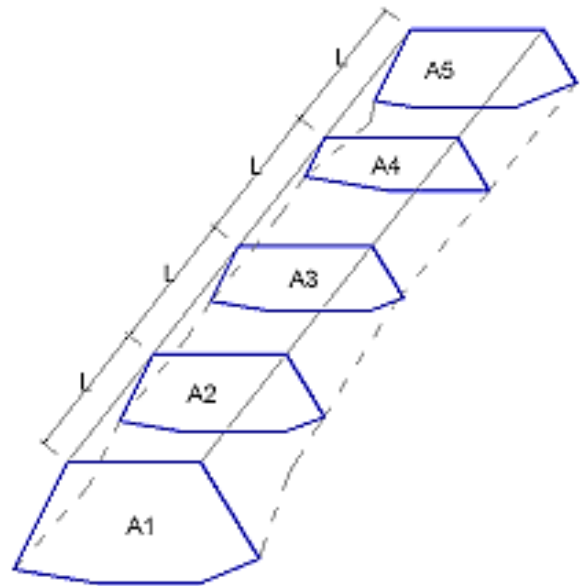
Volumes

Part Two: Volumes

I. Volumes by AEA method



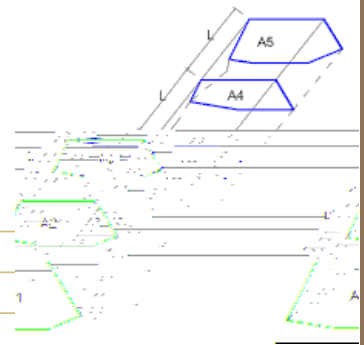
$$V = \left(\frac{A_1 + A_2}{2} \right) \cdot L$$



$$V = \frac{L}{2} \left(A_1 + A_n + 2(A_2 + A_3 + \dots + A_{n-1}) \right)$$



Volumes



Part Two: Volumes

II. Volumes by prismoidal method

The prismoidal formula is equivalent to Simpson's one-third rule for areas. It works only for an even number of equal strips between cross sections.

$$V = \frac{L}{3} [A_1 + A_n + 2(A_3 + A_5 + \dots + A_{n-2}) + 4(A_2 + A_4 + \dots + A_{n-1})]$$

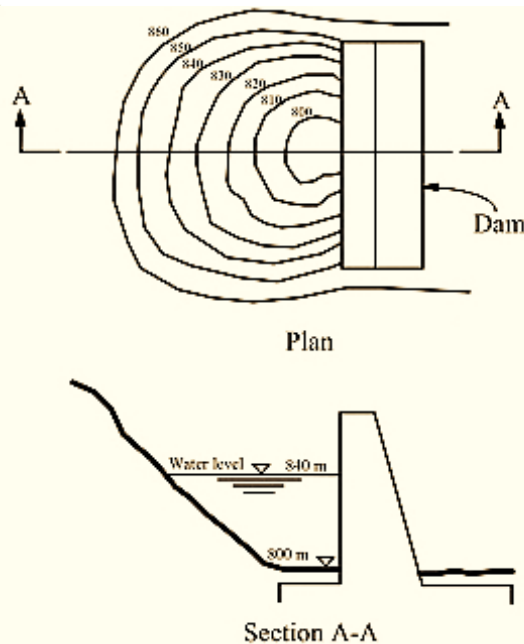
For $n = 3$

$$\Rightarrow V = \frac{L}{3} (A_1 + 4A_2 + A_3)$$

Volumes

III. Volumes from contour maps

Contour AMSL	800	810	820	830	840	850
Area (m ²)	20365	41375	117120	160340	211210	298140



(1) A-E-A Method:

Contour interval = $L = 10$ m

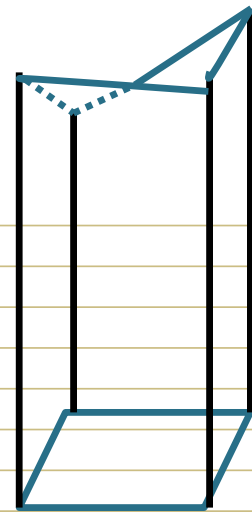
$$\begin{aligned}
 V &= \frac{L}{2} [A_{800} + A_{840} + 2(A_{810} + A_{820} + A_{830})] \\
 &= \frac{10}{2} [20365 + 211210 + 2(41375 + 117120 + 160340)] \\
 &= 4346225 \text{ m}^3
 \end{aligned}$$

(2) By Prismoidal Formula

$$\begin{aligned}
 V &= \frac{L}{3} [A_{800} + A_{840} + 2(A_{820}) + 4(A_{810} + A_{830})] \\
 &= \frac{10}{3} [20365 + 211210 + 2 \times 117120 + 4(41375 + 160340)] \\
 &= 4342250 \text{ m}^3
 \end{aligned}$$

Volumes

IV. Volumes from spot levels



		12m	12m	12m	
	1	2	3	4	
8m	A	203.5m	205.6m	202.1m	201.9m
8m	B	203.9m	204.0m	202.8m	203.7m
	C	205.2m	206.3m	201.3m	

$$\text{Volume of cut} = 8 \times 12 \times \frac{75.8}{4} = 1819.2 \text{ m}^3$$

Point	Old Elev. (m)	New Elev. (m)	Cut (c)	No. of Rectangles (n)	c . n
A1	203.5	200.0	3.5	1	3.5
A2	205.6	200.0	5.6	2	11.2
A3	202.1	200.0	2.1	2	4.2
A4	201.9	200.0	1.9	1	1.9
B1	203.9	200.0	3.9	2	7.8
B2	204.0	200.0	4.0	4	16.0
B3	202.8	200.0	2.8	3	8.4
B4	203.7	200.0	3.7	1	3.7
C1	205.2	200.0	5.2	1	5.2
C2	206.3	200.0	6.3	2	12.6
C3	201.3	200.0	1.3	1	1.3
				Sum =	75.8



THANK YOU