ENGINEERING SURVEY 2 - TACHYMETRY

PREPARED BY : PN RAIHANA BT ABDUL MALEK

INTRODUCTION

- Tachymetry word is derived from the Greek *takhus metron* meaning 'swift measurement'.
- It is a branch of surveying where horizontal distance and vertical distance can be obtained through stadia line by using teodolite.
- The distance between marks (titik) can be obtained without using a tape or chain.
- It suitable to use in valley, river and area where many obstructed.

Use in Civil Engineering

- To measure on the ground details : nature detail (e.g. tree, river, etc..) or human creation (e.g. building, manhole, culvert, road etc...)
- To produce topographic maps contain detailed information and contour lines for the purpose of planning a construction project such as roads, buildings and others.
- To obtain the reduce level (RL) between points on the surface of the earth

Tachymetry systems

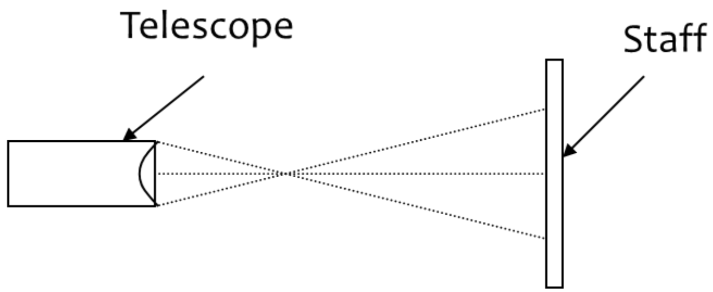
5 systems

i. Stadia System - Fixed & Variable angle
ii. Tangent System
iii. Contact Line System and Substance
iv. "Optical Wedge" or "Double Image" Systems
v. EDM System

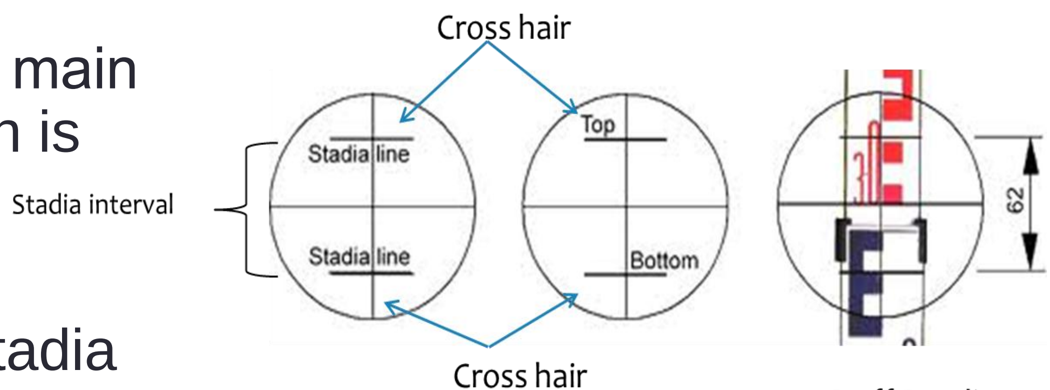
Main purpose - to *calculate* the *horizontal* and *vertical distance* between two points.
- The formula, calculation and adjustments are *different* for each system.

i. Stadia System

- This method using optical means which is measuring distance using a telescope with cross line and a staff rod (see figure).
- Contains two additional horizontal lines known as *stadia lines.*
- It's placed in the middle of main horizontal cross line (which is above and below)
- Distance between these stadia line is called as stadia interval.



Telescope and staff position



Stadia line position

Staff Reading

i. Stadia System - Fixed & Variable Angle

a) Fixed angle stadia system

- Stadia lines set at a certain position on the diaphragm.

b) Variable angle stadia system

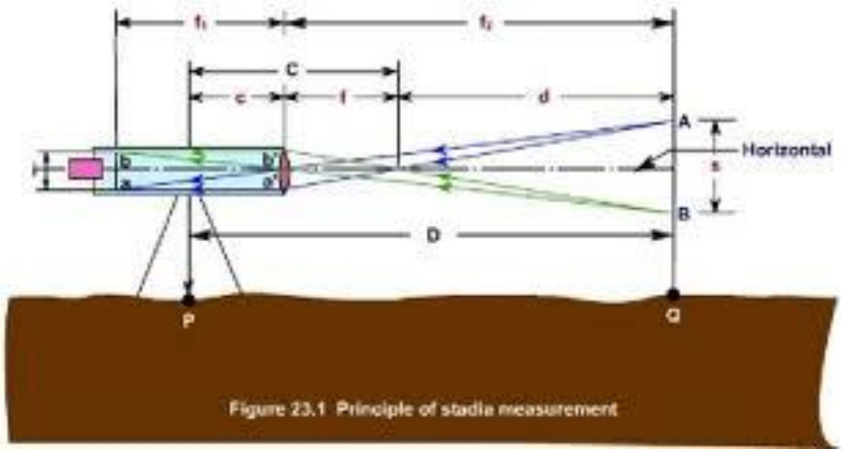
- Stadia lines may be altered in position.
- The interval distance can be measured using micrometer. Therefore it called as variable stadia.

  Garisan-garisan stadia boleh diubah kedudukannya. Jarak sela diukur menggunakan jangkahalus.

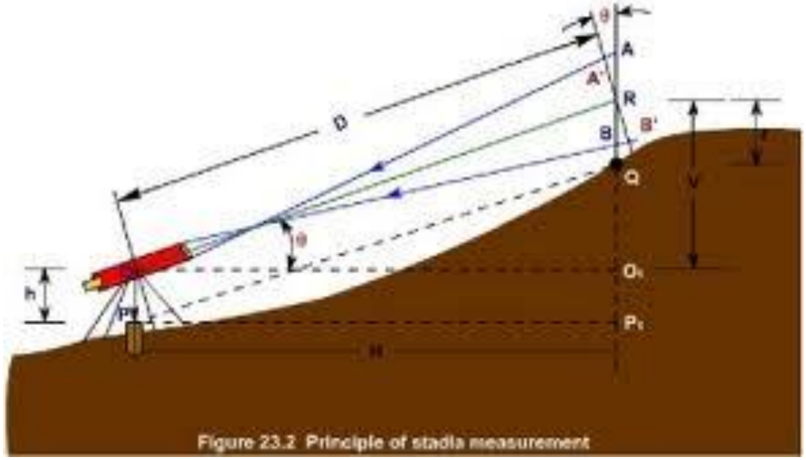
  Oleh itu, sistem ini dikenali sebagai stadia berubah.

- Stadia System Fixed & Variable angle can be apply in 2 methods:

  i. Inclined staff with vertical staff
  ii. Inclined staff with normal staff



normal staff



vertical staff

ii. Tangent system

- Need 2 observation using tachymetry tool to a staff .
- The distance can be obtained by computation

iii. Contact Line System and Substance

- Use theodolite with 1” reading to get precise internal angle.
- Need 2 observation to compute a distance

iv. Wedge Optic or Double Image System

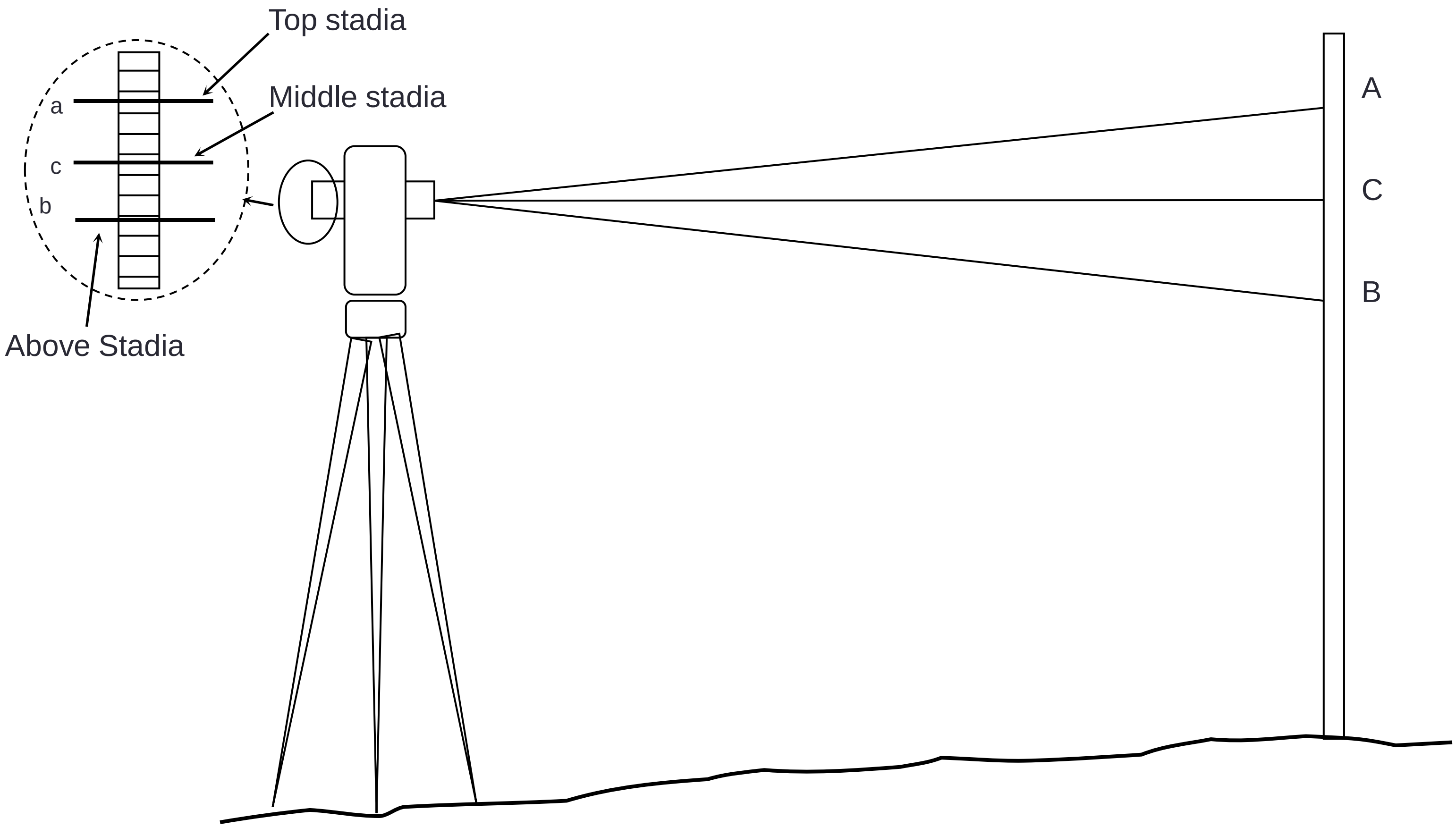
- A special theodolite were design to use with a measurement tool.
- The theodolite is directly towards a special staff
- A sets of measurements can be done to compute a distance.

v. EDM System

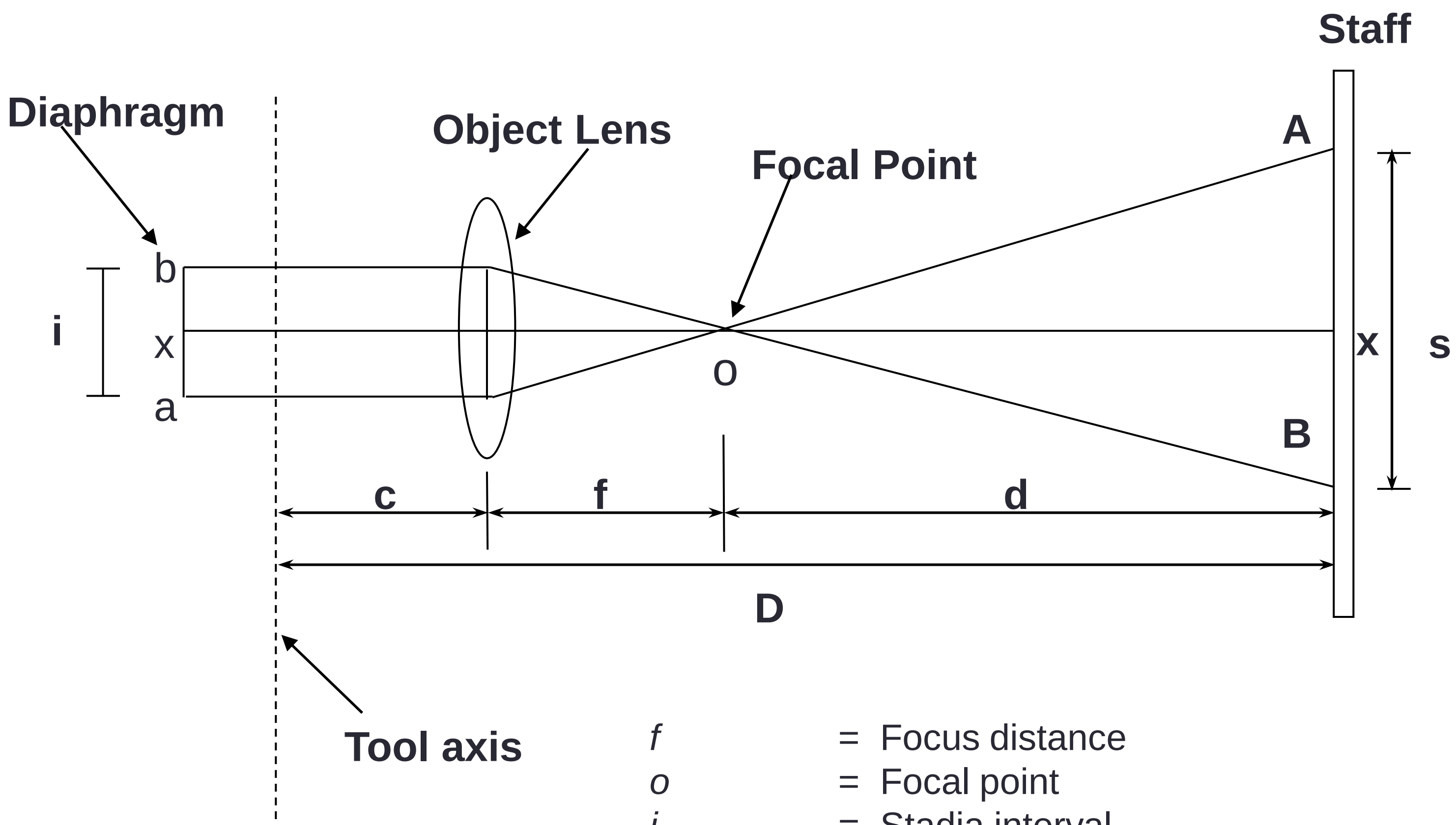
- Use EDM or total station to get a distance. Prism use as target.

In this chapter, we only learn about 2 system which is fixed stadia with vertical staff and EDM system.

Basic principle of odm



Basic Structure of Optical Theodolite



f = Focus distance
o = Focal point
i = Stadia interval
s = Staff intercept
c = The distance between object lens and tool axis.
d = The distance between focal point to staff.
D = The horizontal distance required

Apabila teleskop berada dalam keadaan fokus, imej staf *AB* ialah *ab* dalam satah bebenang. Pancaran dari *A* dan *B* yang melalui titik fokal o akan menghasilkan dua segitiga sebentuk iaitu segitiga *oAB* dan *oab*.

From these similar triangles:

$$\frac{d}{s} = \frac{f}{i}$$

but $d = D - (f + c)$,

$$\frac{D-(f+c)}{s} = \frac{f}{i}$$

So, the stadia formula:

$$D-(f+c) = \frac{f}{i}s$$

$$D = \frac{f}{i}s + (f+c)$$

$$D = \frac{f}{i}s + (f + c)$$

- The term *f / i is a constant in the stadia formula and denoted by the letter K.*
- *The term (f + c) is known as the constant and may be denoted by the letter C.*
- *This reduces the stadia formula to the simple linear equation:*

$$\boxed{D = Ks + C}$$

$$D = Ks + C$$

K = constant multiplication
s = The staff intercept
C = constant additive
D = the distance measured

Most of the theodolite with the K and C are assigned to a single value.

Typically, the value K = 100 and C = 0. So stadia formula would be:

D = 100S

EXERCISE 1

From the table below, calculate the actual distance for each point. K = 100, C = 0

Point	Top stadia	Middle stadia	Below stadia	**Stadia Different, s**
A	1.983	1.583	1.183	
B	2.205	1.405	0.605	
C	2.187	1.287	0.387	
D	2.445	1.945	1.445	
E	1.387	1.187	0.987	

Stadia Different, s = top stadia – below stadia

ANSWER

Point	Top stadia	Middle stadia	Below stadia	**Stadia Different, s**	**Distance**
A	1.983	1.583	1.183	0.800	
B	2.205	1.405	0.605	1.600	
C	2.187	1.287	0.387	1.800	
D	2.445	1.945	1.445	1.000	
E	1.387	1.187	0.987	0.400	

How about distance?

formula: $D = Ks + C$

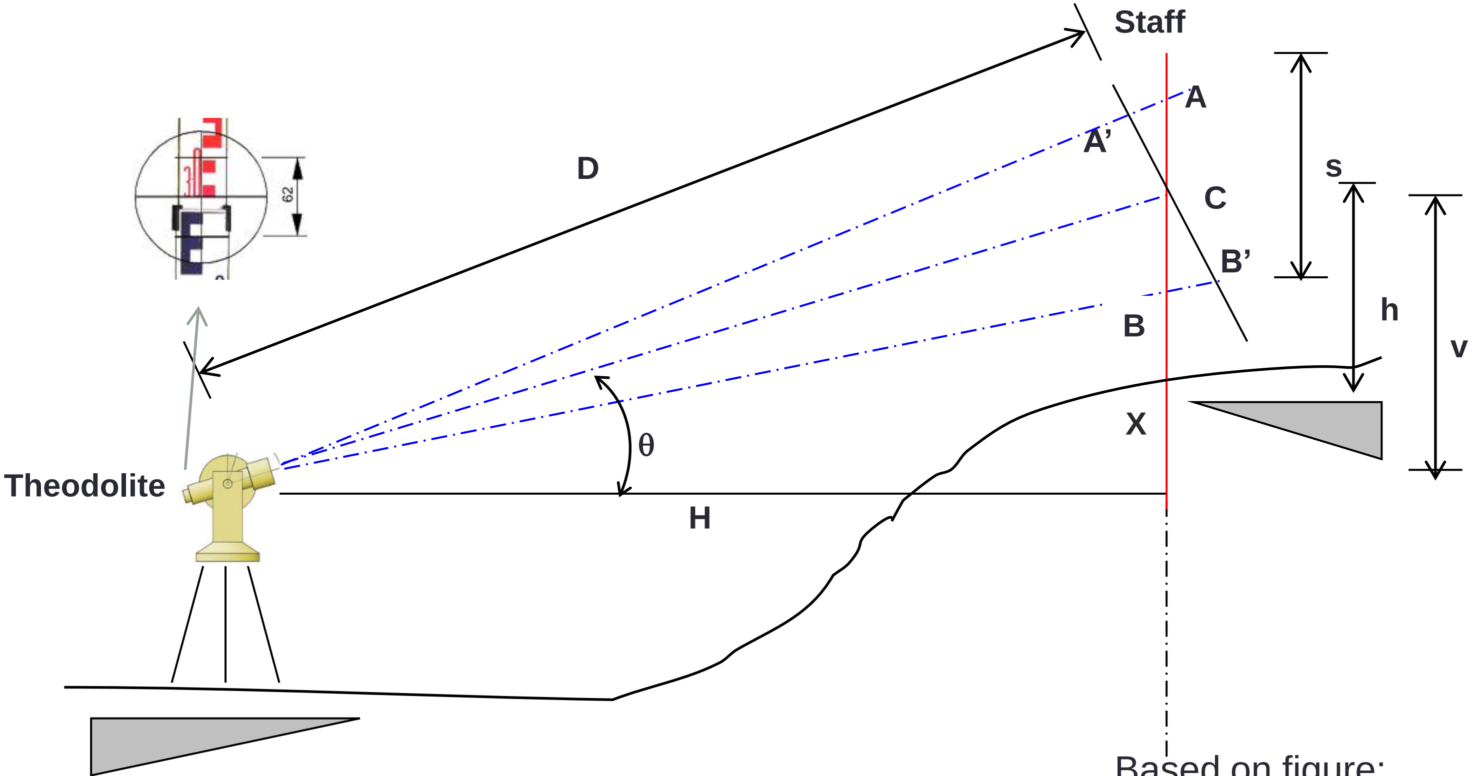
ANSWER

Point	Calculation	Distance
A	0.800x100	80.000
B	1.600x100	160.000
C	1.800x100	180.000
D	1.000x100	100.000
E	0.400x100	40.000

Fixed Stadia with Vertical Staff

- Fixed stadia vertical staff suitable for details survey.
- This method used by surveyor for tachymetry work manually.
- Equipment : Teodolite & staff

Fixed Stadia with Vertical Staff



D = Slope Distance
H = Horizontal Distance
V = Vertical Distance

Based on figure:
'S' = staff reading from A to B
If staff is held inclined (condong) and perpendicular (bersudut tepat) with line view, stadia reading should was A' B'.

To get slope distance;

$D = Ks + C$

$= K(A'B') + C$

But, $A'B' = ABCos\ \Theta$ or $Cos\ \Theta$

$D = KABCos\ \Theta + C$

$D = Ks.Cos\ \Theta + C$

Horizontal distance and vertical distance;

$H = DCos\ \Theta$

$= Ks.Cos2\ \Theta + C.Cos\ \Theta$

$V = Dsin\ \Theta$

$= Ks.Cos\ \Theta\ .Sin\ \Theta + C.Sin\ \Theta$

$= \frac{1}{2}(Ks.Sin\ 2\ \Theta\ ) + C.Sin\ \Theta$

In instruments where the additive constant is zero and $K = 100$, these formulae are simplified as follows:

D	=	Ks.Cos θ
H	=	Ks.Cos ²θ
V	=	½(Ks.Sin 2θ)

D = Slope Distance
H = Horizontal Distance
V = Vertical Distance

To obtain the reduced level at the staff position where the reduced level of the instrument station is known, the height difference between the points is applied as follows:

$$\text{Difference in height, } dH = H.\,I. \pm V - h$$

Where H.I = the height of instrument (always positive)

V = the vertical component (positive for angles of the elevation, negative for angles depression)

h = the centre hair reading (always negative)

The reduced level of the instrument position I plus the difference in height equal the reduced level of the staff position S. Therefore:

$$R.L._s = R.L._I + H.I \pm V - h$$

Question 1:

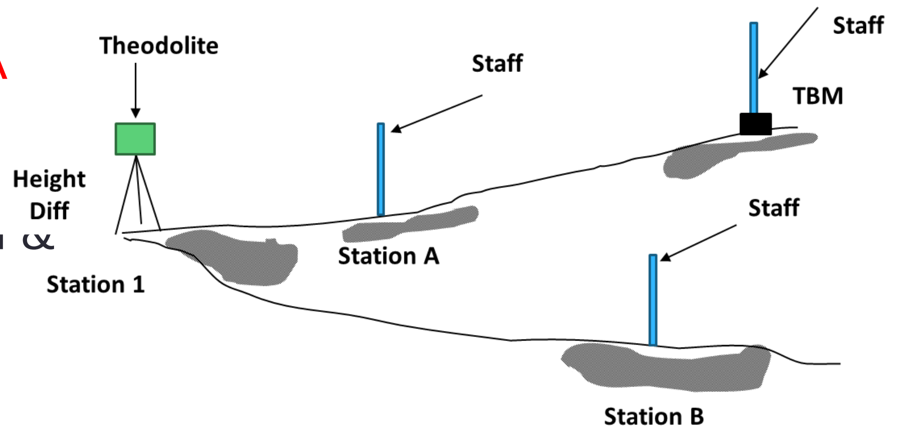
Based on the figure, calculate the above information. If the bearing from the station 1 to point A is 10° 30 '40” and the bearing from the station 1 to point B is 70° 50' 40",

calculate:

i. Reduce level at the station 1, point A and point B

ii. The horizontal distance from A to B.

Given height station (Hi) given as 1.214m & R.L. TBM is 40.00m.



Height Station	Stadia Above	Stadia Center	Stadia Below	Vertical Angle	Notes
1	1.011	0.777	0.542	3° 10’	T.B.M
1.214 m	1.742	1.532	1.321	2° 45’	A
	3.210	3.103	2.955	-4° 10’	B

The answer…

When staff at TBM

S_{TBM} =Top stadia– below stadia

= 1.011- 0.542

= 0.469 m

When staff at station A

S_A = Top stadia – below stadia

= 1.742 - 1.321

= 0.421 m

When staff at station B

S_B = Top stadia – below stadia

= 3.210 - 2.955

= 0.255m

V_{TBM} = ½ K s Sin 2θ°

= ½ 100 (0.469) Sin 2 (3° 10')

= 2.586 m

V_A = ½ K s Sin 2θ°

= ½ 100 (0.421) Sin 2(+2° 45')

= 2.018 m

V_B = ½ K s Sin 2θ°

= ½ 100 (0.255) Sin 2(-4° 10')

= -1.848 m

H = Ks.Cos ² ϴ

The answer

V = ½ Ks.Sin 2ϴ

Height Station	Vertical Angle	Above Stadia	Middle stadia	Below stadia	Horizontal Distance	Vertical Distance	Notes
1.214 m	3° 10’	1.011	0.777	0.542	46.8	+ 2.587	T.B.M
	2° 45’	1.742	1.532	1.321	42.0	+ 2.018	A
	-4° 10’	3.210	3.103	2.955	25.4	- 1.848	B

+/- Symbol….

$R.L._1 = RL_{TBM} - Hi - V + h$

$= 40.00 - 1.214 - 2.587 + 0.777$

$= 36.976m$

$R.L._A = RL_1 + Hi + V - h$

$= 36.977 + 1.214 + 2.018 - 1.532$

$= 38.677m$

$R.L._B = RL_1 + Hi - V - h$

$= 36.977 + 1.214 - 1.848 - 3.103$

$= 33.240m$

R.L. = reduce level
Hi = height instrument
V=vertical distance
h=middle stadia

Horizontal 1 to A (HA)

H_A =Ks.Cos²θ

= 100(1.742 - 1.321)(Cos+2° 45’) ²

= 42.003 m

Horizontal 1 to B (HA)

H_B = Ks.Cos²θ

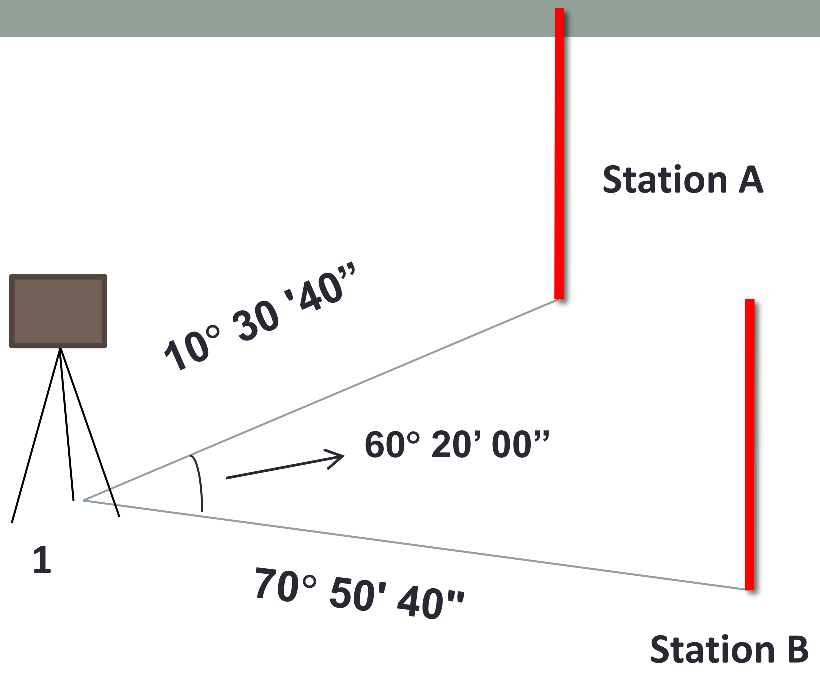
= 100(3.210 - 2.955)(Cos-4° 10’) ²

= 25.365 m

Angle A1B = 60° 20’ 00”

Distance (1 – A) = 42.003 m

Distance (1 – B) = 25.365 m



Therefore AB distance;

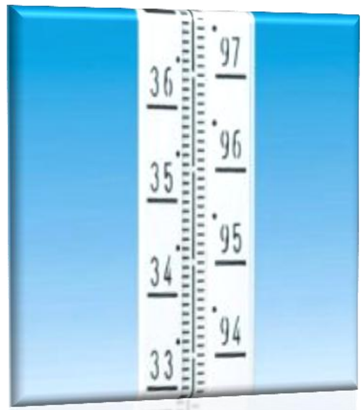
$AB^2 = (1A)^2 + (1B)^2 – 2(1A)(1B)Kos(A1B)$

$= (42.003)^2 + (25.365)^2 – 2(42.003)(25.365)Cos\ 60° 20’ 00”$

AB **= 36.783m**

TACHYMETRY INSTRUMENT – fixed stadia with vertical staff

Teodolite



Invar staff

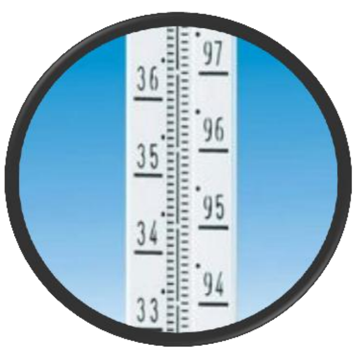
Tripod

Bubble

Picket

Measurement Method using Electronic Equipment

- Purpose - To get the height of reduced level for a point.
- Measurement method - same as vertical stadia method
- The different between using fixed stadia vertical staff is staff was replaced with reflector equipment which is prism.



Staff


prism

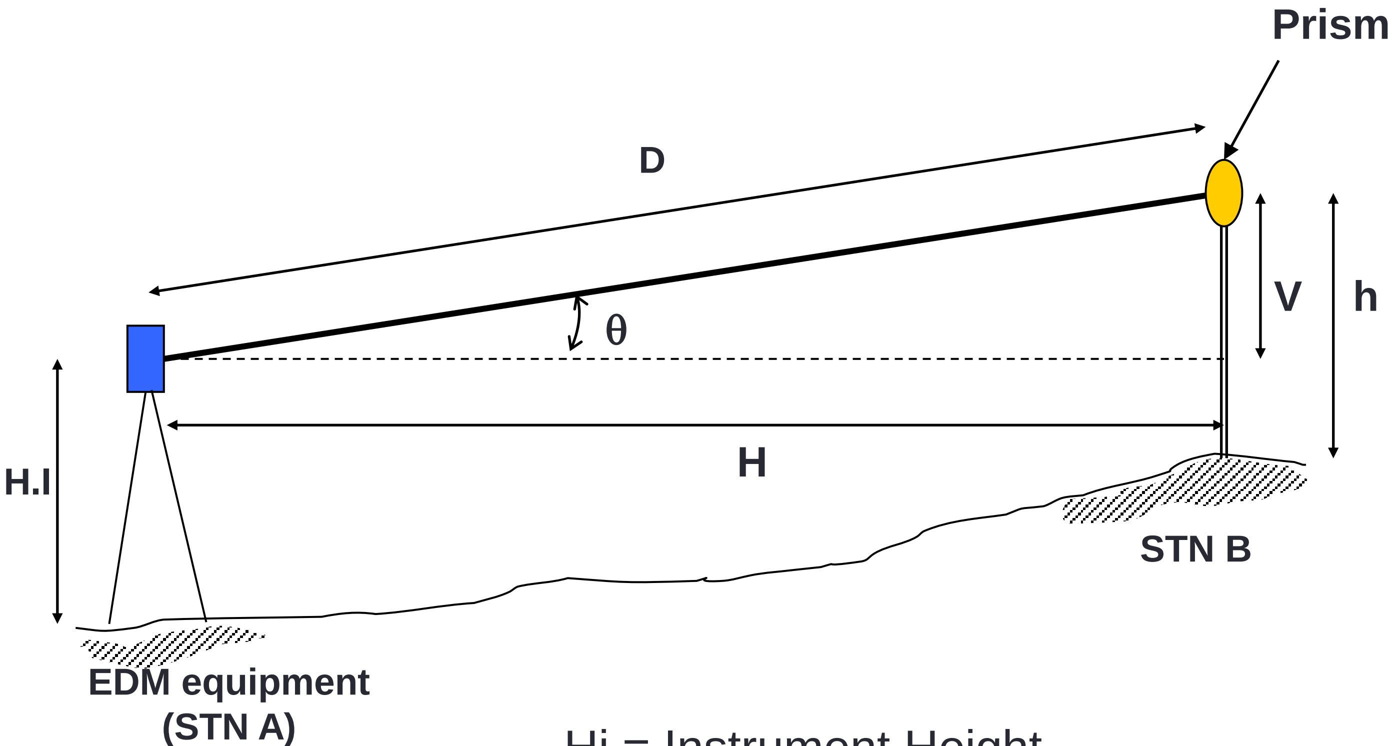
TACHYMETRY INSTRUMENT EDM SYSTEM

EDM

Tripod

prism

EDM SYSTEM



Hi = Instrument Height

V = Vertical distance (+ve for angles of the elevation, -ve for angles depression)

h = Height pole

Determination of Different in Height

If using theodolite, h = middle stadia

Different in Height (AB) = Hi $\pm$ V – h

Hi	=	Instrument Height
V	=	Vertical distance (+ve for angles of the elevation, -ve for angles depression)
h	=	Height pole

Reduce Level Determination

- If R.L. for STN A is known, the R.L. stations of other pole/prism stations can be determine by using the following formula:

R.L. Pole= R.L. STN A + H.I $\pm$ V – h

Example 2:

A fieldwork was carried out using a *Total Station* at STN 5 where the R.L. height and H.i is 16.235m and 1.452m. Vertical angle (θ) = +3° 20’ 30” and height pole = 1.250m. Vertical distance is 35.214m. Calculate R.L. for pole station.

Using this formula :

R.L. Pole = R.L. STN 5 + Hi $\pm$ V – h

The answer…..

Pole R.L.= R.L. STN 5 + Hi $\pm$ V – h

$= 16.235+1.452+(35.214 \sin 3°20'30") - 1.250$

$= 16.235 + 1.452 + 2.056 - 1.250$

$= 18.493$m

3

A fieldwork was carried out using the EDM at STN A which the R.L. height and H.i is 16.000m and 1.500m. Vertical angle (θ) = +2° 20' 30" and pole height(pole) = 1.500m. Slope distance is 36.204m.Give R.L. for pole station.

Answer….

$$R.L\ pole = R.L\ STN\ A + H.I \pm V - h$$

$$= 16.000 + 1.500 + (36.204 \sin 2°20'30'') - 1.500$$

$$= 16.000 + 1.500 + 1.479 - 1.500$$

$$= 17.479m$$

STUDENT MUST KNOW HOW TO USE THIS FORMULA….

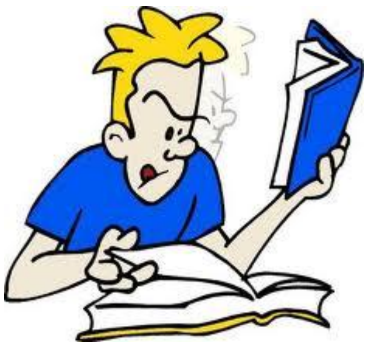
- *Different stadia*, s = Above stadia – below stadia
- *Different height*, dH = Hi ±V-h
- *Vertical distance*, $V = \frac{1}{2} Ks.\sin 2\theta$
- *Horizontal distance,* $H = Ks.\cos^2\theta$
- *Reduce level staf A, R.L. staff A* = R.L. station +Hi ±V-h
- *Trigonometry formula,* $a^2 = (b)^2 + (c)^2 - 2(b)(c).\cos\theta$

Question 4

- Table A show a tachymetry observation (vertical staff) using fix stadia method. If reduce level P is given as 100.027m, compute reduce level for Q and horizontal distance for PQ. Use K constant as 100, and C constant as 0.Height instrument is 1.250m

Equipment station	Staff	Bearing	Vertical angle	Upper stadia reading	Middle stadia reading	Below stadia reading
R	P	140^0 25'	+12^0 10'	2.003	1.803	1.603
R	Q	255^0 20'	-7^0 30'	1.661	1.461	1.261

Question 5



- Below data were obtain from a tachymetry survey work using vertical staff method.
- If reduce level for station 1 = 150.00 m and teodolite height = 1.525 m, K and C constant = 100 and 0.

Station	Staff station	Bearing	Vertical angle	Upper stadia reading	Middle stadia reading	Below stadia reading
1	A	120° 30’ 00”	12^0 34’ 00”	2.100	1.700	1.300
1	B	250° 10’ 00”	-8^0 31’ 00”	2.210	1.988	1.765

Question 6

If reduce level for station 1 = 150.00 m and theodolite height =

1.525 m, K and C constant = 100 and 0.

Compute:

- Vertical distance from station 1 to station A and station 1 to station B
- Reduce level for station A and station B
- Slope or gradient form station A to station B