R. C. Patel College of Engineering & Polytechnic, Shirpur

Department of Civil Engineering

Name of Subject: - **ADVANCED SURVEYING (ASU)**

Course Code: - **313321**

Scheme:- **CE-3K**

Semester:- **Third**

Unit No. 01- Tacheometric Surveying

CO1 - Use the Tacheometer to obtain relevant details of the terrain in given situation

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
I	Tacheometric Surveying	CO1	10	2	8	6	16

THEORY SYLLABUS CONTENT

Tacheometric Surveying

1.1 Principle of tacheometry, Use of Tacheometry

1.2 Tacheometer and its component parts, Analytic lens, Tacheometric formula for horizontal distance with telescope horizontal and staff vertical.

1.3 Methods of Tacheometry: Stadia and fixed hair method

1.4 Field method for determining constants of tacheometer 1.5 Limitations of tacheometry.

Subject Incharge

Mr. D. B. Wagh

Unit 1 - Techeometric surveying

Definition :- It is branch of surveying in which horizontal and vertical distances are determined by taking angular observations with an instrument known as a tacheometer

Situations wher techeometry is preffered / Advantages :-

1) It is adopted in rough and difficult terrain where direct levelling and chaining are not possible.
2) It is mostly used for contouring, in which horizontal distance and elevations are to be determined to give a complete relief map of the ground.
3) It is used in location survey for railway, roads, reserviors, etc
4) It is also used for checking measurment taken by a tape and other means.

Limitations of techeometry :-

1) Less accurate method and chaining is completely eliminated
2) This method is not suitable for precise survey.

Principle of Tacheometry :-

The principal of tacheometry is based on the property of isosceles, where the ratio of the distance of the base from apex and the length of the base is always costant.

In Fig. O_1, a_1, a_2, $O_1 b_1 b_2$, $O_1 C_1 C_2$ are all Isosceles triangles where, D_1, D_2, D_3 are the distances of bases from the apices (distance of staff stations from Instrument stations) and S_1, S_2, S_3 are lengths of the bases (staff Intercepts).

According to stated principle,

$$\frac{D_1}{S_1} = \frac{D_2}{S_2} = \frac{D_3}{S_3} = \frac{f}{i} \text{ (constant)}$$

The constant $\frac{f}{i}$ is known, as the multiplying constant.
where,

f = focal length of objective
i = stadia intercept.

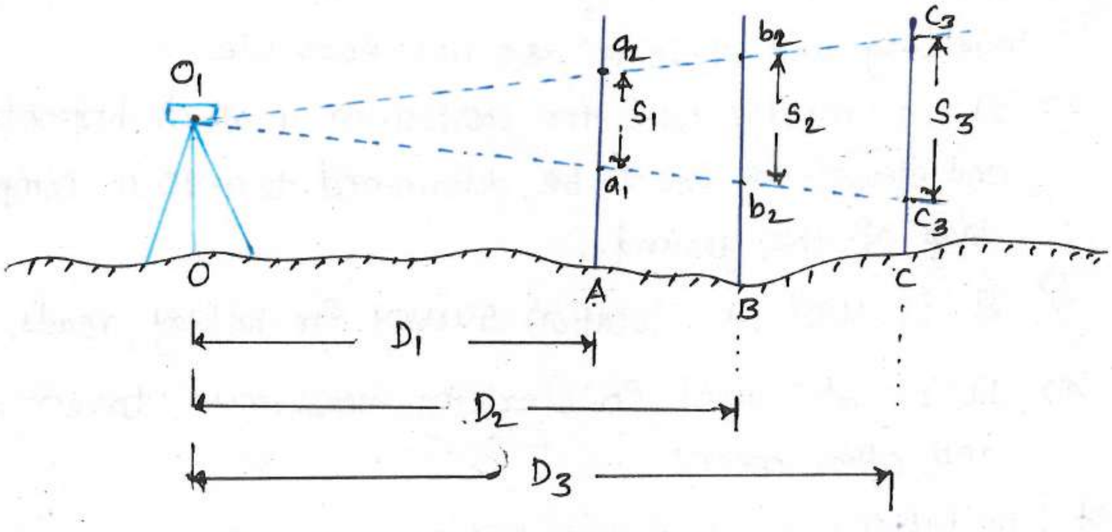


fig. Isosceles Triangles

→ Techeometer and it's component parts

a) The Tacheometer, nothing but a transit theodolite fitted with a stadia diaphragm and an anallatic lens,
- following are different forms of stadia diaphragm commonly used.

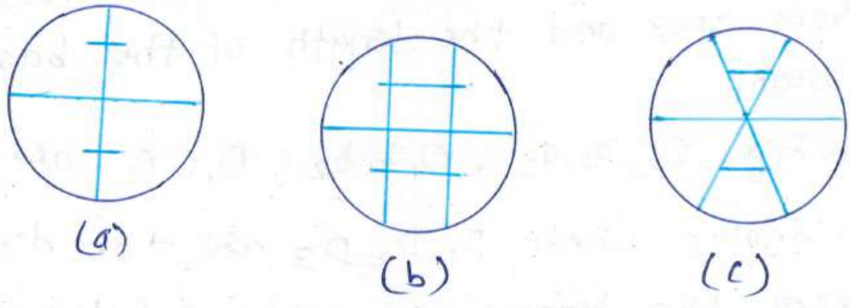


fig. stadia Diaphragm

b) The levelling staff and Stadia Rod

for short distances, ordinary levelling staves are used. The levelling staff is normally 4m long. and can be folded into three parts. The graduations are so marked that a minimum reading of 0.005 or 0.001m, can be taken.

For long sights, a specially designed graduated rod is used, which is known as stadia rod. It is also 4m long, and may be folded or telescopic. the graduations are comparatively bold and clear and minimum reading that can be taken is ~~comparatively bold and clear~~ 0.001m.

characteristics of a Tacheometer

1) The value of the multiplying constant f/i should be 100.
2) The telescope should be powerful, having a magnification of 20 to 30 diameters.
3) The aperture (opening inside a lens) of the objective should be 35 to 45mm diameter to give a bright image
4) The telescope should be fitted with an allallatic lens to make the additive costant (f+d) exactly equal to zero
5) The eyepiece should be of greater magnifying power than usual, so that it is possible to obtain a clear staff reading from a long distance.

Theory of stadia Tacheometry

following notation used in Stadia tacheometry

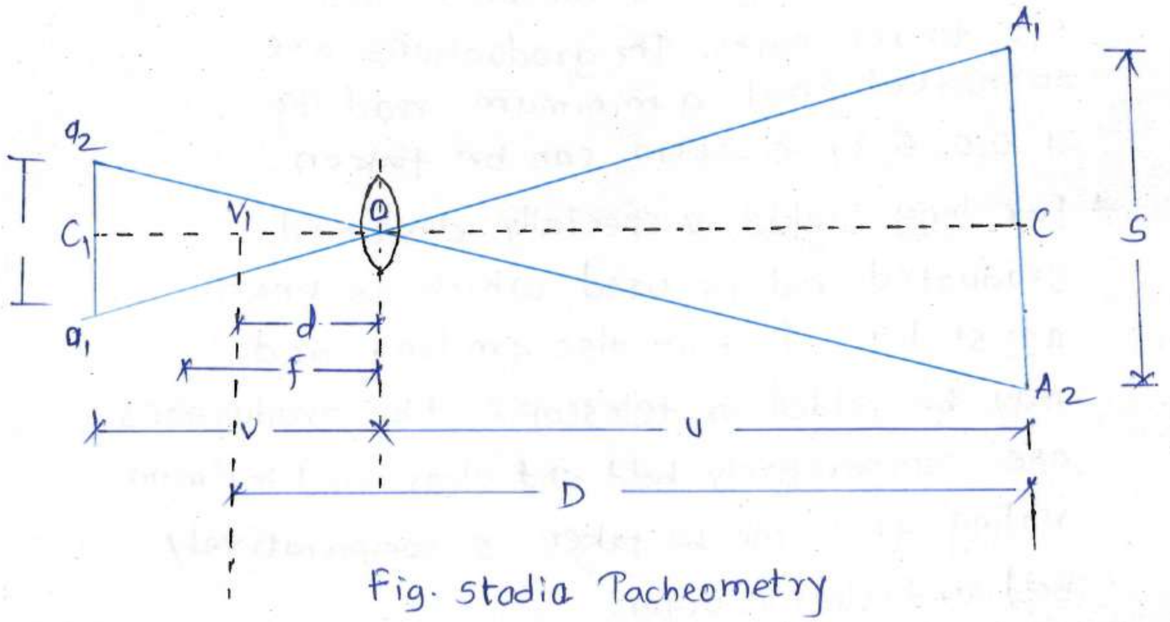


Fig. stadia Tacheometry

O = optical centre of object glass

A_1, A_2, C = readings on staff cut by three hairs

d_1, d_2, C_1 = bottom, top and central hairs of diaphragm

$a_1 a_2 = i$ = length of image

$A_1 A_2 = S$ = staff intercept

F = focus

V_1 = vertical axis of instrument

f = focal length of object glass

d = distance between optical centre and vertical axis of instrument

u = distance between optical centre and staff

v = distance between optical centre and image

From similar triangles $a_1 O a_2$ and $A_1 O A_2$, $\frac{i}{s} = \frac{v}{u}$

$$v = \frac{iu}{s} \quad \text{--- (i)}$$

from the properties of lenses,

$$\frac{1}{v} = \frac{1}{u} = \frac{1}{f} \quad \text{--- (ii)}$$

Putting the value of v in eqn (ii)

$$\frac{1}{iu/s} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{s}{iu} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{u}\left(\frac{s}{i}+1\right) = \frac{1}{f}$$

$$u = \left(\frac{s}{i}+1\right)f$$

But,

$$D = u + d \quad \text{——— (iii)}$$

So,

$$D = \left(\frac{s}{i}+1\right)f + d$$

$$D = \frac{s}{i} \times f + f + d = \left(\frac{f}{i}\right) \times s + (f+d)$$

The values (f/i) and $(f+d)$ are known as tacheometric constants.

$\left(\frac{f}{i}\right)$ is called the multiplying constant, and

$(f+d)$ the additive constant.

By adopting an anallatic lens in the telescope of a tacheometer, the multiplying constant is made 100, the additive constant zero.

⇒ Anallatic lens :

- An additional convex lens is provided between the eyepiece and the object glass at a fixed distance from the object glass.
- This convex lens is known as an anallatic lens.
- The object of providing the anallatic lens in the telescope is to make the additive constant $(f+d)$ exactly zero.
- Advantage :- It simplifies the calculations of distances and heights, as there is only one constant.
- Disadvantage :- Due to anallatic lens the brightness of the image is much reduced due to absorption of light.

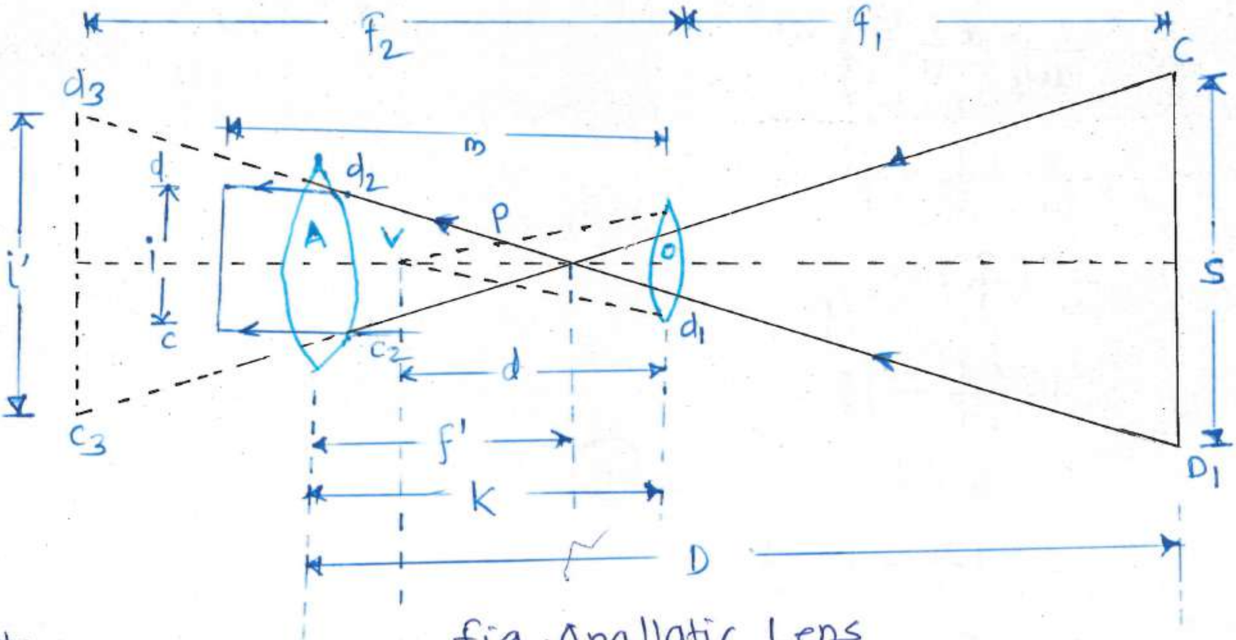


fig. Anallatic Lens

where,

S = Staff intercept CD_1

O = Optical centre of object glass

A = Optical centre of anallatic lens

V = vertical axis of instrument

P = Principal focus of the anallatic lens

f_1 & f_2 = conjugate focal lengths of objects glass

f = focal length of object glass

f' = focal length of anallatic lens

k = Distance between object glass and anallatic lens

d = distance between optical centre of object glass and vertical axis of instrument.

m = distance between optical centre of object glass and real image dc

i = length of real image dc, when anallatic lens is provided

i' = length of image d_3c_3 when anallatic lens is not provided

D = Distance between vertical axis of instrument and the staff.

⇒ Methods of Tacheometry

1) The stadia method
2) The tangential method

1) The stadia method :→

- In this method the diaphragm of the tacheometer is provided with two stadia hairs (upper and lower).
- The difference in these readings gives the staff intercept.
- To determine the distance between the station and the staff, the staff intercept is multiplied by the stadia constant (i.e multiplying constant, 100).

* Stadia method is divided in two types are as follows:

a) Fixed-Hair method

- The distance between the stadia hairs is fixed in in this method, which is one commonly used.

b) Moveable-Hair method

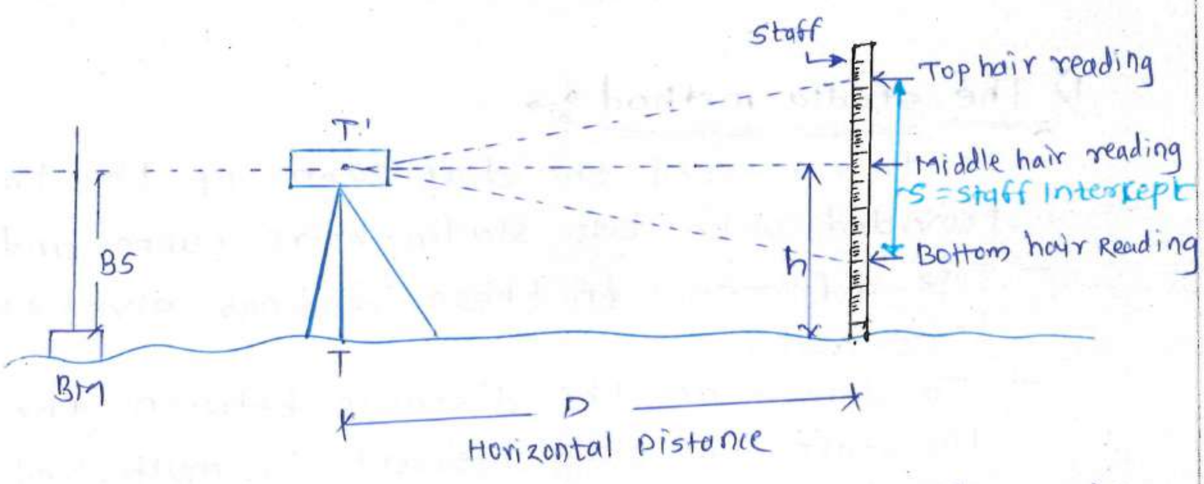
- The stadia hairs are not fixed in this method, they can be moved or adjusted by micrometer screws.
- This method is not generally used.

2) The Tangential method

- In this method, the diaphragm of the tacheometer is not provided with stadia hair.
- The readings are taken by a single horizontal hair.
- In this method, vertical angles are measured from the central cross hair and distance are calculated using trigonometric formulae.

Fixed-Hair Method :-

Case I] When line of sight is horizontal and staff is held vertically.



When the Line of sight is horizontal, Horizontal distance is found by

$$D = \left(\frac{f}{i}\right) \times S + (f+c)$$

Where,

$\frac{f}{i}$ = multiplying constant = 100

$(f+c)$ = Additive constant is zero for anallatic lens

S = staff intercept = difference between top and bottom hair reading.

HI = RL of Bench mark + middle hair reading

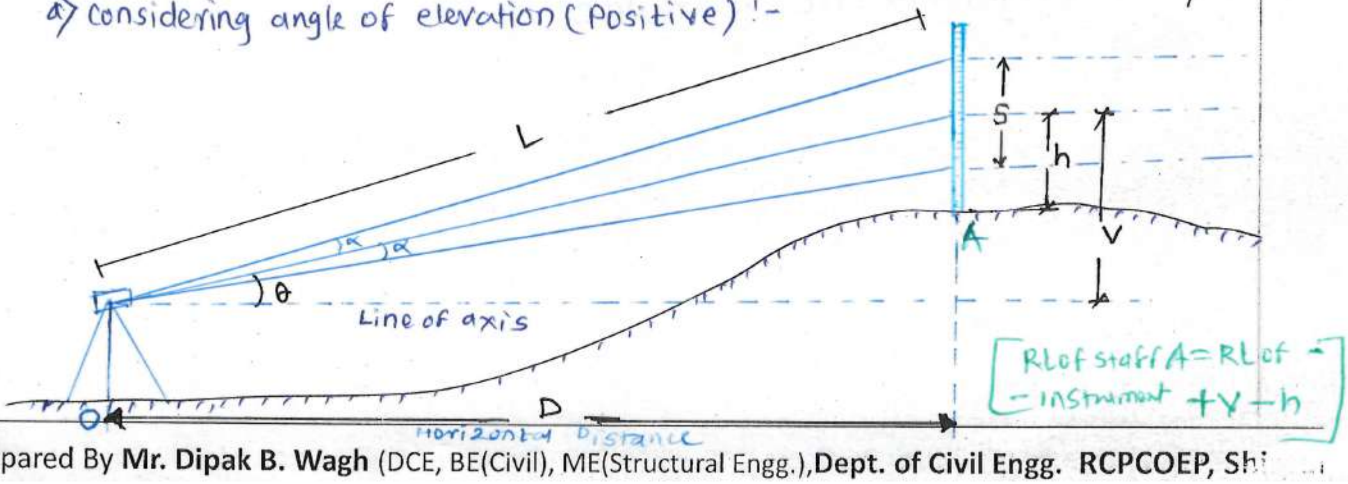
$HI = RL\ of\ BM + h$ ($\because$ h = central hair reading)

OR

$HI = RL\ of\ BM + BS$ ($\because$ BS = Backsight reading)

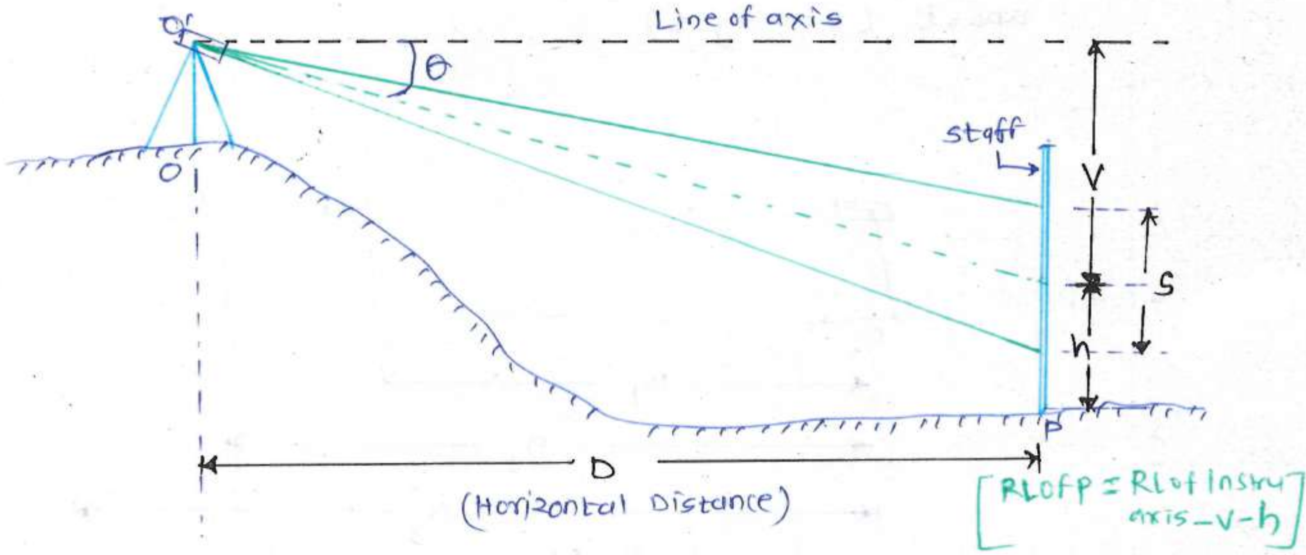
Case II] When Line of sight is Inclined, but staff is held vertically.

a) considering angle of elevation (Positive) :-



RL of staff A = RL of instrument + V − h

b) Considering Angle of Depression (Negative)



In the case - II (a) & (b), the expressions for D and V are same as following

1) Horizontal Distance,

$$D = \left(\frac{f}{i}\right) \times S \times \cos^2\theta + (f+c)\cos\theta$$

2) Vertical distance,

$$V = \left(\frac{f}{i}\right) \times S \times \frac{\sin 2\theta}{2} + (f+c)\sin\theta$$

} Telescope without anallatic lens

Telescope fitted with anallatic lens

1) Horizontal Distance,

$$D = \left(\frac{f}{i}\right) \times \cos^2\theta$$

(∴ Anallatic lens in telescope is to make the additive constant (f+d) exactly zero)

2) Vertical Distance

$$V = \left(\frac{f}{i}\right) \times S \times \frac{\sin 2\theta}{2}$$

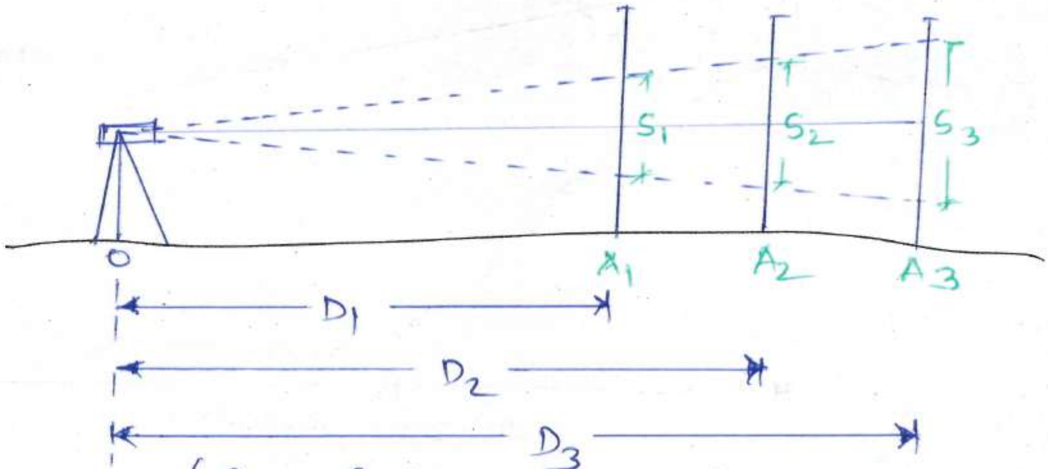
3) HI = RL of BM + BS

4) Case II (a) RL of staff = RL of axis of instrument + V − h

(b) RL of staff = RL of axis of Instrument − V − h

→ Field method of Determining tacheometric constants

a) A fairly level ground is selected, the tacheometer is set up at O and pegs are fixed at A_1, A_2 and A_3 known distances apart (see fig. 1)



(fig.1 field measurment)

b) The staff intercepts (stadia hair readings) are noted at each of the pegs. Let these intercepts be S_1, S_2, and S_3

c) The horizontal distances of the pegs from O are accurately measured. Let these distances be D_1, D_2, and D_3.

d) By substituting the values of $D_1, D_2, \ldots$ and $S_1, S_2 \ldots$ in the general equation

$$D = \left(\frac{f}{i}\right) s + (f+d)$$

We get the equation as follows.

$$D_1 = \left(\frac{f}{i}\right) S_1 + (f+d)$$

$$D_2 = \left(\frac{f}{i}\right) S_2 + (f+d) \quad \text{.. and so on.}$$

e) By solving the equations in pairs, several values of (f/i) and $(f+d)$ are obtained. The mean of these values gives the required constant.

Problems of Line of sight Horizontal and staff is vertical

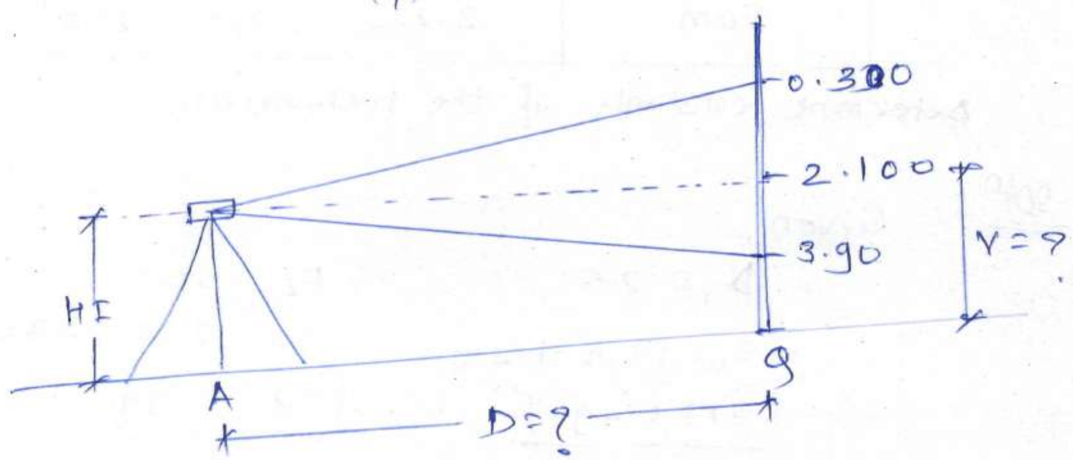
Ex. 1 A tacheometer having 100 and 0.4m readings were taken on vertical staff at station P and Q as follows.

Instrument Station	Staff station	Hair Reading	Remark
A	P	1.200, 2.300, 3.400	RL of P = 100.00m
	Q	0.300, 2.100, 3.900	

calculate the horizontal distance between A and Q and reduced level of Q. Assume line of sight horizontal.

Soln :-

Given data, $\left(\frac{f}{i}\right) = 100$, $(f+c) = 0.4$



$S_1 = 2.200$, $S_2 = 3.600$

Step 1 :- Find horizontal Distance between A and Q by observation at A

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

$$D = 100 \times 3.600 + 0.4$$

$$D = 360.4\ m$$

Step 2 :- RL of instrument axis = RL of BM + central hair reading

= 100 + 2.300

= 102.3 m

RL of Q = RL of Instrument axis − central hair reading

= 102.3 − 2.100

RL of Q = 100.2 m

⇒ Problems on Determination of Tacheometry Constants :-

Ex.1 following reading were obtained on a vertically held staff with a tacheometer (line of sight being horizontal)

Horizontal	Stadia reading
25m	1.900, 1.655, 1.410
50m	2.22, 1.725, 1.230

Determine constants of the tacheometer.

Soln:

Given,

$D_1 = 25$ $\quad$ $D_2 = 50$

$s_1 = 1.900 - 1.410$ $\quad$ $s_2 = 2.22 - 1.230$

$s_1 = 0.49$ $\quad$ $s_2 = 0.99$

We know,

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

$$D_1 = \frac{f}{i} \times s_1 + (f+c) \quad \text{--- eq}^n \text{ (1)}$$

$$D_2 = \frac{f}{i} \times s_2 + (f+c) \quad \text{--- eq}^n \text{ (2)}$$

∴ Put the values in eqn (1) & (2)

$$25 = \frac{f}{i}(0.49) + (f+c)$$

$$50 = \frac{f}{i}(0.99) + (f+c)$$

∴ Substracting eqn (1) from eqn (2)

$$25 = 0.49\frac{f}{i} + (f+c)$$

$$-\quad 50 = 0.99\frac{f}{i} + (f+c)$$

$$-25 = -0.5\frac{f}{i}$$

$$\frac{f}{i} = \frac{25}{0.5}$$

$$\boxed{\frac{f}{i} = 50}$$

Put the value of $\frac{f}{i}$ in eqn (1)

We get,

$$25 = (50) \times (0.49) + (f+c)$$

$$25 = 24.5 + (f+c)$$

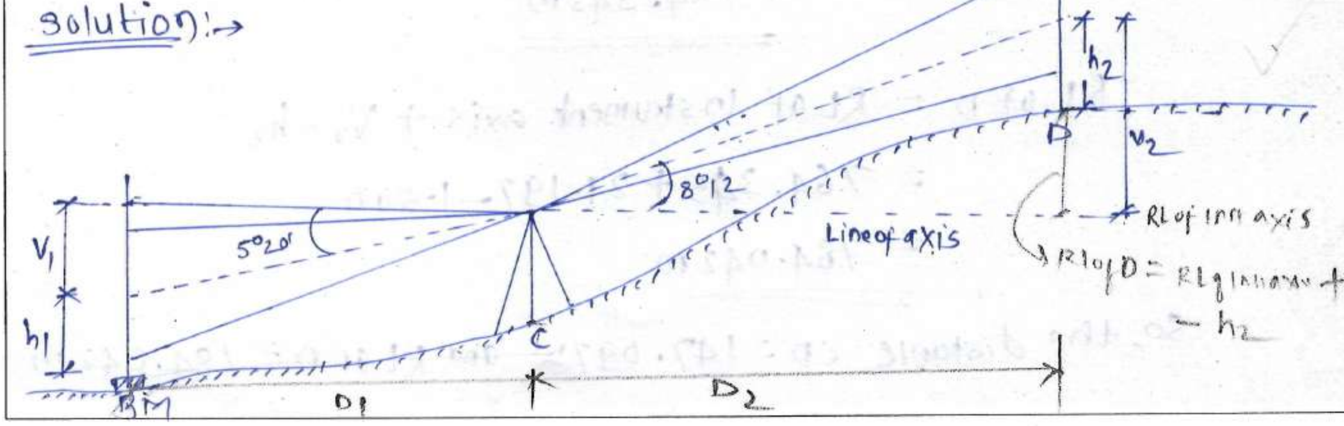
$$\boxed{f+c = 0.5}$$

Ex. A tacheometer was set up at a station C and the following readings were obtained on a staff vertically held.

Inst. station	Staff station	Vertical Angle	Hair Readings (m)	Remark
C	BM	$-5^{\circ}20'$	1.500, 1.800, 2.450	RL of BM = 750.50 m
C	D	$+8^{\circ}12'$	0.750, 1.500, 2.250	

Calculate the horizontal distance CD and RL of D, when the constants of instrument are 100 and 0.15.

Solution:→



Given data,

$$\frac{f}{i} = 100 \quad \text{and} \quad (f+d) = 0.15$$

RL of BM = 750.50 m.

1st observation. (C to BM)

$S_1 = 2.450 - 1.150 = 1.300\,m$

$\theta_1 = 5°20'$ (depression)

$$V_1 = \frac{f}{i} \times S \times \frac{\sin 2\theta}{2} + (f+d)\sin\theta$$

$$= 100 \times 1.300 \times \frac{\sin 10°40'}{2} + 0.15 \times \sin 5°20'$$

$$\boxed{V_1 = 12.045\,m}$$

2nd observation,

$S_2 = 2.250 - 0.750 = 1.500$

$\theta_2 = 8°12'$ (elevation)

$$V_2 = \left(\frac{f}{i}\right) \times S \times \frac{\sin 2\theta}{2} + (f+d)\sin\theta$$

$$= 100 \times 1.500 \times \frac{\sin 16°24'}{2} + 0.15 \times \sin 8°12$$

$$\boxed{V_2 = 21.197\,m}$$

$$D_2 = \frac{f}{i} \times S\cos^2\theta + (f+d)\cos\theta$$

$$= 100 \times 1.500 \times \cos^2 8°12' + 0.15 \times \cos \times 8°12'$$

$$\boxed{D_2 = 147.097\,m}$$

RL of instrument axis = RL of BM + h_1 + V_1

= 750.500 + 1.800 + 12.045

= 764.345 m

. RL of D = RL of Instrument axis + $V_2 - h_2$

= 764.345 + 21.197 − 1.500

= 784.042 m

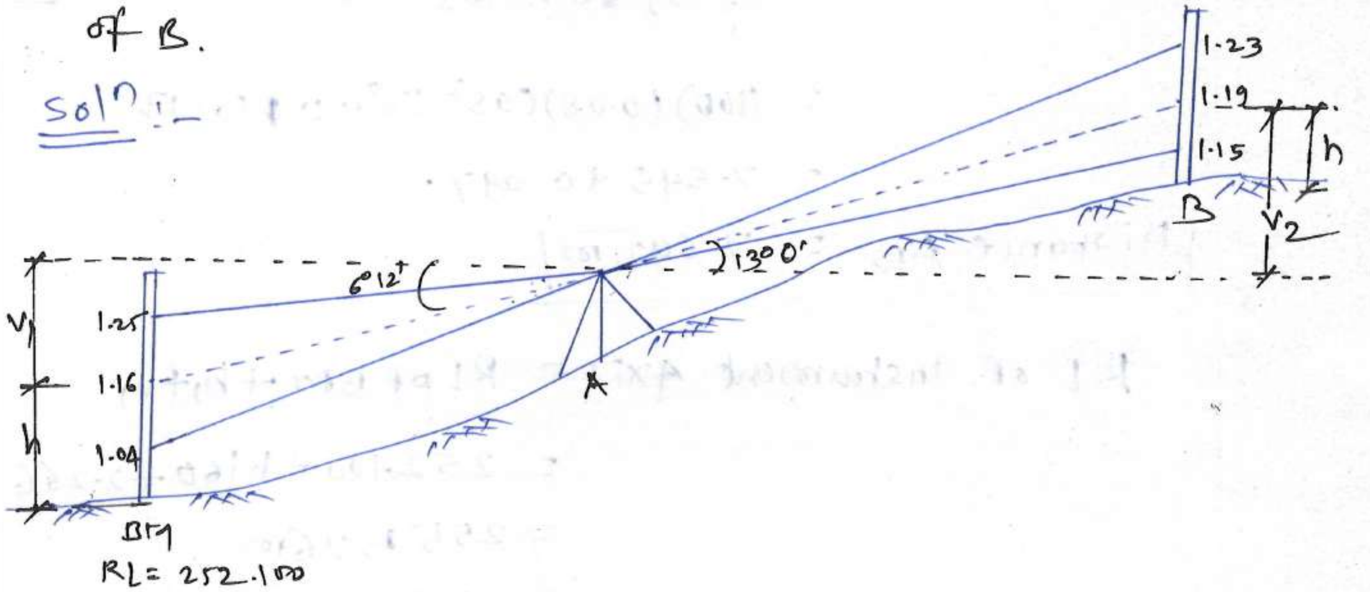
So, the distance CD = 147.097 m and RL of D = 784.042 m

Ex. A tacheometer was set up at a station A and the readings on a vertically held staff were recorded as follows.

Station	Staff station	Vertical angle	Hair Reading	Remark
A	BM	$-6°12'$	1.150, 1.190, 1.230	RL of BM
	B	$+13°0'$	1.040, 1.160, 1.250	= 252.1m

If the constants of the instruments were 100 and 0.1, find the horizontal distance from A to B and the reduced level of B.

Soln :-



1st observation :-

$$S_1 = 1.250 - 1.040 = 0.21$$

$$\theta_1 = 6°12$$

$$\frac{f}{i} = 100; \quad f+c = 0.1$$

$$V_1 = \frac{f}{i} \times S_1 \times \frac{\sin 2\theta_1}{2} + (f+c)\sin\theta_1$$

$$= (100) \times (0.21) \times \frac{\sin 2 \times 6°12'}{2} + (0.1)\sin 6°12'$$

$$V_1 = 2.255 + 0.011 = 2.266m$$

2nd observation :-

$$S_2 = 1.230 - 1.150 = 0.08$$

$$\theta_2 = 13°$$

$$f/i = 100; \quad f+c = 0.1$$

$$V_2 = \frac{f}{i} s_2 \frac{\sin 2\theta_2}{2} + (f+c)\sin\theta_2$$

$$= 100 \times 0.08 \times \frac{\sin 2\times 13^\circ}{2} + (0.1)\sin 13^\circ$$

$$V_2 = 1.75 + 0.02 = 1.77m$$

Distance AB $= \frac{f}{i} s_2 \cos^2\theta_2 + (f+c)\cos\theta_2$

$= (100)(0.08)\cos^2 13^\circ + 0.1 \cos 13$

$= 7.595 + 0.097$

Distance AB = 7.692 m

RL of Instrument Axis = RL of BM + h_1 + V_1

$= 252.100 + 1.160 + 2.266$

$= 255.526m$

RL of station B $= 255.526 + V_2 - h$

$= 255.526 + 1.77 - 1.190$

RL of station B = 256.111 m

unit No.1 - Tacheometric surveying

Important Questions

1) State any two advantages of Tacheometry (2m) (W-25)
2) List any four essential characteristics of Tacheometer (4m) (W-25, S-25, W-22, S-22, S-19, S-15)
3) State any four situations where tacheometry is preferred. (4m) (W-25, W-24)
4) State the meaning of analytic lens in tacheometer. Also state its purpose (4m) (W-25, S-14, S-12)
5) Describe the field method of determining constant of tacheometer. (6m) (W-25, W-23, S-18, W-16)
6) A tacheometer fitted with analytic lens was set up at station 'O' and the following readings were taken on a staff held vertical. find the horizontal distance 'OB' and RL of 'B' if RL of BM is 50.000 m. Take the constant of tacheometer as 100. (W-25)

Inst. Station	Staff Station	Vertical angle	Stadia readings
O	BM	+7°30'	0.900, 1.200, 1.500
O	B	−2°30'	1.100, 1.350, 1.600

(6m)

7) Mention the statement of principle of tacheometry (2m) (S-25)
8) Write any two objects of tacheometry. (2m) (S-25,
9) A tacheometer was set up at a station "C" and following readings were taken on a staff held vertically.

Station	Staff Station	Vertical Angle	Stadia hair readings	Remark
C	BM	+9° 31'	0.950, 1.055, 1.160	RL of BM
C	E	−3° 0'	1.050, 1.105, 1.160	= 400 m

The constants of tacheometer were 100 and 0.4 respectively Determine the distance "CE" and RL at "E" (S-25) (6m)

10) The following observations were made by tacheometer. find the tacheometer constants, consider, line of sight is horizontal and staff held vertical. (S-25)

(P.T.O.)

Distance (m)	90	130
Stadia readings (m)	2.345, 3.100, 3.550	2.245, 2470, 2.755

(6m)

(S-21)

11) Recall the formula for calculating horizontal distance by using tacheometer when line of sight is horizontal and staff held vertical. (2m) (W-24)

12) Explain principle of tacheometer (4m) (W-24, S-23, S-19)

13) Define tacheometry. State the principle of tacheometry with sketch. (S-16)

14) State the two advantages of tacheometry. (W-08)

15) The following are the observations made by tacheometer with anallatic lens, the multiplying constant being 100. The staff was held vertically.

Inst station	HI	Staff station	Vertical Angle	Hair readings	Remark
P	1.50	BM	$-6^\circ 12'$	0.965, 1.515, 2.065	RL of BM
P	1.50	Q	$7^\circ 5'$	0.820, 1.340, 1.860.	= 460.650

Find RL of P and Q horizontal distance PQ. (6m)

(W-14, W-12, W-09)

20.05.26