THEODOLITE SURVEYING

The theodolite is most accurate instrument used mainly (i) for measuring horizontal & vertical angles.

Use → (ii) for locating points on a line.
(iii) prolonging survey lines.
(iv) finding diff' in gradients.
(v) setting out grades.
(vi) ranging curves.

Classification of Theodolite

when telescope can be transited

1)- (i) Transit (when its telescope revolves 360°).

(ii) Non-transit. (cannot be transited).

2)- (i) Vernier (vernier is fitted to read graduated circle).

(ii) Digital.

transit – vertical
swinging – horizontal plane.

focussing takes place internally & (ii) telescope not change.

3)- (i) Internal focussing Theodolite.

(ii) External focussing Theodolite.
or moving focussing screw length of telescope change

- size of theodolite = dia of graduated circle on the lower plate.

- least count — 20" (vernier scale).

Adjustments — – once made but for long time.
– for accuracy of observation.
to establish fixed relationship b/t fundamental lines of instrument.

(i) Permanent adjustments —

1- Adjustment of the horizontal plate levels.
(axis of horizontal plate, ⊥ to vertical axis).

2- Collimation adjustment (line of collimation should coincide with axis of telescope).

3- Horizontal axis adjustment.

(horizontal axis must be ⊥ to vertical axis.

4- Adjustment of Telescope level. (line of telescope must be ∥ to line of collimation)

5- Vertical circle Index Adjustment. (vertical circle ... line of collimation is horizontal)

(ii) Temporary Adjustments — (made at each set up of instrument before taking obs.)

1- Centering. (Plumb-bob, optical plumet) (... vertical axis of theodolite immediately over a station mark)

2- Levelling. (foot screws, bubble tube). (bubble to centre)

3- Focussing. (i) ... of eye piece (until cross hair are seen)
(ii) — object glass (to obtain clear image of object)

* Measurement of horizontal angles —

(i) Ordinary method — To measure horizontal angle.

(ii) Repetition method — This method is used for very accurate work. In this, same angle is added several times mechanically. (3 face left & 3 face right), total 6 readings

Correct value = $\frac{\text{accumulated reading}}{\text{no. of repetitions}}$

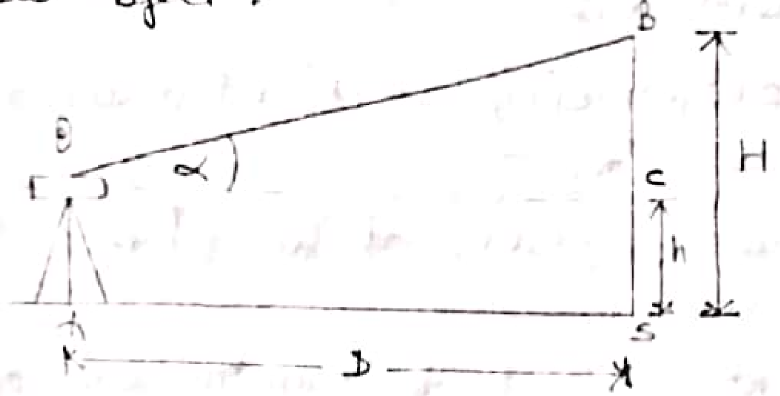
(iii) Reiteration method — This method consists of measuring several angles successively & finally closing the horizon at the starting point. (performed ... particular station)
Final reading on vernier A = initial reading.

* Measurement of vertical angle

* error in theodolite survey & precautions.

Height of object —

1- Accessible object:



Let H = ht of object above bench Mark.

h = ht of instrument axis above BM.

α = vertical angle at station.

D = dis. from instrument station to object.

In ΔOBC,

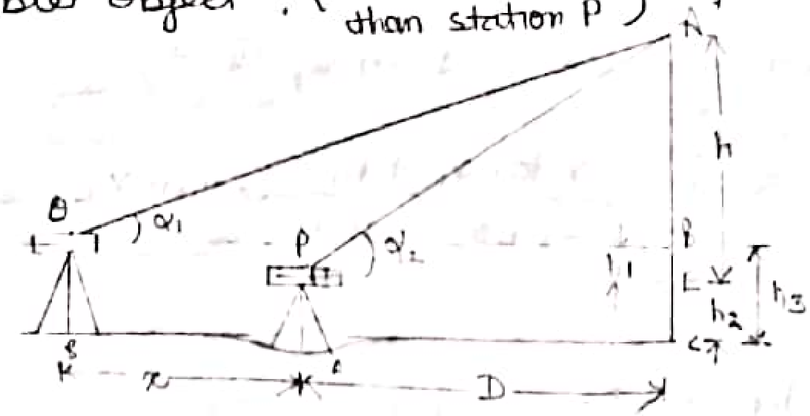
$\tan\alpha = \frac{BC}{D}$.

$\Rightarrow BC = D\tan\alpha$.

Now, $H = BC + h$.

$\underline{H = D\tan\alpha + h}$.

2- In-accessible object: (when station O is higher than station P)



Let α_1 = angle of elevation observed at O.

α_2 = " " " " at P.

x = dis. between instrument st. O & P.

D = dis. of Object from A.

h_1 = level diff.

h_2 = staff reading at BM. when instrument is at A.

h_3 = staff reading at BM. when instrument is at B.

h = ht. of object above instrument axis P.

Now, In Δ PAE,

$$h = D \tan \alpha_2 . \quad \text{— (1)}$$

& In Δ OAB,

$$h - h_1 = (D + x) \tan \alpha_1 . \quad \text{— (2)}$$

Putting value of h in eq. (2) →

$$D \tan \alpha_2 - h_1 = (D + x) \tan \alpha_1 ,$$

$$D \tan \alpha_2 - D \tan \alpha_1 = x \tan \alpha_1 + h_1 .$$

$$D = \frac{x \tan \alpha_1 + h_1}{\tan \alpha_2 - \tan \alpha_1}$$

Putting value of D in eq. (1) →

$$h = \frac{x \tan \alpha_1 + h_1}{\tan \alpha_2 - \tan \alpha_1} \cdot \tan \alpha_2 .$$

Height of object above BM. →

$$H = h + h_2 .$$

* Prolonging a straight line —

(i) Fore sight method.

(ii) Back sight method.

Q:- dist. from instrument centre to chimney,

$d = 2000m$,

angle of elevation, $\alpha = 10°30'$,

height of instrument $= 0.955m$,

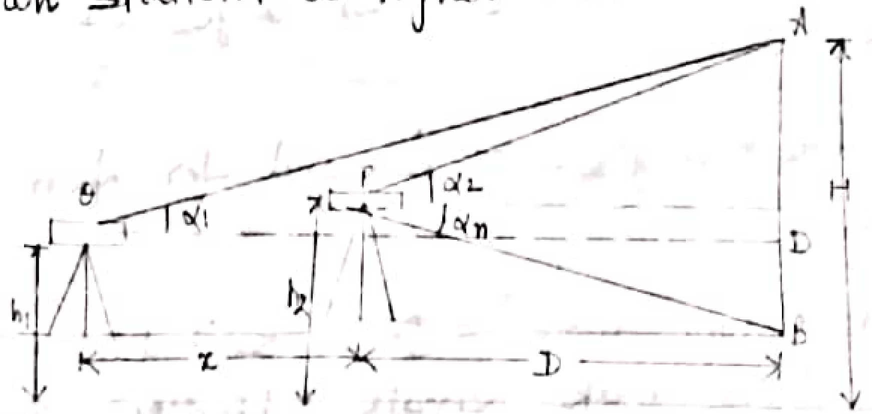
height of chimney $= ?$

— $\tan(10°30') = \dfrac{H - 0.955}{2000}$.

$0.185 \times 2000 = H - 0.955$.

$H = 370 + 0.955 = 370.955m$.

(ii) When station P is higher than station O —



$H = (D+x)\tan\alpha_1 + h_1$ — ①.

$H = D\tan\alpha_2 + h_2$ — ②.

eq ① = eq ② →

$(D+x)\tan\alpha_1 + h_1 = D\tan\alpha_2 + h_2$

$$D(\tan\alpha_1 - \tan\alpha_2) = h_2 - h_1 - \tan\alpha_1.$$

$$D = \frac{(h_2 - h_1) - \tan\alpha_1}{\tan\alpha_1 - \tan\alpha_2}.$$

from eq. ① → $H = \left(\frac{(h_2 - h_1) - \tan\alpha_1}{\tan\alpha_1 - \tan\alpha_2}\right) \cdot \tan\alpha_1 + h_2.$

if α = depression angle.

$\therefore$ $AB = D\tan\alpha_2 + D\tan\alpha_n.$

★ Methods of traversing —

(a) By measurement of angles between two successive lines.

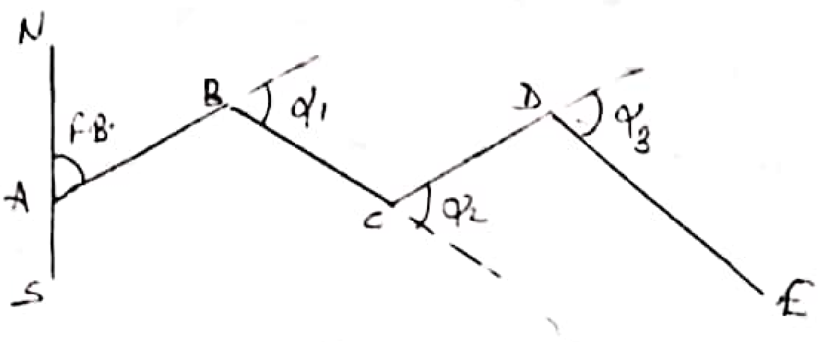
(b) By the direct observation of bearings of the survey lines.

(a) (i)★ by included angles — In a closed traverse, (ii) either interior or exterior angles are measured.

(ii) by direct angles — It is used for open traverses.

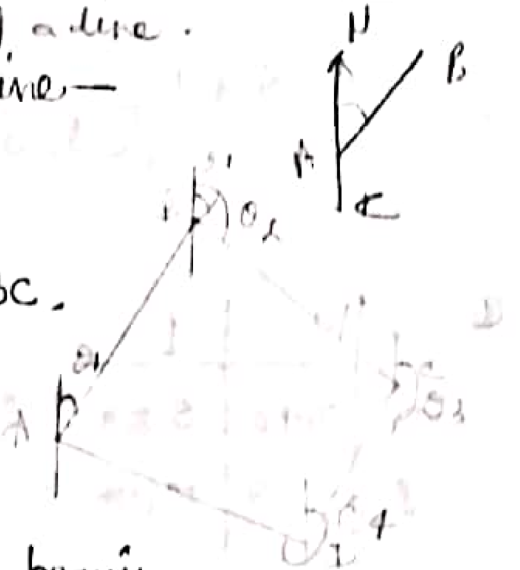
(iii)★ by deflection angles — It is suitable when survey lines make small deflection angle with each other.

E.g., roads, railways, pipe lines etc.



Measurement of bearing of a line.

(iv) Magnetic bearing of a line—



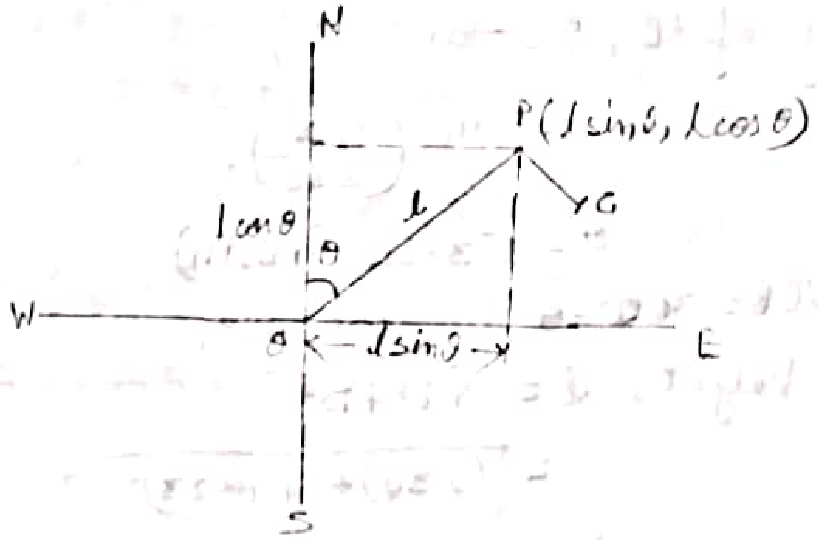
θ_1 = bearing of line AB.

θ_2 = fore bearing of line BC.

★ Co-ordinates—

- Latitude— If the length & bearing of a line are known, its projection on y-axis is called latitude.

- Departure— The projection of a line on x-axis is known as departure.

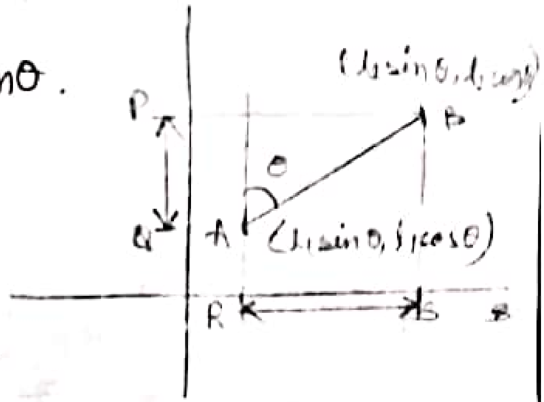


★ latitude, $L = l_2\cos\theta - l_1\cos\theta$.

Departure, $D = l_2\sin\theta - l_1\sin\theta$.

$$\tan\theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{D}{L}.$$

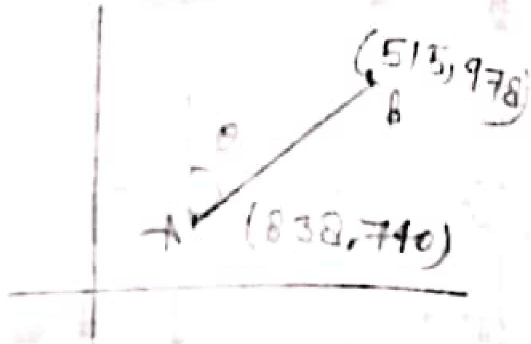
$$= \frac{l_2\sin\theta - l_1\sin\theta}{l_2\cos\theta - l_1\cos\theta}.$$



$$\theta = \tan^{-1}\left(\frac{l_2 \sin\theta - l_1 \sin\theta}{l_2 \cos\theta - l_1 \cos\theta}\right).$$

①

	N	E
A	740	838
B	978	515



Find bearing of AB (θ) & slant length of AB?

$L = 978 - 740 = 238.$ (IInd quadrant).

$D = 515 - 838 = -323.$

Bearing of AB, $\theta = \tan^{-1}\left(\frac{D}{L}\right)$

$= \tan^{-1}\left(\frac{323}{238}\right).$

$\theta = 53.62^\circ$ (north).

$WCB = 360^\circ - \theta = 306.38^\circ.$

slant height, $l = \sqrt{L^2 + D^2}.$

$= \sqrt{(238)^2 + (323)^2}.$

$l = 401.21\,m.$

①

line	length	Bearing		L = l cos θ		D = l sin θ	
		WCB	RB	N(+)	S(-)	E(+)	W(-)
AB	75.50	30°24'	N30°24'E	75.50 cos 30°24'	—	75.50 sin 30°24'	
BC	180.50	110°36'	S69°24'E		180.50 cos 69°24'	180.50 sin 69°24'	
CD	60.25	210°30'	S30°30'W		60.25 cos 30°30'		60.25 sin 30°30'
DA	l	θ	-	l cos θ		l sin θ.	

$\Sigma L = 75.50 \cos 30°24' - 180 \cos 69°24' - 60.25 \cos 30°30'$
$+ l \cos\theta.$

$\Rightarrow 65.12° - 63.51° - 51.91° + l\cos\theta = 0.$

$-50.3° + l\cos\theta = 0.$

$l\cos\theta = 50.3°$ —— ①

$\Sigma D = 75.50 \sin 30°24' + 180.50 \sin 69°24' - 60.25 \sin 30°30'$
$+ l\sin\theta.$

$\Rightarrow 38.21° + 168.96° - 30.58° + l\sin\theta = 0.$

$$176.59 + l\sin\theta = 0.$$

$$l\sin\theta = -176.59 \quad \text{—⑤}$$

$$\therefore \tan\theta = \frac{D}{L} = \frac{-176.59}{50.3}.$$

$$\tan\theta = 3.51.$$

$$\theta = 74.090°.$$

from ④ → $l\cos\theta = 50.3°.$

$$l = \frac{50.3°}{\cos 74.09°}.$$

$$l = 183.49\ m.$$

②

line	length	Bearing		L = l cos θ		D = l sin θ	
		WCB	RB	N (+)	S (−)	E (+)	W (−)
AB	100	θ	N θ E	1000 cos θ		1000 sin θ	
BC	80	140°30'	S39°30'E		80 cos 39°30'	80 sin 39°30'	
CD	60	220°30'	S40°30'W		60 cos 40°30'		60 sin 40°30'
DA	l	310°15'	N49°45' W	l cos 49°45'			l sin 44°45'

$$\Sigma L = 1000\cos\theta - 80\cos 39°30' - 60\cos 40°30' + l\cos 49°45'.$$

$$100\cos\theta - 61.730 - 45.620 + 0.65l = 0.$$

$$100\cos\theta + 0.65l = 107.35°. \quad \text{—⑥}$$

$$\Sigma D = 100\sin\theta + 80\sin 39°30' - 60\sin 70°30' - l\sin 49°45'$$

$$\Rightarrow 100\sin\theta + 50.89° - 33.97° - 0.761 l = 0.$$

$$100\sin\theta - 0.76 l = -11.92. \quad -(2)$$

eq (1)^2 + eq. (2)^2 →

$$100^2 = (107.35 - 0.65)^2 + (0.76 l + 11.92)^2.$$

$$= 11524 - 138.69 l + 0.42 l^2 + 0.58 l^2$$

$$- 18.12 l + 142.1.$$

$$1666.1 - 156.8 l + l^2 = 0.$$

$$l = \frac{156.81 \pm \sqrt{(156.8)^2 - (4 \times 1666.1 \times 1)}}{2}.$$

$$= \frac{156.81 \pm 133.88}{2}.$$

$$l = 145.385\,m \text{ or } 11.50\,m.$$

from eq (1) → $100\cos\theta = 107.35 - (0.646 \times 145.38).$

$$100\cos\theta = 13.44,$$

$$\cos\theta = 0.13.$$

from eq (2) → $100\sin\theta = 0.763 l - 11.50.$

$$= (0.763 \times 145.38) - 11.50.$$

$$100\sin\theta = 99.42.$$

$$\sin\theta = 0.99.$$

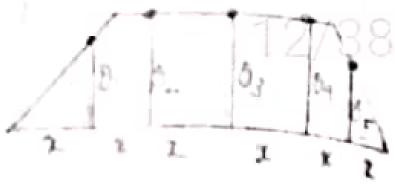
$$\tan\theta = \frac{D}{L}. = \frac{0.99}{0.13} = 7.14.$$

$$\theta = 82.18°.$$

$$l = 11.5\,m.$$

★ Computation of area

(i) Trapezoidal rule:



$$x\left[\frac{O_1+O_5}{2}+O_2+O_3+O_4\right].$$

$$= x\left[\frac{O_1+O_n}{2}+O_2+O_3+O_{n-1}\right].$$

(ii) Simpson's rule:

$$=\frac{x}{3}\left(O_1+O_5+4(O_2+O_4)+2(O_3+O_5)\right).$$

$$=\frac{x}{3}\left\{(O_1+O_n)+4(O_2+O_4+\ldots)+2(O_3+O_5+\ldots)\right\}.$$

★ Bowditch's Method:

Correction for latitudes, L_c = total error in latitude $\times \dfrac{\text{length of that side}}{\text{Parameter of traverse}}$

$$L_c = \frac{\Sigma L \times L_{AB}}{\text{Parameter of traverse} (\Sigma L)}.$$

Correction for departure, D_c = total error in departure $\times \dfrac{\text{length of that side}}{\text{Parameter of traverse}}$

$$D_c = \frac{\Sigma D \times L_{AB}}{\Sigma L}.$$