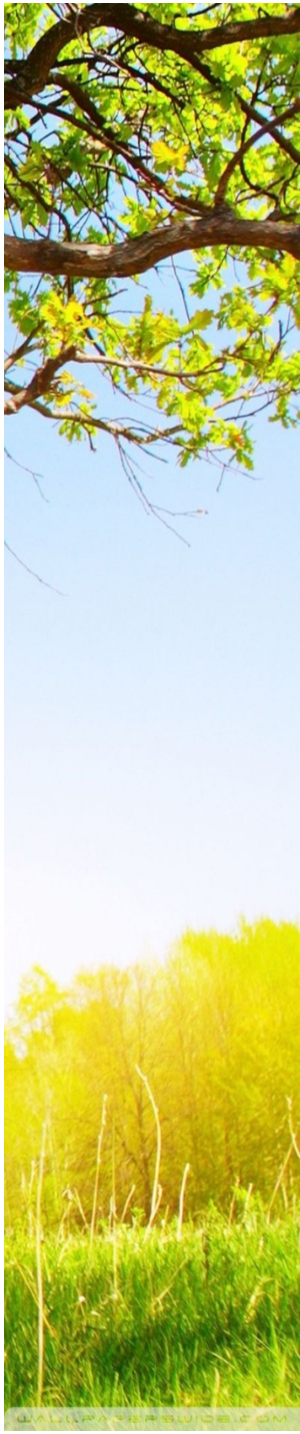
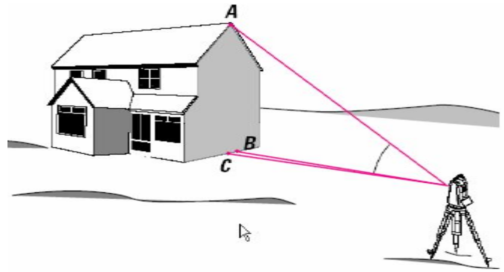
Theodolite

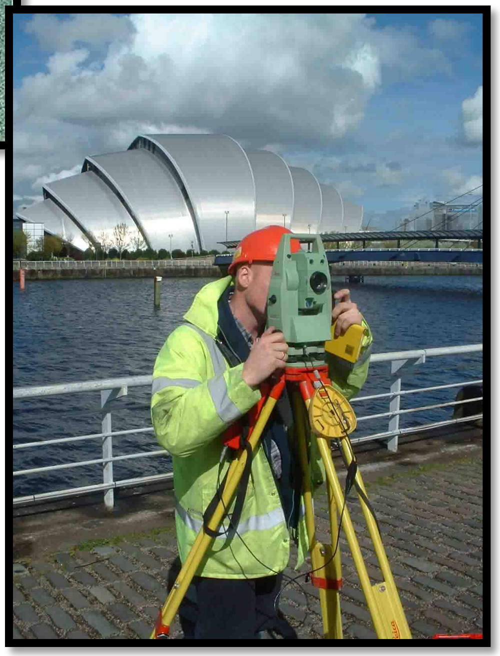
Introduction

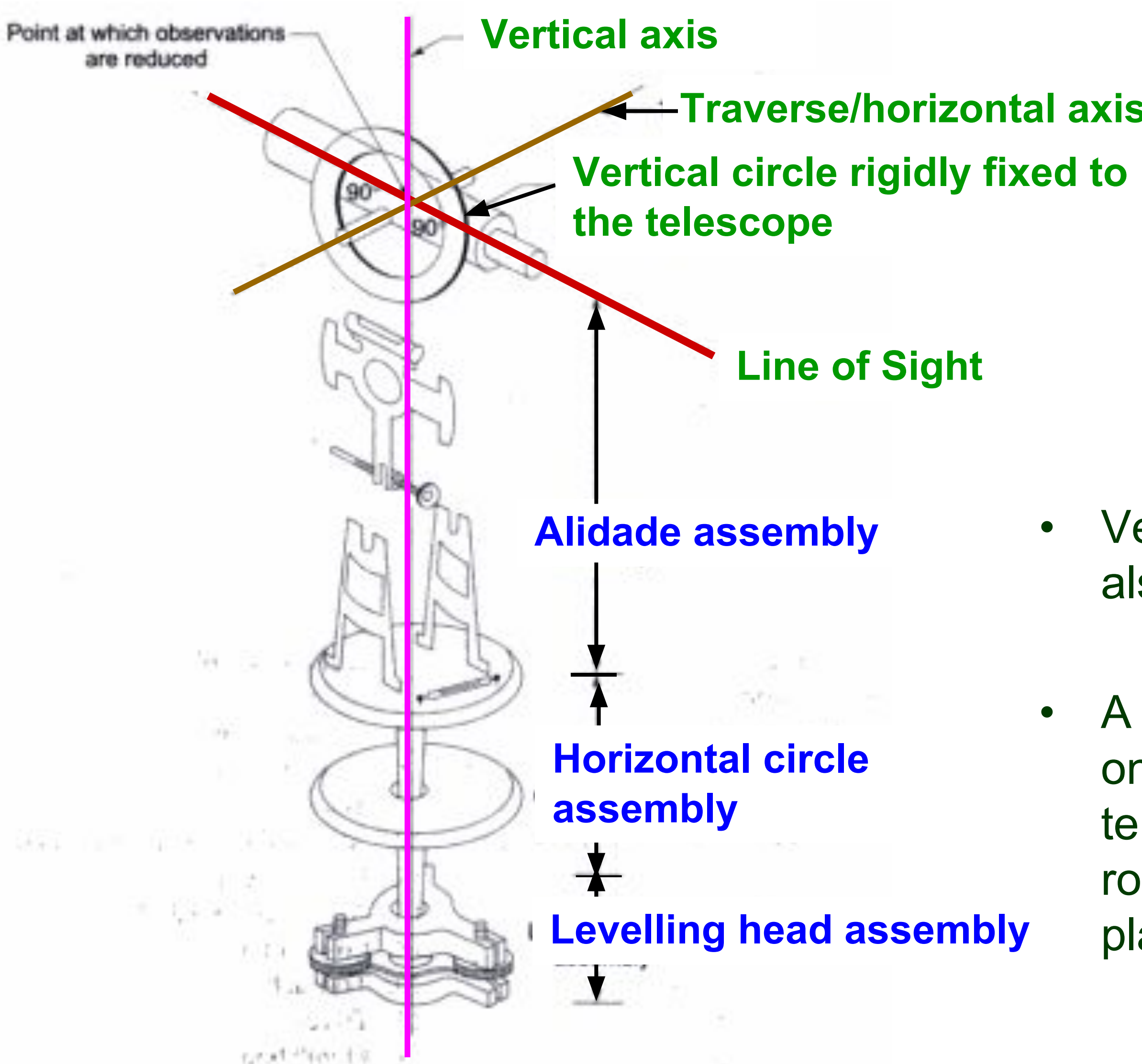




- Theodolite is used to measure the horizontal and vertical angles.
- Theodolite is more precise than magnetic compass.
- Magnetic compass measures the angle up to as accuracy of 30’. However a vernier theodolite measures the angles up to and accuracy of 10’’, 20”.
- There are variety of theodolite vernier, optic, electronic etc.

Type of theodolite





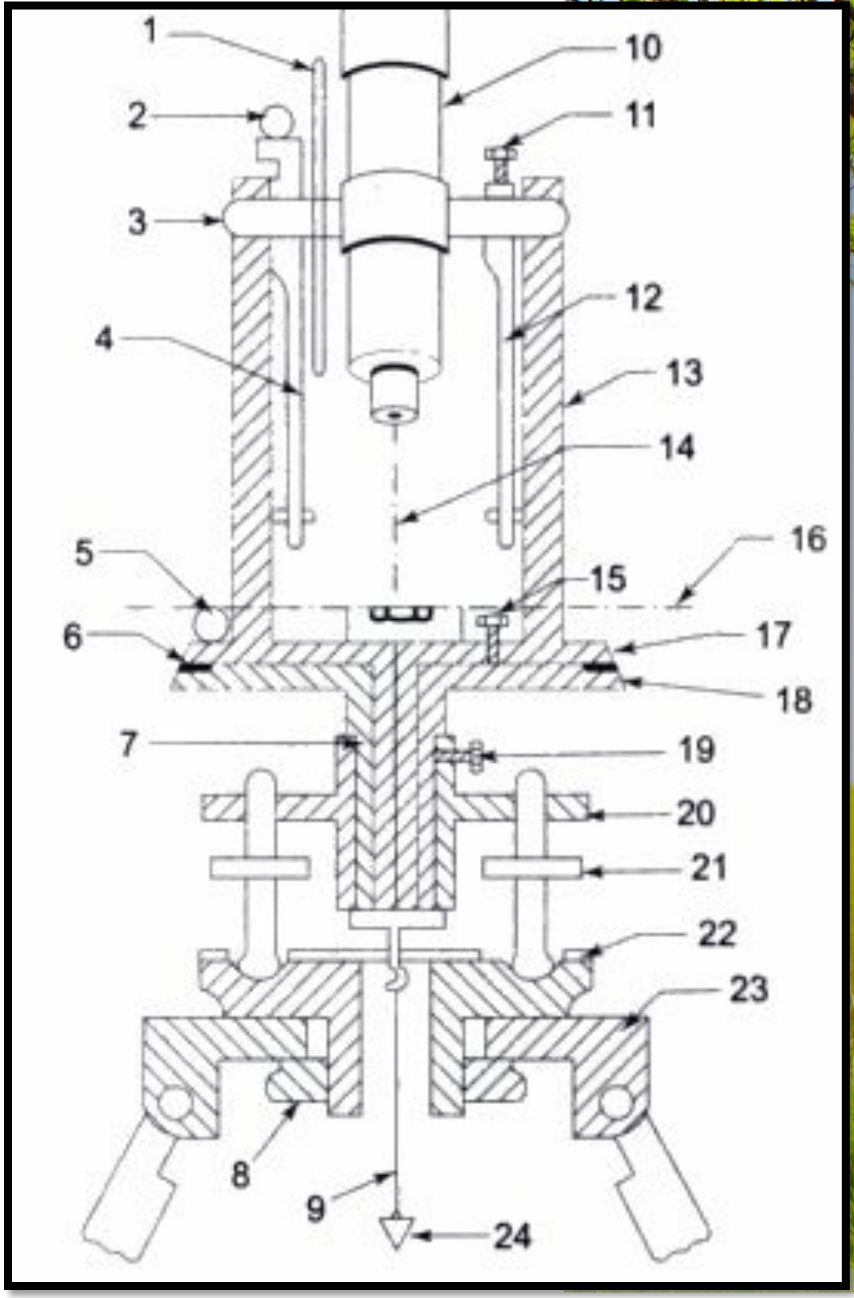
Three assemblies of Theodolite

- Vernier theodolite is also known and transit.
- A transit theodolite is one in which the telescope can be rotated in a vertical plane.

MAIN PARTS

- **Plate level (5):**
  - Spirit level with the bubble and graduation on glass cover.
  - A single level or two levels fixed in perpendicular direction may be provided.
  - The spirit level can be adjusted with the foot screw **(21)** of the levelling head **(7)**.

- **Telescope (10):** The essential parts of the telescopes are eye-piece, diaphragm with cross hairs, object lens and arrangements to focus the telescope.

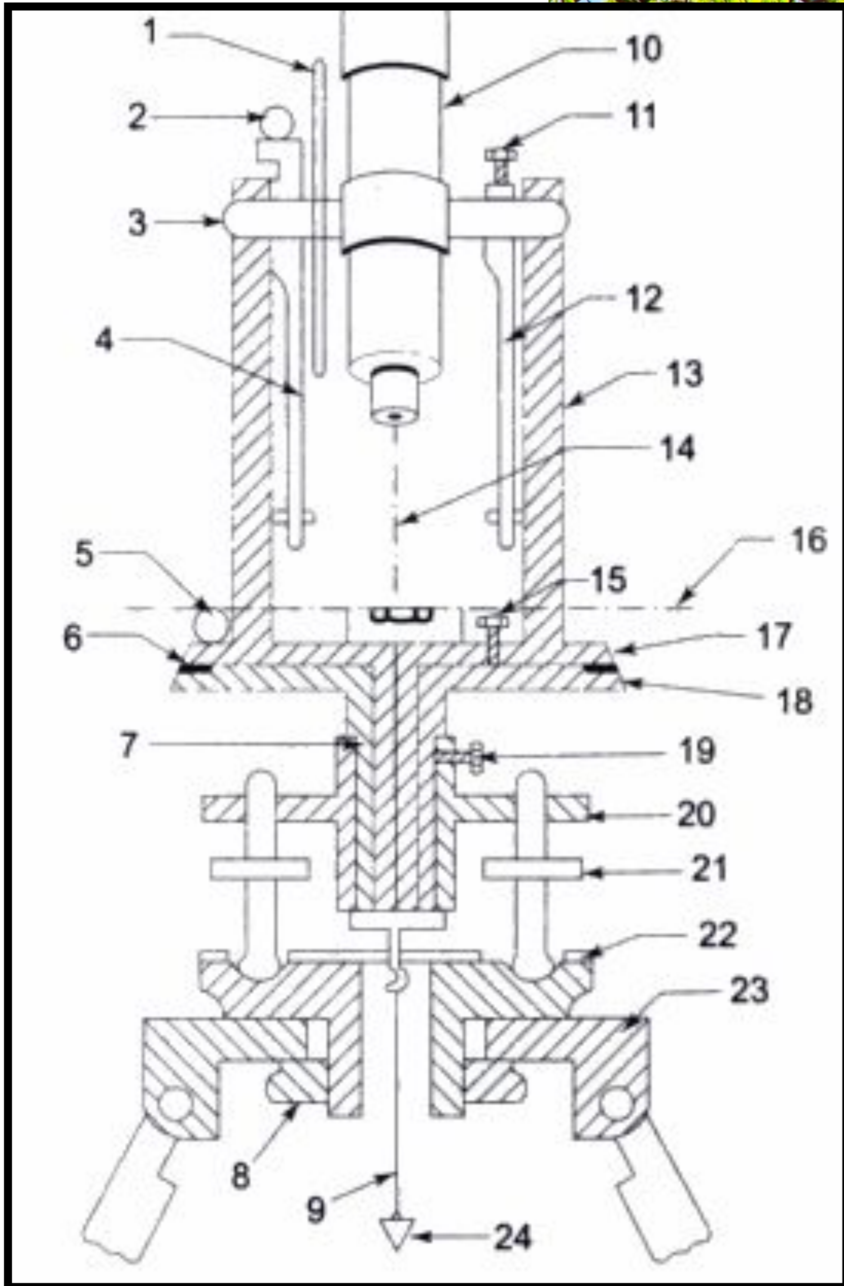


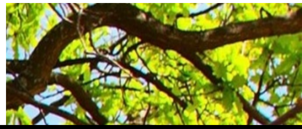
MAIN PARTS

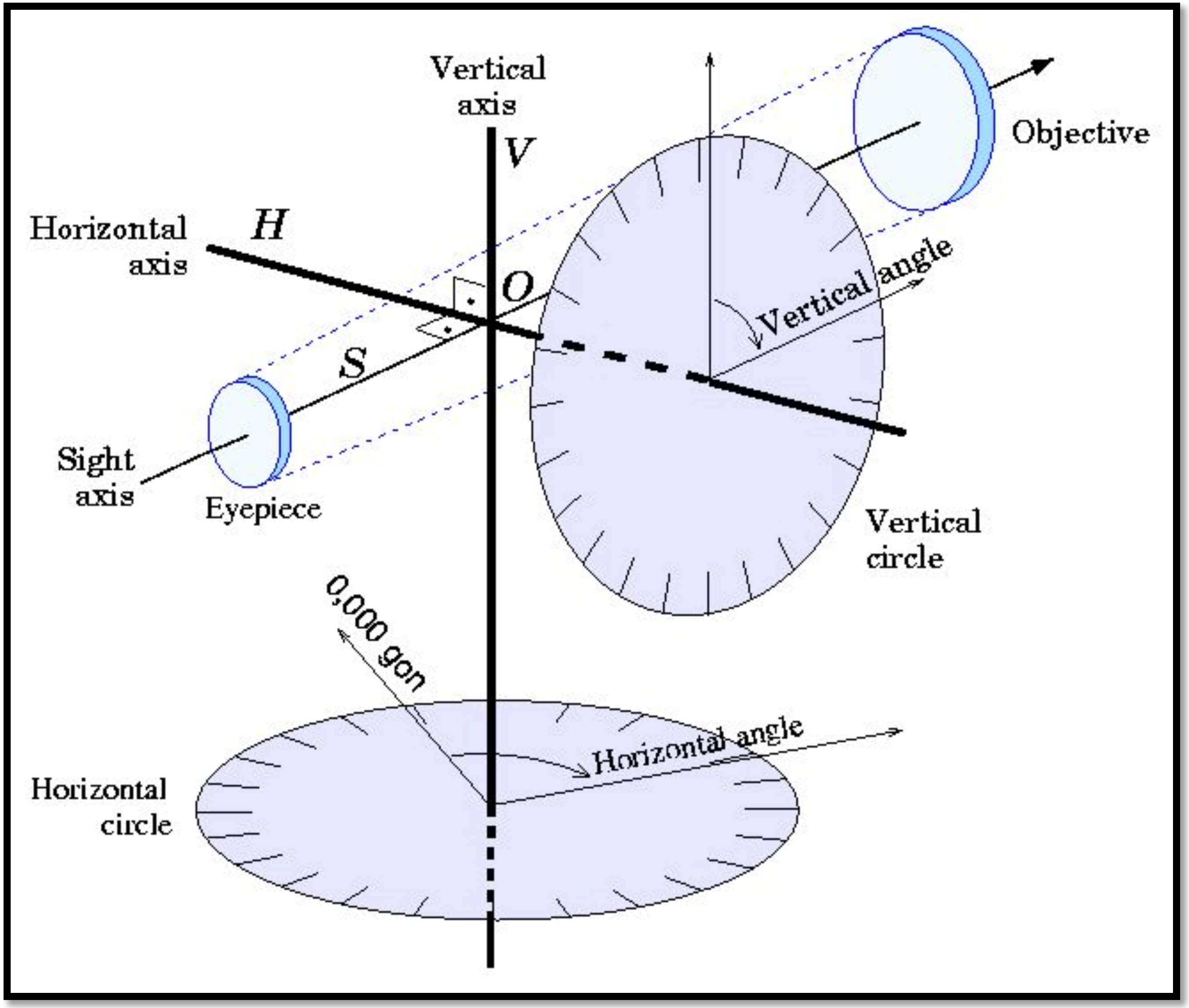
- **Vertical circle (1):** circular plate supported on horizontal axis of the instrument between the A-frames. Vertical circle has graduation 0-90 in four quadrants. Vertical circle moves with the telescope when it is rotated in the vertical plane.

- **Vertical circle clamp and tangent screw (11):** Clamping the vertical circle restrict the movement of telescope in vertical plane.

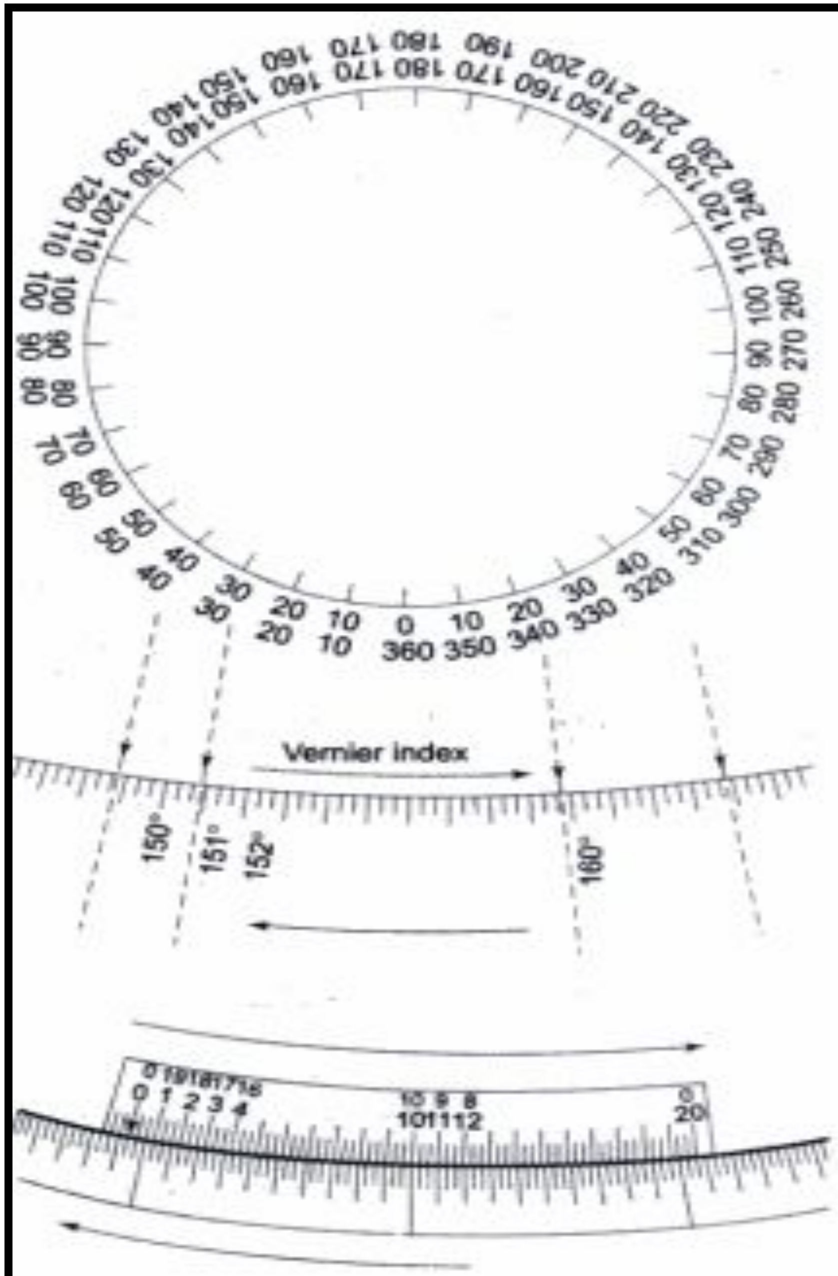
- **Altitude level (2):** A highly sensitive bubble is used for levelling particularly when taking the vertical angle observations.






Vertical axis
V
Objective
Horizontal axis
H
O
Vertical angle
S
Sight axis
Eyepiece
Vertical circle
0,000 gon
Horizontal angle
Horizontal circle

Reading a theodolite



Vernier scale graduation

Adjustment of the theodolite

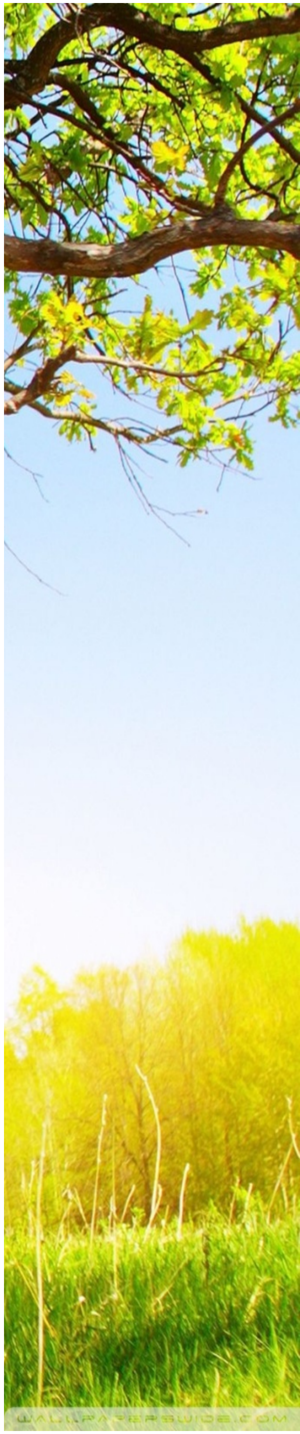
- Temporary Adjustment

1. The levelling screws are at the centre of their run.
2. The shifting head of the theodolite is at its centre so that equal movement is possible in all the directions.
3. The wing nuts on the tripod legs are tight enough so that when raised, the tripod legs do not fall under their own weight.

- Setting up the theodolite

Centring This involves setting the theodolite exactly over the station mark or on the station peg. It is done by the following steps:

1. The plumb bob is suspended from a small hook attached to the vertical axis of the theodolite.
2. The instrument is placed over the station mark with the telescope at a convenient height and with the tripod legs set well apart.
3. Two legs of the tripod are set firmly into the ground and the third leg is moved radially to bring the plumb bob exactly over the station mark. Then the third leg is also pushed into the ground.
4. If the instrument has a shifting head, the instrument is roughly centred over the station mark and then by means of the shifting head, the plumb bob is brought exactly over the station mark.



Approximate levelling This implies levelling the instrument with the legs of the tripod, i.e. by bringing the small circular bubble provided on the tribrach in the centre. To achieve this, two of the tripod legs are pushed firmly into the ground and the third leg of the tripod is moved to the right or to the left, i.e. in the circumferential direction until the bubble is centred. This leg is then pushed into the ground.

4.9.2 Levelling up

This means making the vertical axis truly vertical. This is done with the help of the foot screws. The procedure is as follows:

1. The longer plate level is brought parallel to any two foot screws.

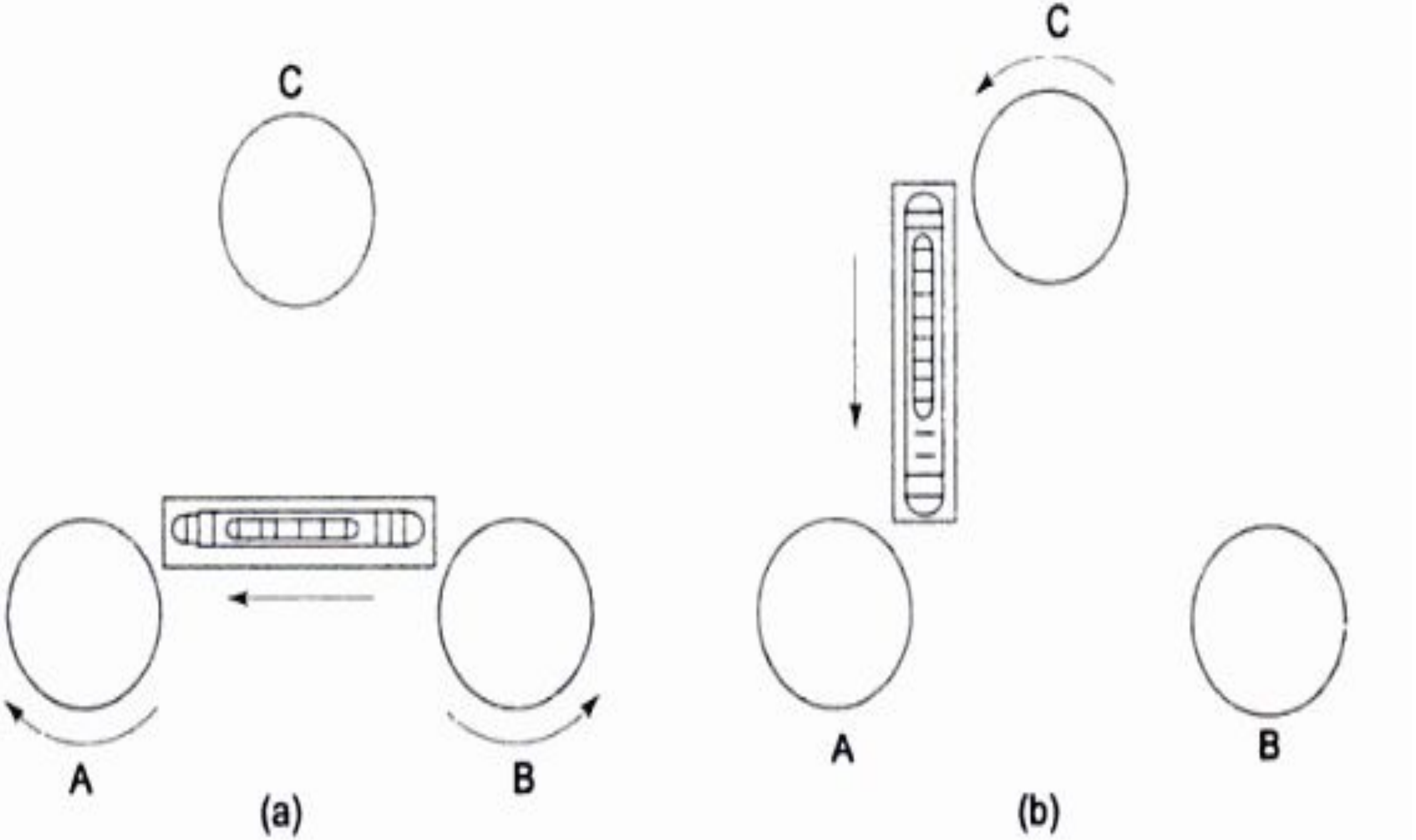
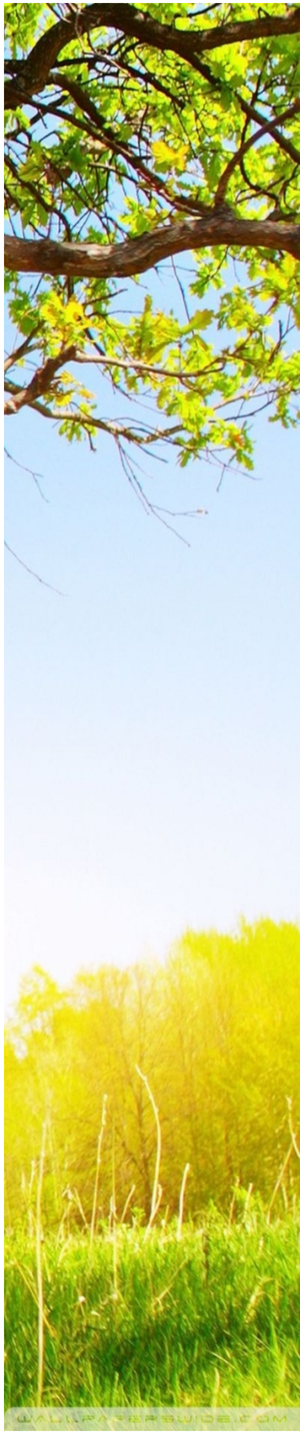
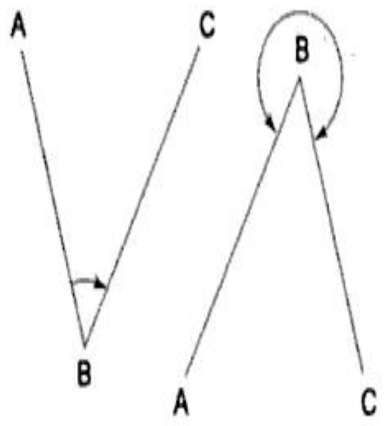


Fig. 4.4 Levelling with three foot screws

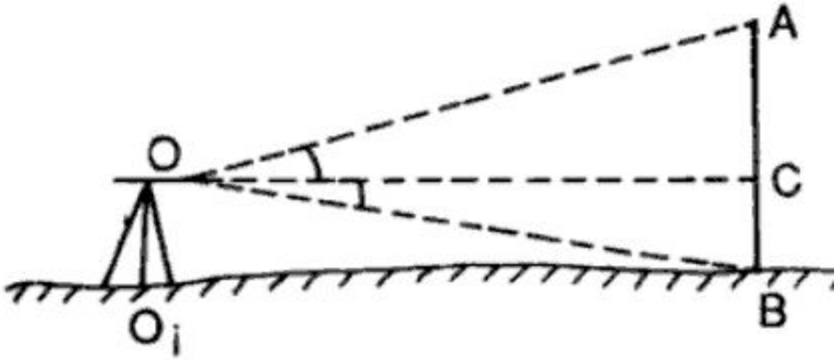


Measurement of horizontal angle



- **Measurement of Angle ABC**
  - The instrument is set over B.
  - The lower clamp is kept fixed and upper clamp is loosened.
  - Turn the telescope clockwise set vernier A to 0° and vernier B to approximately 180°.
  - Upper clamp is tightened and using the upper tangent screw the vernier A and B are exactly set to 0° and 180°.
  - Upper clamp is tightly fixed, lower one is loosened and telescope is directed towards A and bisect the ranging rod at A.
  - Tightened the lower clamp and turn the lower tangent screw to perfectly bisect ranging rod at A.
  - Loose the upper clamp and turn the telescope clockwise to bisect the ranging rod at C tightened the upper clamp and do the fine adjustment with upper tangent screw.
  - The reading on vernier A and B are noted. Vernier A gives the angle directly and vernier B gives the reading by subtracting the initial reading (180°) from final reading

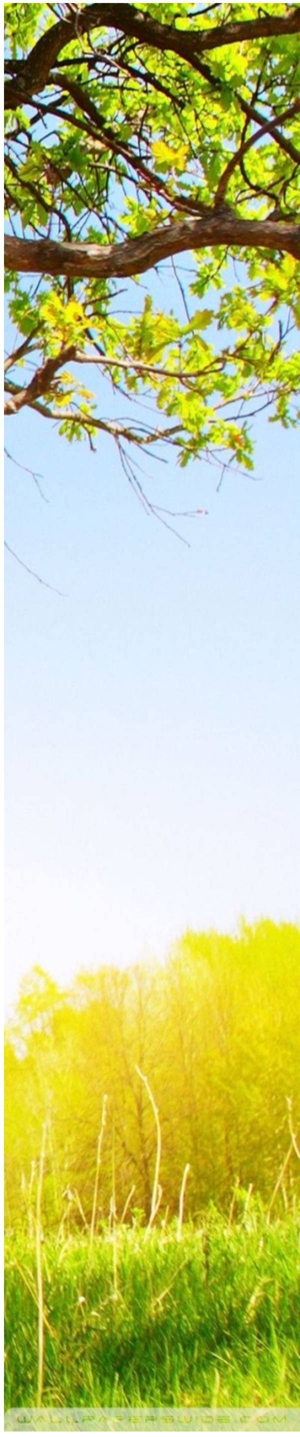
Vertical angle measurement-1

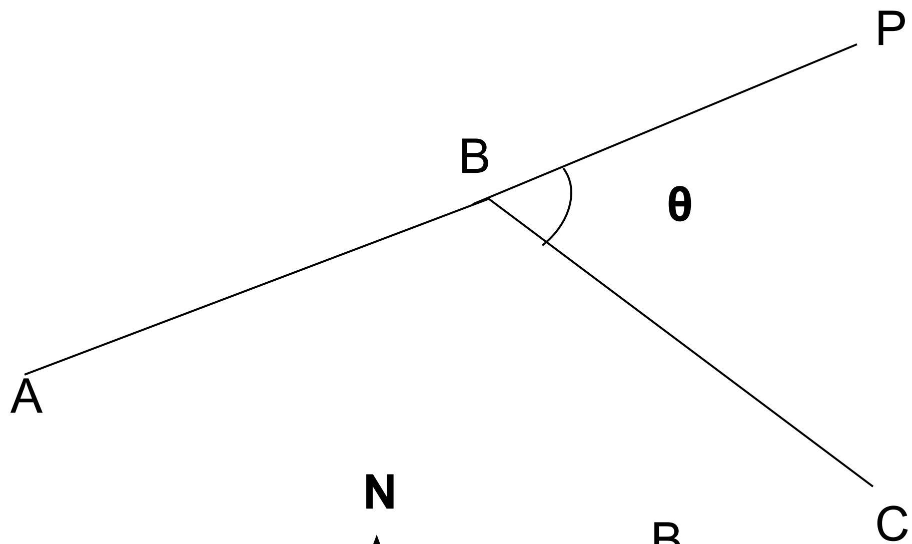


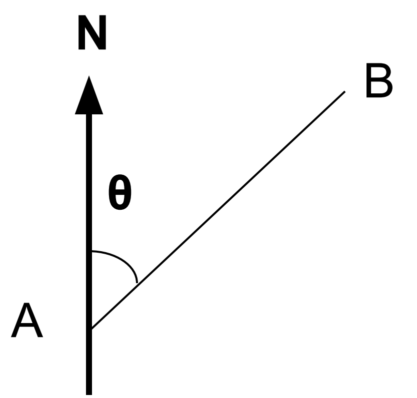
1. The theodolite is set up at O. It is centred and levelled properly. The zeros of the verniers (generally C and D) are set at the 0°–0° mark of the vertical circle (which is fixed to the telescope). The telescope is then clamped.
2. The plate bubble is brought to the centre with the help of foot screws (in the usual manner). Then the altitude bubble is brought to the centre by means of a clip screw. At this position the line of collimation is exactly horizontal.
3. To measure the angle of elevation, the telescope is raised slowly to bisect the point A accurately. The readings on both the verniers are noted, and the angle of elevation recorded.

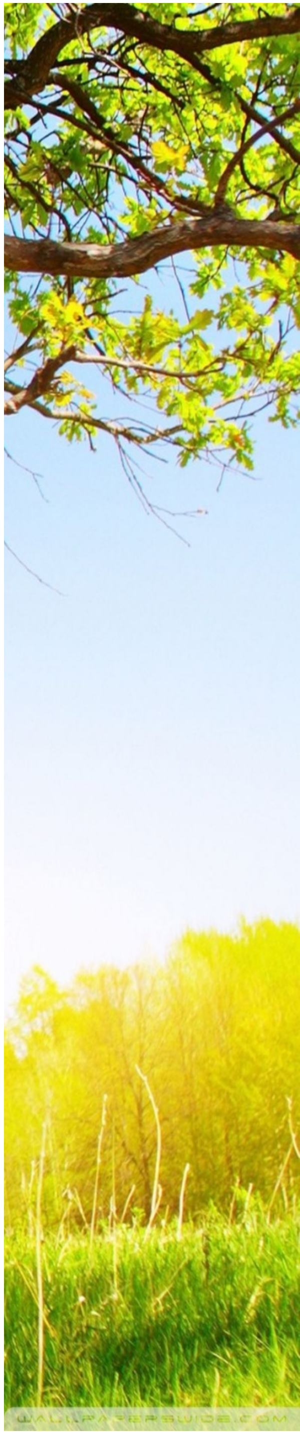
Vertical angle measurement-2

4. The face of the instrument is changed and the point A is again bisected. The readings on the verniers are noted. The mean of the angles of the observed is assumed to be the correct angle of elevation.
5. To measure the angle of depression, the telescope is lowered slowly and the point B is bisected. The readings on the verniers are noted for the two observations (face left and face right). The mean angle of the observation is taken to be the correct angle of depression. The result is tabulated as

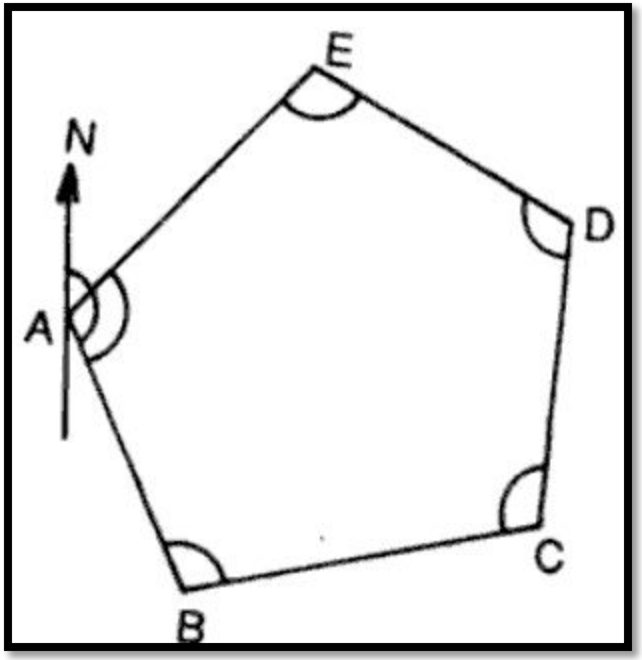



P
B
θ
A
C


N
B
θ
A



- Method of traversing
  - Included angle method
  - Deflection angle method
  - Fast angle (or magnetic bearing method)



Computation of latitude and departure

- Latitude of a line is the distances measured parallel to the north south of the North-South direction
- Departure of the line is the distance measured parallel to the east-west direction

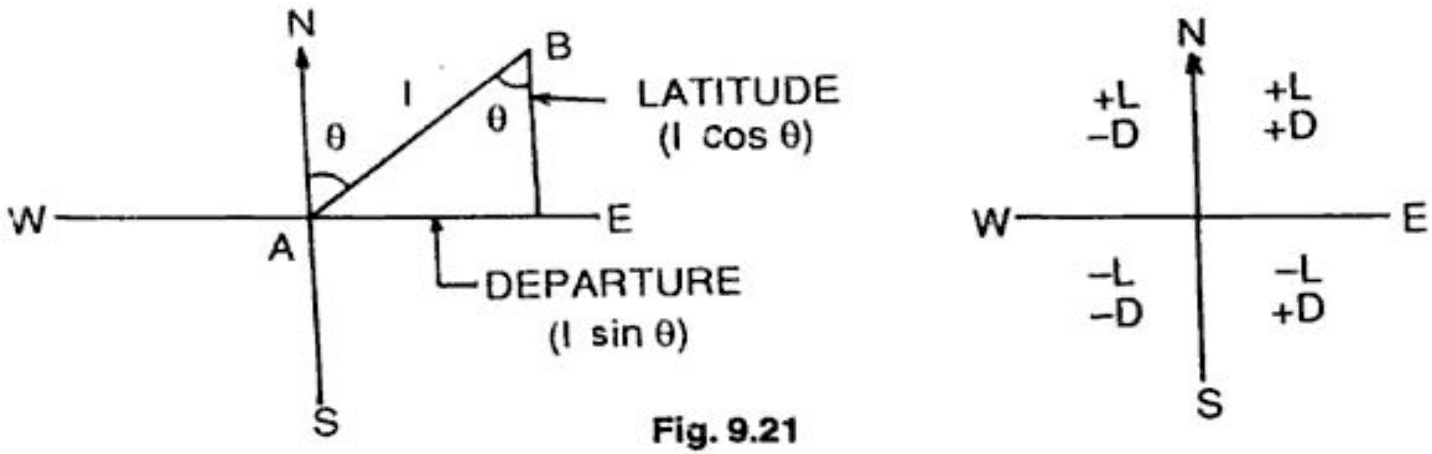


Fig. 9.21

The latitude and departure of lines are also expressed in the following ways:

Northing = latitude towards north = + L
Southing = latitude towards south = − L
Easting = departure towards east = + D
Westing = departure towards west = − D

Computing latitude and departure

Table 9.6 *Table for computing latitude and departure*

Line	Length (L)	Reduced bearing (θ)	Latitude ($L \cos \theta$)	Departure ($L \sin \theta$)
AB	L	N θ E	+ L cos θ	+ L sin θ
BC	L	S θ E	− L cos θ	+ L sin θ
CD	L	S θ W	− L cos θ	− L sin θ
DA	L	N θ W	+ L cos θ	− L sin θ

Check for closed traverse

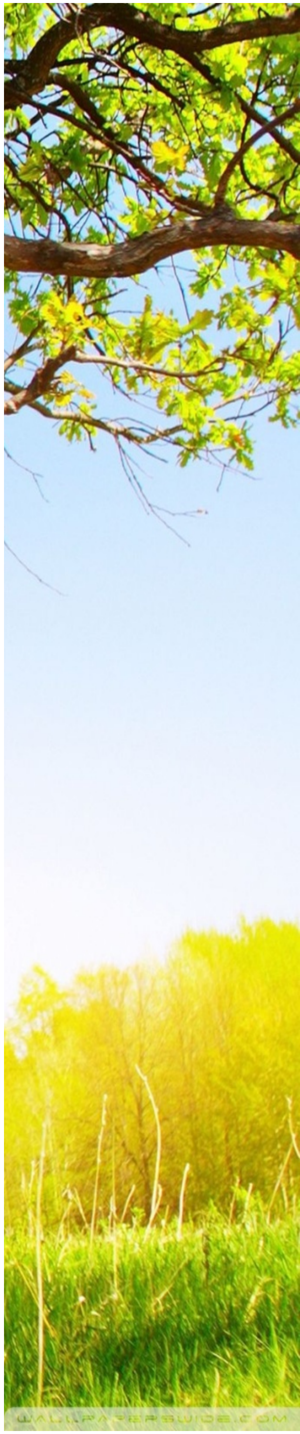
1. The algebraic sum of latitudes must be equal to zero.
2. The algebraic sum of departures must also be equal to zero.

Table 9.7

Line	Length	Reduced bearing	Consecutive Coordinates			
	(L)	(θ)	Northing (+)	Southing (−)	Easting (+)	Westing (−)
AB	L	N θ E	L cos θ		L sin θ	
BC	L	S θ E		L cos θ	L sin θ	
CD	L	S θ W		L cos θ		L sin θ
DA	L	N θ W	L cos θ			L sin θ

Check for closed traverse

1. Sum of northings = sum of southings
2. Sum of eastings = sum of westings



3. Third rule

(a) Correction to northing of any side

$$= \frac{\text{northing of that side}}{\text{sum of northings}} \times \frac{1}{2} \text{(total error in latitude)}$$

(b) Correction to southing of any side

$$= \frac{\text{southing of that side}}{\text{sum of southings}} \times \frac{1}{2} \text{(total error in latitude)}$$

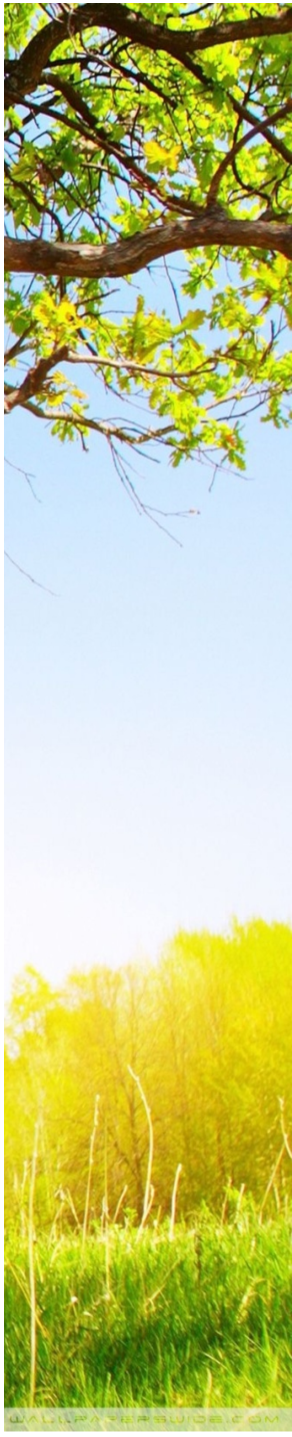
(c) Correction to easting of any side

$$= \frac{\text{easting of that side}}{\text{sum of eastings}} \times \frac{1}{2} \text{(total error in departure)}$$

(d) Correction to westing of any side

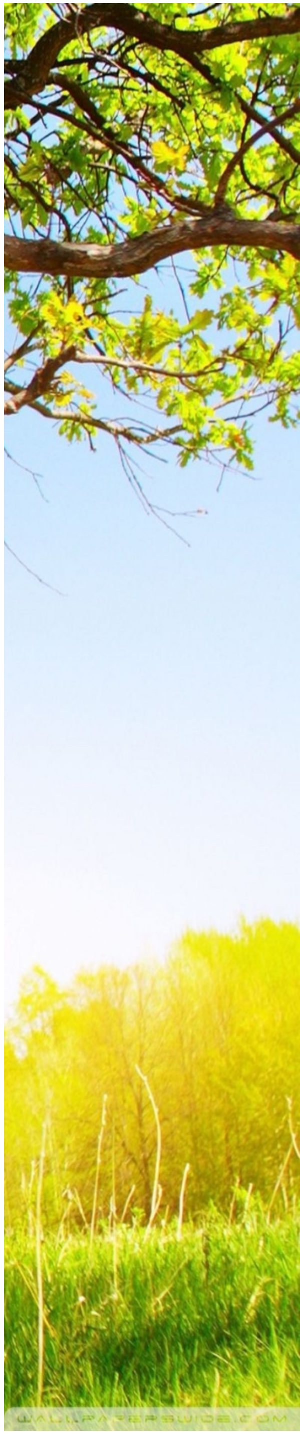
$$= \frac{\text{westing of that side}}{\text{sum of westings}} \times \frac{1}{2} \text{(total error in departure)}$$

Note: If the error is positive, correction will be negative, and vice versa.



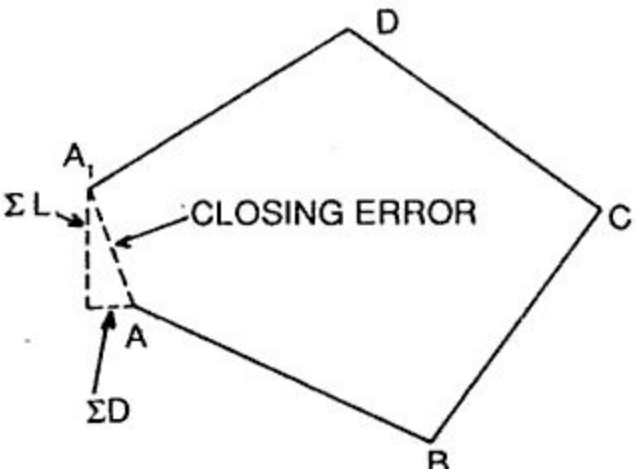
Sources of errors in theodolite

- **Instrumental errors**
  - Non adjustment of plate bubble
  - Line of collimation not being perpendicular to horizontal axis
  - Horizontal axis not being perpendicular to vertical axis
  - Line of collimation not being parallel to axis of telescope
  - Eccentricity of inner and outer axes
  - Graduation not being uniform
  - Verniers being eccentric



- Personal errors
- Natural errors
  - High temperature causes error due to irregular refraction.
  - High winds cause vibration in the instrument, and this may lead to wrong readings on vernier

- **Closing error**



$$\text{Closing error, } AA_1 = \sqrt{(\Sigma L)^2 + (\Sigma D)^2}$$

where L = latitude

and D = departure

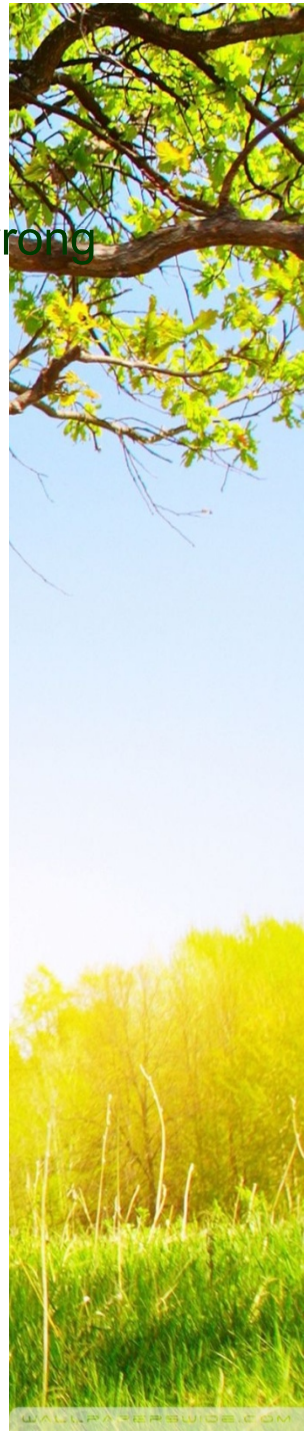
$$\text{Relative closing error} = \frac{\text{closing error}}{\text{perimeter of traverse}}$$

$$\text{Permissible angular error} = \text{least count} \times \sqrt{N}$$

where N = number of sides

$$\tan\theta = \frac{\Sigma D}{\Sigma L}$$

where θ indicates the direction of closing error.



Balancing of traverse

▯ Bowditch’s rule:

- Total error is distributed in proportion to the lengths of the traverse legs.

(a) Correction to latitude of any side

$$= \frac{\text{length of that side}}{\text{perimeter of traverse}} \times \text{total error in latitude}$$

(b) Correction to departure of any side

$$= \frac{\text{length of that side}}{\text{perimeter of traverse}} \times \text{total error in departure}$$

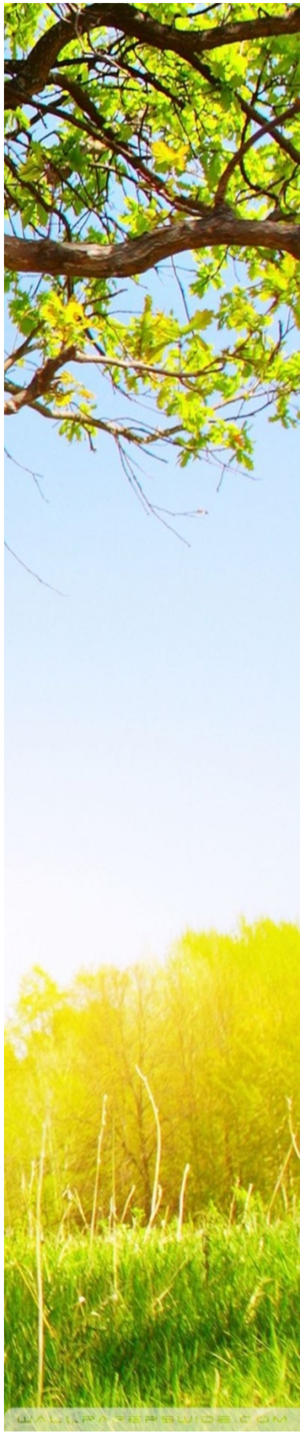
2. Transit rule

(a) Correction to latitude of any side

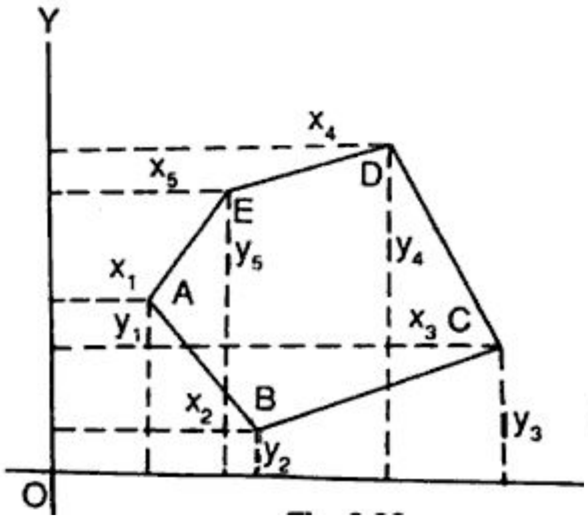
$$= \frac{\text{latitude of that side}}{\text{arithmetical sum of all latitudes}} \times \text{total error in latitude}$$

(b) Correction to departure of any side

$$= \frac{\text{departure of that side}}{\text{arithmetical sum of all departures}} \times \text{total error in departures}$$



Calculation of traverse area



Then, the coordinates are arranged in determinant form as follows:

$$\begin{array}{cccccc} y_1 & y_2 & y_3 & y_4 & y_5 & y_1 \\ x_1 & x_2 & x_3 & x_4 & x_5 & x_1 \end{array}$$

The sum of the products of coordinates joined by solid lines,

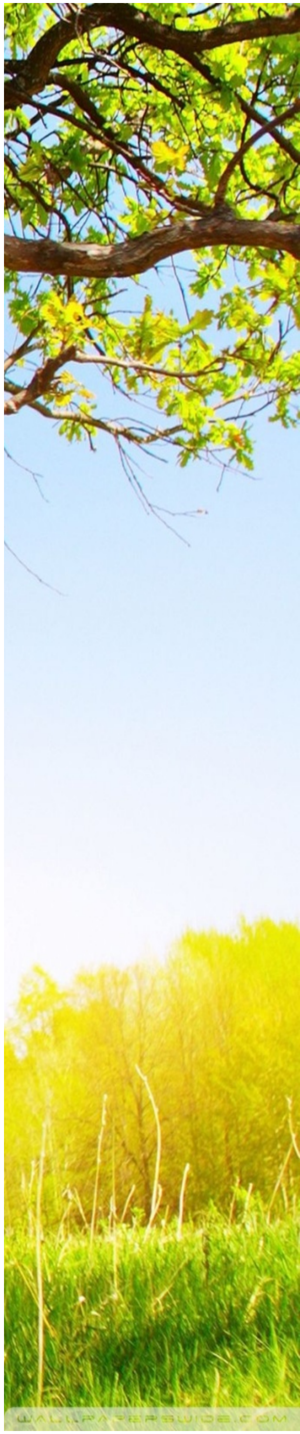
$$\Sigma P = (y_1x_2 + y_2x_3 + y_3x_4 + y_4x_5 + y_5x_1)$$

The sum of the products of coordinates joined by dotted lines,

$$\Sigma Q = (x_1y_2 + x_2y_3 + x_3y_4 + x_4y_5 + x_5y_1)$$

$\therefore$ Double area $= \Sigma P - \Sigma Q$

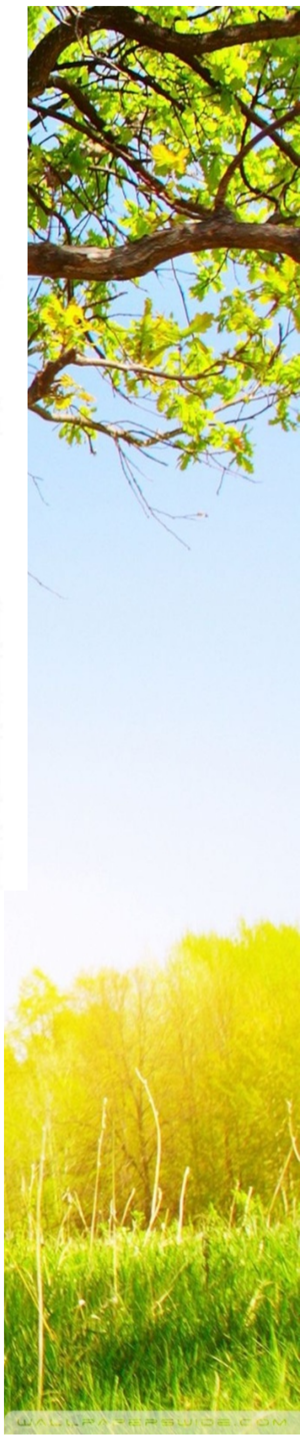
So, Required area $= \frac{1}{2} = (\Sigma P - \Sigma Q)$



AB	+ 225.5	+ 120.5
BC	− 245.0	+ 210.0
CD	− 150.5	− 110.5
DA	+ 170.0	− 220.0

Solution The consecutive coordinates are arranged in independent coordinate form as follows:

Station	Side	Consecutive coordinates		Independent coordinates	
		Latitude (y)	Departure (x)	Latitude (y)	Departure (x)
A				+ 200.00	+ 100.00
B	AB	+ 225.5	+ 120.5	+ 425.50	+ 220.50
C	BC	− 245.0	+ 210.0	+ 180.50	+ 430.50
D	CD	− 150.5	− 110.5	+ 30.00	+ 320.00
A	DA	+ 170.0	− 220.0	+ 200.00	+ 100.00



The independent coordinates of the most westerly station A are assumed to be (+ 200, + 100).

Thus, the independent coordinates of all the stations become positive (i.e. they come to the first quadrant).

The coordinates are now arranged in determinant form as follows:

200.00	425.50	180.50	30.00	200.00
100.00	220.50	430.50	320.00	100.00

Sum of products of coordinates joined by solid lines,

$$\Sigma P = (200.0 \times 220.5 + 425.5 \times 430.5 + 180.5 \times 320.0 + 30.0 \times 100.0)$$
$$= 288{,}037.75$$

Sum of products of coordinates joined by dotted lines,

$$\Sigma Q = (100.0 \times 425.5 + 220.5 \times 180.5 + 430.5 \times 30.0 + 320 \times 200.0)$$
$$= 159{,}265.25$$

$$\text{Required area} = \frac{1}{2}(\Sigma P - \Sigma Q) = \frac{1}{2}(288{,}037.75 - 159{,}265.25)$$
$$= 64{,}386.25 \text{ m}^2$$