Theodolite

The system of surveying in which the angles are measured with the help of a theodolite, is called Theodolite surveying and used for :

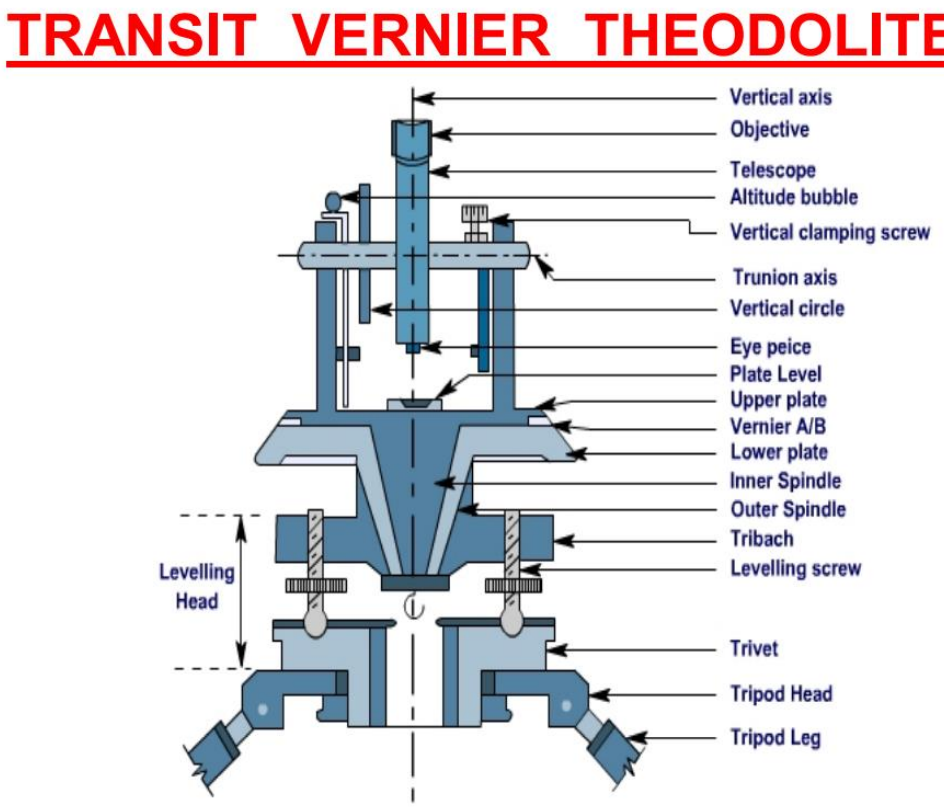
1-Measuring horizontal and vertical angles.

2- Locating points on a line.

3-Prolonging survey lines.

4- Finding difference of level

5- Setting out grades



4. Face Left (F.L)

If the vertical circle of the instrument is on the left side of the observer while taking a reading ,the position is called the face left and the observation taken on the horizontal or vertical circle in this position, is known as the face left observation.

5. Face Right (F.R)

If the vertical circle of the instrument is on the right side of the observer while taking a reading ,the position is called the face right and the observation taken on the horizontal or vertical circle in this position, is known as the face right observation.

Measurement of F.L ,F.R and horizontal angle:

1- **From the point of level installation, measure the F.L of the selected point**
2- **IF** $\boldsymbol{F.R} < 180 \qquad F.R + 180$
3- **IF** $\boldsymbol{F.R} > 180 \qquad F.R - 180$

$F.R_{new} = F.R \pm 180$

$\text{mean} = (F.L_1 + F.R_{new})/2$

Example 1:

Theodolite instrument used to measure the horizontal angle as :

Theodolite station	Measured points	Reading of horizontal circle	
		F.L	**F.R**
B	A	$345^0\ 20'\ 10''$	$165^0\ 20'\ 40''$
	C	$30^0\ 42'\ 20''$	$210^0\ 42'\ 50''$

Find the horizontal angle ?

For BC :

$F.R_{new} = 210^0\ 42'\ 50'' - 180^0 = 30^0\ 42'\ 50''$

$$\text{mean} = \frac{30^0\ 42'\ 50'' + 30^0\ 42'\ 20''}{2} = 30^0\ 42'\ 35''$$

For BA :

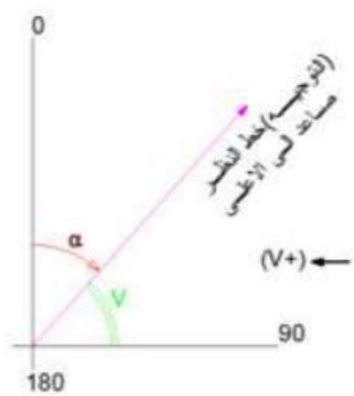
$F.R_{new} = 165^0\ 20'\ \ 40'' + 180^0 = 345^0\ 20'\ \ 40''$

$$\text{mean} = \frac{345^0\ 20'\ \ 10'' + 345^0\ 20'\ \ 40''}{2} = 345^0\ 20'\ \ 25''$$

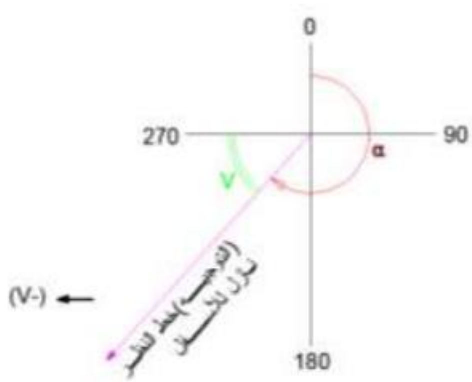
Horizontal angle $= 30^0\ 42'\ \ 35'' - 345^0\ 20'\ \ 25'' = 314^0\ 37'\ \ 50'' + 360^0 = 45^0\ 22'\ \ 10''$

Vertical angle (V)

The vertical angle is defined as an angle between the horizon line and the guidance line. Theodolite is not measured the vertical angle directly but measured the vertical circle angle (α). We can measured the V angle through measuring the α angle accordance to F.L and F.R.



$V = 90 - \alpha$ **for F.L**



$V = \alpha - 270$ **for F.R**

$V_{final} = \frac{V\ at\ F.L + V\ at\ F.R}{2}$

Example 2:

What is the height of a building measured by Theodolite as follows and the horizontal distance from the Theodolite to the building is 20 m:

Theodolite station	Measured points	Reading of horizontal circle	
		F.L	**F.R**
M	A (top of building)	$54^0\ 12'\ 36''$	$305^0\ 47'\ 30''$
	B (bottom of building)	$93^0\ 14'\ 53''$	$266^0\ 45'\ 19''$

Solution:

Line MA

V at F.L = $90 - \alpha = 90 - 54^0\ 12'\ 36'' = 35^\circ\ 47'\ 24''$

V at F.R = $\alpha - 270 = 305^0\ 47'\ 30'' - 270 = 35^\circ\ 47'\ 30''$

$$V_{final} = \frac{V\ at\ F.L + V\ at\ F.R}{2}$$

$V_{final} = \frac{35^\circ\ 47'\ 24'' + 35^\circ\ 47'\ 30''}{2} = +35^\circ\ 47'\ 27''$ زاوية الارتفاع

Line MB

V at F.L = $90 - \alpha = 90 - 93^0\ 14'\ 53'' = -3^\circ\ 14'\ 53''$

V at F.R = $\alpha - 270 = 266^0\ 45'\ 19'' - 270 = -3^\circ\ 14'\ 41''$

$$V_{final} = \frac{V\ at\ F.L + V\ at\ F.R}{2}$$

$V_{final} = \frac{-3^\circ\, 14'\;\, 53'' + (-3^\circ\, 14'\;\, 41'')}{2} = -3^\circ\; 14'\;\; 47''$ زاوية الانخفاض

Height of building (H) = $H_1 + H_2$

$H_1 = 20 \tan V_1 = 20\; \times \tan 35^\circ\, 47'\;\; 27'' = 14.42\; m$

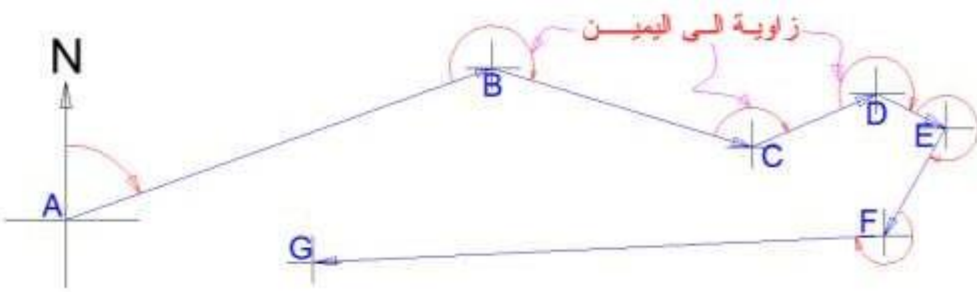
$H_2 = 20 \tan V_2 = 20\; \times \tan -3^\circ\, 14'\;\; 47'' = 1.134\; m$

Height of building (H) = $14.42\; m + 1.134 = 15.554\; m$

<u>**Types of horizontal angle**</u>

<u>1- **Angle to the right** :</u> angle that measured from the previous azimuth to the forward azimuth with direction of clockwise. Angles could be interior and exterior.

Forwar



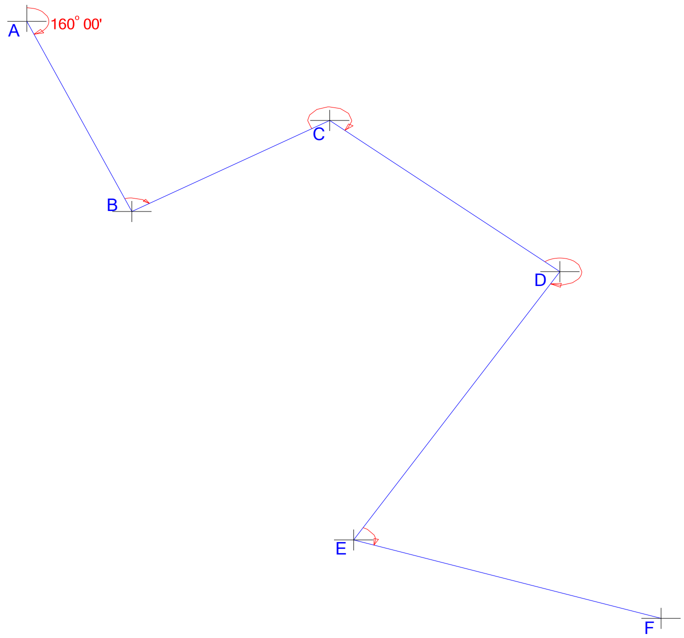
Example 1:

For the polygon below, the angles are measured with angle to the right method as follwes:

$ABC = 88^o\ 20'$, $BCD = 250^o\ 15'$,

$CDE = 265^o\ 25'$, $DEF = 82^o\ 10'$

If the direction of forward azimuth (line) AB is $160^0\ \ 00'$, find the directions of other lines?



Solution :

$AB = 160^o$ $BA = 160 + 180 = 340^o$

BC = BA + Angle to the right BC = $340^o + 88^o\ 20' = 428^o\ 20'$

BC = $428^o\ 20' - 360^o = 68^o\ 20'$

CB = $68^o\ 20' + 180 = 248^o\ 20'$

CD = CB + Angle to the right = $248^o\ 20' + 250^o\ 15' = 498^o\ 35'$

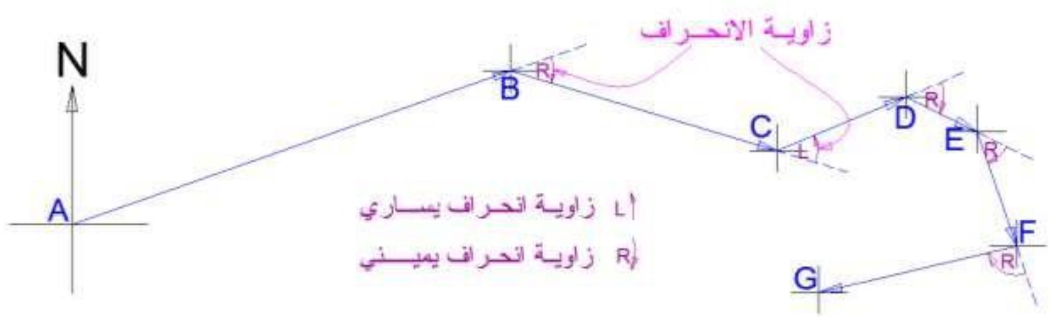
CD = $498^o\ 35' - 360 = 138^o\ 35'$ □ DC = $138^o\ 35' + 180 = 318^o\ 35'$

DE = DC + Angle to the right = $318^o\ 35' + 265^o\ 25' = 584^o\ 00'$

$DE = 584^o\ 00' - 360 = 224^o\ 00$ □ $ED = 224^o\ 00 - 180 = 44^o\ 00'$

$EF = ED + \text{Angle to the right} = 44^o\ 00' + 82^o\ 10' = 126^o\ 10'$

2- **<u>Deflection angle</u>**: is the angle measured from the extension of previous azimuth to the forward azimuth. The direction of angle is not necessarily clockwise or anticlockwise.



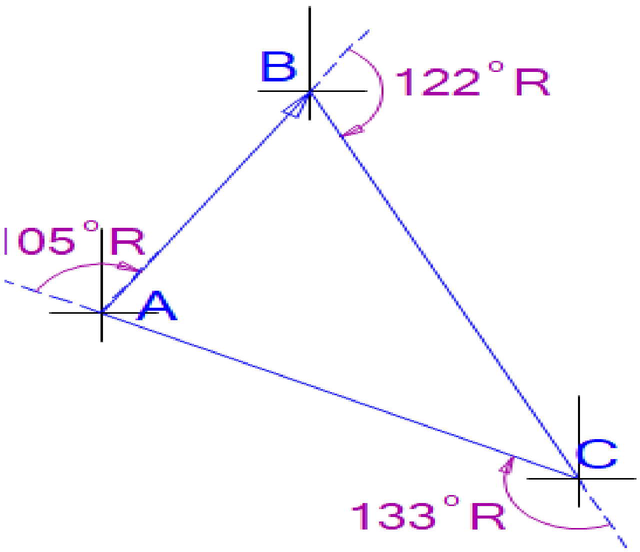
Forward Az.(لاحق) = Forward Az. (سابق) + Deflection angle to right

Or

Forward Az.(لاحق) = Forward Az. (سابق) - Deflection angle to right

Example 2:

The polygon angles were measured as : ABC = $122^0 R$, BCA = $133^0 R$, CAB =$105^0 R$. Find the direction of CA using the method of deflection angle?



Solution:

AB= $45^0\ 00'$

BC = AB +Deflection angle to R = $45^0 + 122^0 = 167^0$

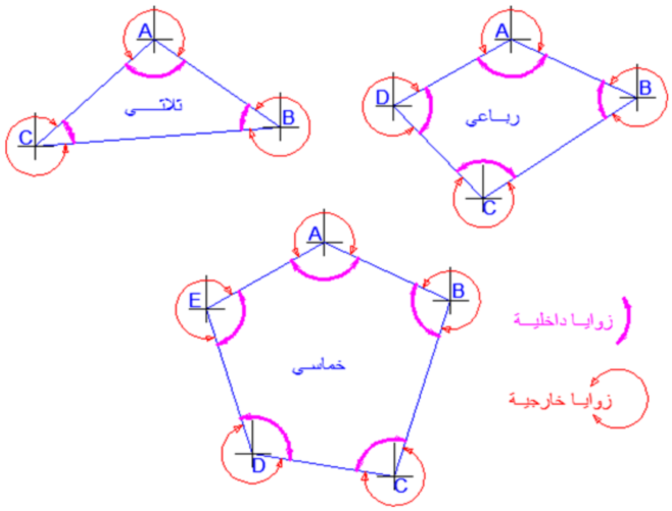
CA = BC +Deflection angle to R = $167^0 + 133^0 = 300^0$

AB = CA +Deflection angle to R = $300^0 + 105^0 = 405^0$

$\therefore AB = 405 - 360 = 45^0 00'$ $\therefore$ OK

Loops

3- Closed loops : is the loops that starts from point and ends with the same point. It is used to reduce the errors in calculations.



$$\sum Internal\ Standered\ Angles = (n - 2) \times 180$$

$$\sum External\ Standered\ Angles = (n + 2) \times 180$$

n: number of angles

Summation of internal and external angles **should be = 360**

Example 1:

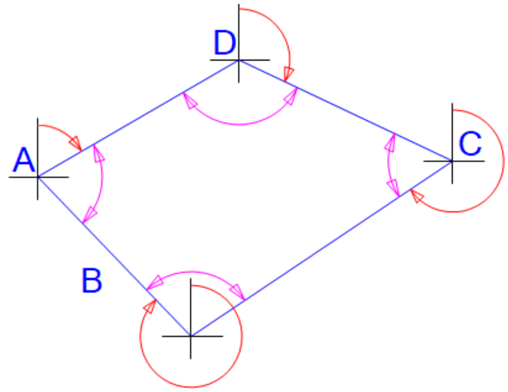
If the direction of lines in the polygon ABCDA as follows:

$AB = 130^0\ 14'$ $BC = 50^0\ 20'$ $CD = 305^0\ 15'$ $DA = 220^0\ 10'$

Determine the internal angles of the polygon?

Solution:

First, we have to plot the polygon :



From the forward directions, we can calculate the backward directions as follows:

Line	Forward direction	Backward direction
AB	$130^0\ 14'$	$310^0\ 14'$
BC	$50^0\ 20'$	$230^0\ 20'$
CD	$305^0\ 15'$	$125^0\ 15'$
DA	$220^0\ 10'$	$40^0\ 10'$

Point	line	Direction	Internal angle=Forward-backward
A	اماميAB	130^o 14'	130^o 14' - 40^o 10' = 90^o 4'
	خلفيAD	40^o 10'	
B	اماميBC	50^o 20'	50^o 20' - 310^o 14' = - 259^o 54' + 360 = 100^o 6'
	خلفيBA	310^o 14'	
C	أماميCD	305^o 15'	305^o 15' - 230^o 20' = 74^o 55'
	خلفيCB	230^o 20'	
D	أماميDA	220^o 10'	220^o 10' - 125^o 15' = 94^o 55'
	خلفيDC	125^o 15'	

Check for calculations

$$\sum Internal\ Standered\ Angles = (n-2)\times 180 = (4-2)x\ 180 = 360$$

Summation of angles : 90^o 4' +100^o 6'+ 74^o 55'+94^o 55'=360 **ok**

Coordinates

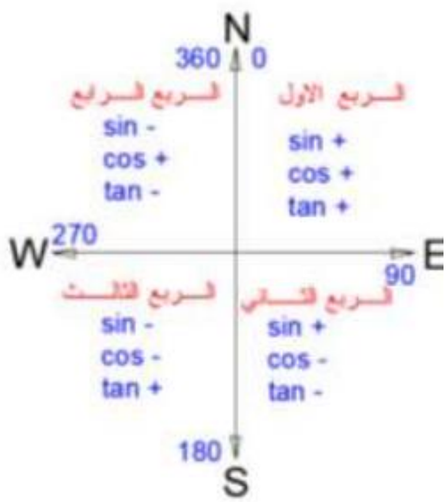
1- Northing

It is the coordinates of any point according to the **North**. It is usually called the **vertical component** of line (**Latitude**) or (ΔN).

2- Easting

It is the coordinates of any point according to the **East**. It is usually called the **horizontal component** of line (**Departure**) or (ΔE).

Departure and Latitude depend on **Quarter of circle** as shown :



Latitude (Lat) = $\boldsymbol{L \cos AZ}$

Departure (Dep) = $\boldsymbol{L \sin AZ}$

L: Length of line according to Departure and Latitude.

AZ : The direction of line according to the circle quarter (from north with clockwise).

Lat: Vertical component of line (with sign).

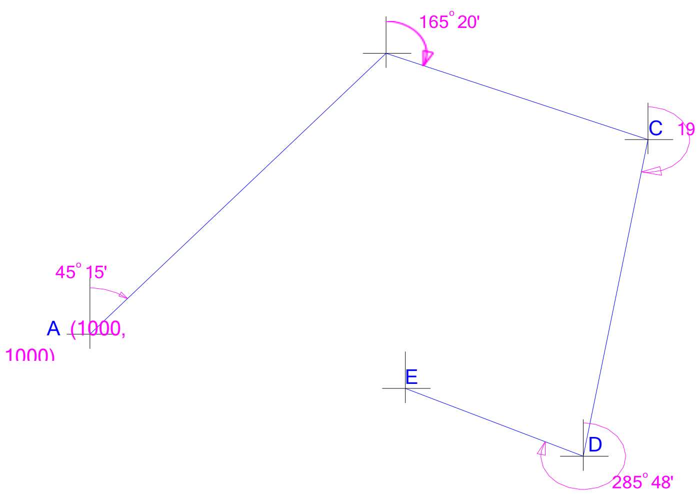
Dep: Horizontal component of line (with sign).

If we want to calculate the coordinates of point :

$x(\text{لاحق}) = x(\text{سابق}) \pm Dep$

$x(\text{لاحق}) = x(\text{سابق}) \pm Dep$

Example 1: for the polygon below, find the coordinates of B,C,D,E if the coordinates of A (1000,1000)m.



Solution :

Line AB

Departure (Dep) =$L \sin AZ = 450 \sin 45^0\ 15' = 319.6\ m$

Latitude (Lat) = $L \cos AZ = 450 \cos 45^0\ 15' = 316.8\ m$

$x_B = x_A + Dep = 1000 + 319.6 = 1319.6m$

$y_B = y_A + Lat = 1000 + 316.8 = 1316.8m$

B (1319.6, 1316.8) m

Line BC

Departure (Dep) =$L \sin AZ = 120 \sin 165^0\ 20' = 30.4\ m$

Latitude (Lat) = $L \cos AZ = 120 \cos 165^0\ 20' = -116.09\ m$

$x_c = x_c + Dep = 1319.6 + 30.4 = 1350m$

$y_c = y_c + Lat = 1316.8 - 116.09 = 1200.71m$

C (1350, 1200.17) m

Line CD

Departure (Dep) =$L \sin AZ = 300 \sin 194^0\ 36' = -75.62\ m$

Latitude (Lat) = $L \cos AZ = 300 \cos 194^0\ 36' = -290.31\ m$

$x_D = x_D + Dep = 1350 - 75.62\ = 1274.38m$

$y_c = y_c + Lat = 1200.71 - 290.31 = 910.4m$

C (1274.38, 910.4) m

Line DE

Departure (Dep) =$L \sin AZ = 80 \sin 285^0\ 48' = -76.98\ m$

Latitude (Lat) = $L \cos AZ = 80 \cos 285^0\ 48' = 21.78\ m$

$x_E = x_E + Dep = 1274.38 - 76.98\ = 1197.4m$

$y_E = y_E + Lat = 910.4 + 21.78 = 932.18m$

C (1197.4, 932.18) m

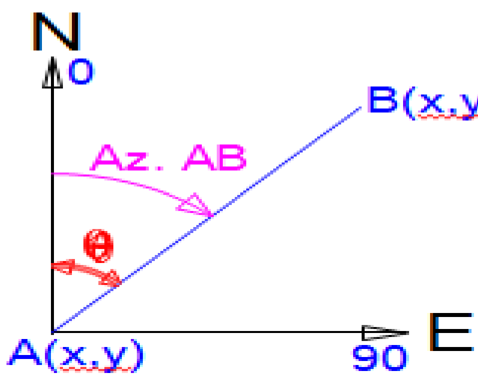
Note: if the **direction and length** of Azimuth (line) is **unknown**, and the **coordinates of line** is **known.** We can calculate the length and direction as :

$L_{AB} = \sqrt{(\Delta x)^2 + (\Delta y)^2}$

$\Delta x = x_B - x_A,$

$\Delta y = y_B - y_A$

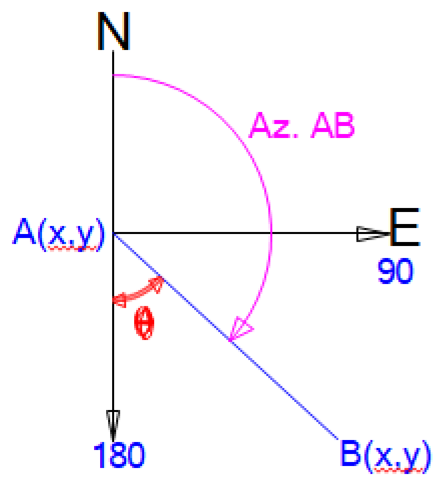
$\theta = tan^{-1} \frac{\Delta x}{\Delta y}$



$\Delta x = x_B - x_A \rightarrow \Delta x = +$

$\Delta y = y_B - y_A \rightarrow \Delta y = +$

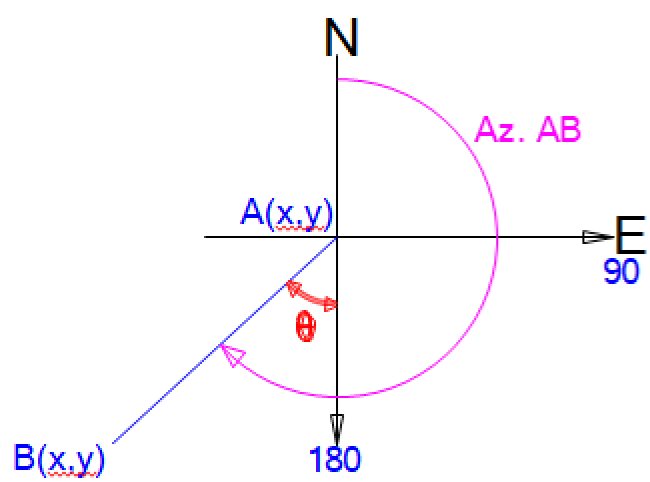
$\theta = tan^{-1} \frac{\Delta x}{\Delta y} \Rightarrow \theta = + \rightarrow \theta = Az.AB$



$\Delta x = x_B - x_A \rightarrow \Delta x = +$

$\Delta y = y_B - y_A \rightarrow \Delta y = -$

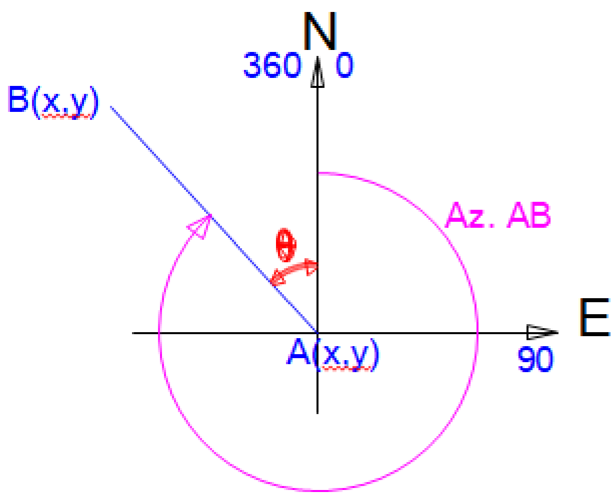
$\theta = tan^{-1}\dfrac{\Delta x}{\Delta y} \Rightarrow \theta = - \rightarrow \theta = Az.AB = 180 - \theta$



$\Delta x = x_B - x_A \rightarrow \Delta x = -$

$\Delta y = y_B - y_A \rightarrow \Delta y = -$

$\theta = tan^{-1} \dfrac{\Delta x}{\Delta y} \Rightarrow \theta = + \rightarrow \theta = Az.AB = 180 + \theta$



$\Delta x = x_B - x_A \rightarrow \Delta x = -$

$\Delta y = y_B - y_A \rightarrow \Delta y = +$

$\theta = tan^{-1} \dfrac{\Delta x}{\Delta y} \Rightarrow \theta = - \rightarrow \theta = Az.AB = 360 - \theta$

Example 2: if the coordinated of polygon points are :

Point	x	y
A	100	100
B	150	170
C	140	60
D	60	50
E	75	180

Find the lengths and directions of lines :

AB, AC, AD,AE, BE, CD,CB, DE

Solution :

Line AB:

$\Delta x = x_B - x_A \rightarrow \Delta x = 150 - 100 = 50m$

$\Delta y = y_B - y_A \rightarrow \Delta y = 170 - 100 = 70m$

$$\theta = tan^{-1} \frac{\Delta x}{\Delta y} = \frac{50}{70} = 35^0 32' 15'' \Rightarrow \theta = Az.AB = 35^0 32' 15''$$

$$L_{AB} = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(50)^2 + (70)^2} = 86m.$$

Line AC:

$\Delta x = x_B - x_A \rightarrow \Delta x = 140 - 100 = 40m$

$\Delta y = y_B - y_A \rightarrow \Delta y = 60 - 100 = -40m$

$$\theta = tan^{-1}\frac{\Delta x}{\Delta y} = \frac{40}{-40} = -45^0 \Rightarrow \theta = Az.AC = 180 - \theta = 135^0$$

$$L_{AB} = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(40)^2 + (-40)^2} = 56.57m.$$

Line AD:

$\Delta x = x_B - x_A \rightarrow \Delta x = 60 - 100 = -40m$

$\Delta y = y_B - y_A \rightarrow \Delta y = 50 - 100 = -50m$

$$\theta = tan^{-1}\frac{\Delta x}{\Delta y} = \frac{-40}{-50} = -45^0 \Rightarrow \theta = 38^0 39' 35'' \rightarrow Az.AD = 180 + \theta = 218^0 39' 35''$$

$$L_{AD} = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(-40)^2 + (-50)^2} = 64m.$$

Line AE:

$\Delta x = x_B - x_A \rightarrow \Delta x = 75 - 100 = -25m$

$\Delta y = y_B - y_A \rightarrow \Delta y = 180 - 100 = 80m$

$$\theta = tan^{-1}\frac{\Delta x}{\Delta y} = \frac{-25}{80} = -45^0 \Rightarrow \theta = -17^0 21' 14'' \rightarrow Az.AE = 360 - \theta = 342^0 38' 16''$$

$$L_{AE} = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(-25)^2 + (80)^2} = 83.8m.$$

Line BE:

$Az.BE = 277^0 35' 41''$

$L_{BE} = 75.66m.$

Line CD:

$Az.CD = 262^0 57' 41''$

$L_{CD} = 80.62m.$

Line CB:

$Az.CB = 5^0 11' 40''$

$L_{CB} = 110.45m.$

Line DE:

$Az.DE = 5^0 11' 40''$

$L_{DE} = 110.45m.$

Coordinates Errors

Coordinates Errors

The errors in coordinates values is due to the Departure and latitude components, therefore , there are two methods to solve these errors :

1- Compass Rule

(مع الاشاره) مقدار تصحيح المركبة = $Error\ in\ (Dep, Lat) \times \frac{L}{\sum L}$

$correct\ (Dep, Lat) = computer\ (Dep, Lat) +$ مقدار التصحيح

L : length of corrected line

$\sum L$ = Summation of lengths for the closed polygon

Example 1:

Find the Departure and Latitude for points B,C,D,E,F , and adjust the traverse using the compass rule?

Line	Length	Azimuth
AB	405.24	$106^0 20^0 00''$
BC	336.6	$57^0 54^0 30''$
CD	325.13	$335^0 29^0 00''$
DE	212.91	$219^0 29^0 00''$
EF	252.19	$266^0 55^0 00''$
FA	237.69	$219^0 40^0 00''$

Solution:

Line	Length	Azimuth	Dep = L sin Az.	Lat = L cos AZ.
AB	405.24	$106^0 20^0 00''$	388.885	-113.964
BC	336.6	$57^0 54^0 30''$	385.167	178.827
CD	325.13	$335^0 29^0 00''$	- 134.915	295.816
DE	212.91	$219^0 29^0 00''$	-135.379	-164.326
EF	252.19	$266^0 55^0 00''$	-251.825	-13.565
FA	237.69	$219^0 40^0 00''$	-151.722	-182.967
Summation	1769.76		**0.211**	**-0.179**

Since the summation of Departure and Latitude **are not equal to zero**, therefore we have to correct the Departure and Latitude.

Corrections for Departure

Line AB : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{405.24}{1769.76} = 0.048$

Line BC : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{336.6}{1769.76} = 0.04$

Line CD : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{325.13}{1769.76} = 0.0387$

Line DE : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{212.91}{1769.76} = 0.0254$

Line EF : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{252.19}{1769.76} = 0.03$

Line FA : (مع الإشارة) مقدار تصحيح المركبة = $0.211 \times \frac{237.69}{1769.76} = 0.0283$

$\therefore correct\ (Dep) = computer\ (Dep) +$ مقدار التصحيح

$AB = 388.885 + [0.048 \times -1] = 388.837m$

$BC = 285.167 + [0.04 \times -1] = 285.127m$

$CD = -134.915 + [0.0388 \times -1] = -134.945m$

$DE = -135.379 + [0.0245 \times -1] = -135.405m$

$EF = -251.825 + [0.03 \times -1] = -251.855m$

$FA = -151.722 + [0.0283 \times -1] = -151.75m$

$\therefore \sum correction\ Departures = 0$ ok.

<u>Corrections of Latitude :</u>

<u>Line AB :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{405.24}{1769.76} = -0.041$

<u>Line BC :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{336.6}{1769.76} = -0.034$

<u>Line CD :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{325.13}{1769.76} = -0.0329$

<u>Line DE :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{212.91}{1769.76} = -0.0215$

<u>Line EF :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{252.19}{1769.76} = -0.0255$

<u>Line FA :</u> (مقدار تصحيح المركبة (مع الإشارة = $-0.179 \times \frac{237.69}{1769.76} = -0.024$

$\therefore correct\ (Lat) = computer\ (Lat) +$ مقدار التصحيح

$AB = -113.964 + [0.048 \times -1] = -113.923m$

$BC = 178.827 + [-0.034 \times -1] = 178.861m$

$CD = 295.816 + [-0.0329 \times -1] = -295.849m$

$DE = -164.326 + [0.0215 \times -1] = -164.304m$

$EF = -13.565 + [0.0255 \times -1] = -13.54m$

$FA = -182.967 + [-0.024 \times -1] = -182.943m$

$\therefore \sum correction\ Departures = 0$ ok.