7 th. Week:

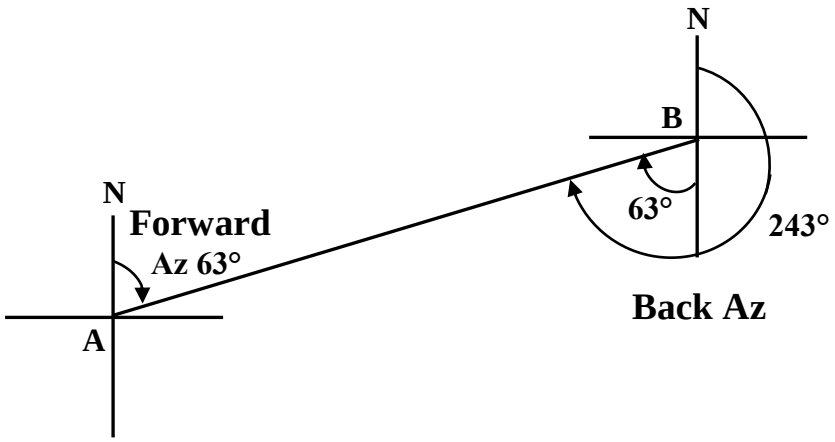
Forward and Inverse Computations:

Forward computation use to obtain the coordinates.

$$E_2 = E_1 + S.Sin(Az_{1\to 2})$$

$$N_2 = N_1 + S.Cos(Az_{1\to 2})$$

Because the algebraic sign will be seen directly and enter the computations.



<u>Inverse Computations</u>:

Inverse Computation use to obtain the length and the direction (Azimuth) of the line between the two points (initial and final) for that line.

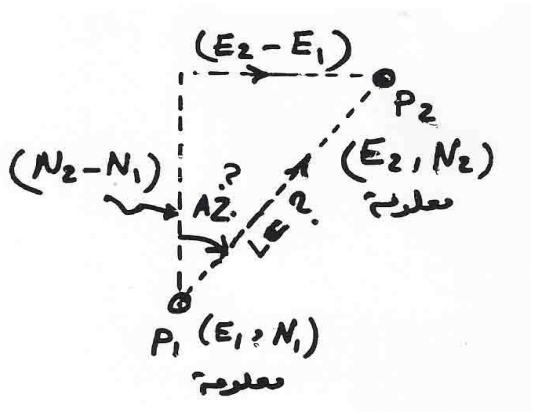
$$\text{Length} = \sqrt{(E_2 - E_1)^2 + (N_2 - N_1)^2}$$

and

$$Az_{1\to 2} = \tan^{-1}\left(\frac{E_2 - E_1}{N_2 - N_1}\right)$$

$$\text{or} = \tan^{-1}\frac{\Delta E}{\Delta N}$$

$$\text{or} \quad L = \frac{E_2 - E_1}{SinAz_{1\to 2}} = \frac{N_2 - N_1}{CosAz_{1\to 2}}$$



Ex :- compute the coordinates of the open traverse (OPQRS), if you have O= (4321. 404 , 6240.562) & they have the following data:

St.	Line	H. Dist.	Azimuth	Dep.	Lat.	X	Y
O						4321.404	6240.562
	OP	305.400	147° 31′12″	+164.001	-257.629		
P						4485.405	5982.933
	PQ	359.670	30° 51′ 42″	+184.499	+308.744		
Q						4669.904	6291.677
	QR	612.277	109° 02′ 00″	+578.803	-199.675		
R						5248.707	6092.002
	RS	485.220	49° 47′ 19″	+370.547	+313.263		
S						5619.254	6405.265

Ex.: The angles for close c.t(hexagon) are measured clock wise by theodolite and they are as follows:-

Angle	Measured angle
J	132° 02′ 10″
K	38° 54′ 41″
L	232° 10′ 46″
M	41° 02′ 36″
N	245° 38′ 28″
O	30° 11′ 52″

Solution:-

$\sum Measured\ angles = 720°\ 00'\ 33"$

$\sum Theory\ for\ interior\ angle = 180°(N-2) = 180°(6-2) = 720°$

$Misclosure = \sum Measured\ angles - \sum Theory\ angles$

$Misclosure = 720°\ 00'\ 33" - 720° = +33"$

Total correction (T.C.) for angles = - (Misclosure)= - 33″

Correction for an angle= T.C./ N =-33/6 =5.5″

Angle	Measured angle	Correction	Corrected angle
J	132° 02′ 10″	-6″	132° 02′ 04″
K	38° 54′ 41″	-5″	38° 54′ 36″
L	232° 10′ 46″	-6″	232° 10′ 40″
M	41° 02′ 36″	-5″	41° 02′ 31″
N	245° 38′ 28″	-6″	245° 38′ 22″
O	30° 11′ 52″	-5″	30° 11′ 47″
∑	720° 00′ 33″	-33″	720° 00′ 00″

Week No.4

HORIZONTAL ANGLES

Objectives:

The student should be able to:

1-Select the most appropriate method of measuring horizontal angles.

2-Measure and record these angles and determined their most probable values.

3-Understand the errors that affect angle measurement and minimize their effects.

1.1) MEASUREMENT OF HORIZONTAL ANGLES:

There are two methods of measuring horizontal angles:

i) **Reiteration Method.** It is a method of measuring horizontal angles with high precision. It is less tedious and is generally preferred when there are several angles to be measured at a station. Several angles are measured successively and finally the horizon is closed. Closing the horizon is the process of measuring the angles around a point to obtain a check on their sum which should be equal to 360°.

Procedure:

1. Select a station point O in fig. below.

2. Set the theodolite at O and do the temporary adjustments. The telescope is adjusted for left face left swing.

3. Set the vernier A to zero using upper clamp. Loosen the lower clamp, direct the telescope to the station point A and bisect A exactly by using the lower clamp and lower tangent screw.

4. Note the vernier readings (A and B).

5. Loosen the upper clamp and turn the telescope clockwise until the point B is exactly bisected.

6. Note the vernier readings (A and B).

7. The mean of the two vernier readings gives the value of <AOB.

8. Bisect all the points successively and note the readings of both verniers at each bisection.

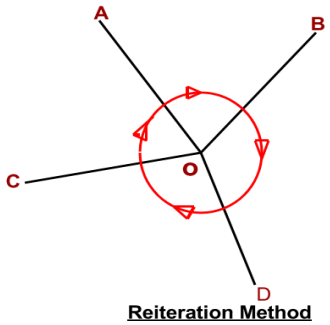
9. Finally close the horizon by sighting the station point A. The A vernier should be 360°. If not, note the closing error.

10. Adjust the telescope for right face right swing.

11. Repeat the whole process by turning the telescope in anticlockwise direction.

12. Distribute the closing error proportionately the several observed angles.

13.Take the average of face left and face right observations to give the corresponding horizontal angles.



Reiteration Method

ii) Repetition Method:

1.Measure the angle (e.g. 23° 19')

2.Tighten the lower motion clamp

3.Re-sight on the initial point

4.Sight the second point and re-measure the angle (e.g. 46° 40")

5.Repeat process as many times as desired

6.Solution equals the average of the measurement, or the final measurement

7.divided by the number of measurements

For example:

1) 1st measurement : 23° 19′

2) 2nd measurement : 46° 40′

3) 3rd measurement : 69° 59′

4) 4th measurement : 93° 23′

5) 5th measurement : 116° 44′

6) 6th measurement : 140° 32′

Average angle measurement : 23° 20′

Experiment No. 1

When exactly set over a survey mark and properly leveled, the theodolite can be used in two positions namely:

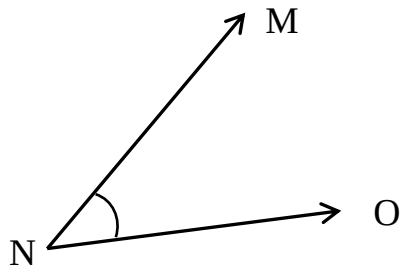
a) Face left,

b) Face right.

The instrument is to be facing left when vertical circle is on observers left as an object is sighted, and vice versa. In fig.(1) horizontal angle MNO is be measured .

a-Direction or Reiteration method. With out setting to zero, this methoed may be used with any type of theodolite.

1-Close the lower plate clamp, if fitted, and do not touch either of them again.Figure(1).



Figure(1)

	1	2	3	4	5
	Observation	Target station	face		Accepted mean angle
			Left reading	Right reading	
1	N	M	25° 30′	205° 30′	
2		O	90° 56′	270° 54′	
3			65° 26′	65° 24′	65° 25′

2-Set the instrument on face left.

3-Open the upper plate clamp on the alidade and the telescope clamp.

4-Turn the instrument carefully toward the left hand target (M) and sight to the target using the auxiliary finder sights fitted to the telescope.Lock the upper plate clamp and telescope clamp.

5-Focus the telescope on the target. The cross-wires will not be on the target but should be close. Use the slow-motion screws on the upper plate clamp to bisect the target accurately.

6-Read the horizontal circle and note the reading (25° 30′) in column 3 line 1.

7-Repeat operations 3,4,5 and for the right-hand target (R) booking the horizontal circle readings (90° 56′) in column 3 line 2.

8- Subtract reading (M) from reading (O) {90° 56′-25° 30′=65° 26′}and note in column (3) line (3).

In order to measure the angle above:

Two circle readings and, two booking were required. Clearly, error could easily occur with an inexperienced operator.

These possible sources of error are eliminated by remeasuring the angle on face Right.

9-Transit the telescope to set the instroment to face right and make preparations to remeasure the angle.

10-Repeat operations (3,4,5)and (6) noting the left hand target reading (M) (205° 30′) in column (4) line (1).

This reading should differ by (180°) from that in column (3) line (1) if no error are present.

11- Repeat operations (3,4,5) and (6) for the right –hand targt noting the reading (270° 54′) in column (4) line (2).

12-Subtract reading (M) from reading (O) {270° 54′-205° 30′}=the upper clamp and telescope clamp to bisect the target accurately.

13-Calculate the mean value of the angle and note in column (5) line (3).

b-Direction or Reiteration method. With setting to zero, this methoed also may be used with any type of theodolite.

The actual measurement procedure is the same as for method (a) except that the initial setting of the horizontal circle has to be (00° 00′ 00″). The mechanic of setting the circle varies with the type of theodolite.

The theodolite with circle – setting screw.

1-Set the instrument to face left position.

2-Set the micrometer (if filled) to (00° 00′ 00″).

3-Release the upper plate clamp and telescope clamp sight the left-hand station (M) and using the slow motion screws, actually bisect the target.

4-Raise the hinged cover of the circle-setting screw and rotate the screw carefully untill the horizontal circle reads exactly zero.

POST-TEST:

Compute the accepted mean angles for the following horizontal readings.

Observation station	Target station	Face		Accepted mean angle
		Left reading	Right reading	
B	A	(00° 00′ 00″)	(180° 00′ 00″)	
	B	(93° 14′ 20″)	(273° 14′ 20″)	
		(93° 14′ 20″)	(93° 14′ 20″)	(93° 14′ 20″)
C	B	(00° 00′ 00″)	(180° 00′ 20″)	
	D	(81° 24′ 00″)	(261° 24′ 00″)	
		(81° 24′ 00″)	(81° 24′ 20″)	(81° 24′ 50″)
D	C	(00° 00′ 00″)	(179° 59′ 40″)	
	A	(72° 29′ 40″)	(252° 29′ 40″)	
		(72° 29′ 40″)	(72° 30′ 00″)	(72° 29′ 50″)
A	D	(00° 00′ 00″)	(179° 00′ 40″)	
	B	(112° 51′ 20″)	(292° 50′ 20″)	
		(112° 51′ 20″)	(112° 50′ 40″)	(112° 51′ 00″)

b-Direction or Reiteration method,With setting to zero:

The actual measurement procedure is the same as for method (a) except that the initial setting of the horizontal circle has to be (00º 00' 00"). The mechanic of setting the circle varies with the type of theodolite.

Theodolite with circle – setting screw

1- Set the instrument to face left position.
2- Set the micrometer (if filled) to (00º 00' 00").
3- Release the upper plate clamp and telescope clamp sight the left – hand station M and using the slow motion screws, actually bisect the target.
4- Raise the hinged cover of the circle – setting screw and rotate the screw carefully until the horizontal circle reads exactly zero.

Week No.	**(1,2,3)**		
Subject	**Theodolite**		
Rationale	**1-The benefits of measuring the horizontal and vertical angles** **2-**		
Central Idea	**More accurate instrument to measure the horizontal and the vertical angles**		
Objectives	**The student should know:** **1-The Classification of the theodolite,** **2- The main components of the theodolite.**		
Pre-Test	**1- What are the benefits of measuring the horizontal and vertical angles** **a- To draw sketch or map to the observed features** **b- To Draw triangle.** **2- Which instrument is the more accurate for measuring the horizontal and the vertical angles?** **a-The theodolite.** **b-The level.**		
Presentation	**As attached**		
Self-Test	**1-What are the main methods used to read the theodolite circle?** **2-Mention the main components of theodolite.**		
Post-Test	**Choose the correct answer for the following questions.** **1)What is benefit of the tripod?** **a-To carry out things,** **b-To support the theodolite.** **2)When the slow motion screw work?** **a-It works all the time,** **b-When the lower plate clamp is locked.**		
Key-Answers	**Question No.**	**Pre-Test**	**Post-Test**
	1	**b**	**b**
	2	**a**	**b**

References:

1)Surveying for construction 4th. Edition by William Irvine.

2)Wild T16-Catalogue.

3) Fundamentals of surveying by S.K. Roy,1999.

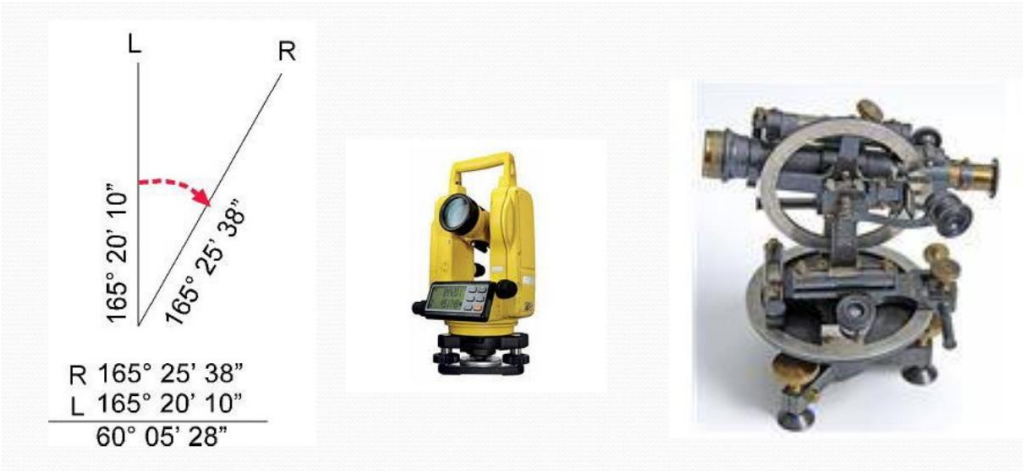
Applied Surveying

SECOND CLASS

Theodolite

1.1) WHAT IS THEODOLITE?

A surveying instrument and precision instrument for measuring angles in the horizontal and vertical planes, accuracy of theodolite varying from 1 to 60 second of arc.



1.2) USES OF THEODOLITE:

The theodolite is an instrument that used to:

1- Mapping applications and in the construction industry…

2- Measurement of Horizontal and vertical angle

3- Measurement of magnetic bearing of lines

4- Locating points on line

5- Prolonging survey lines

6- Determining difference in elevation

7- Setting out curves

8- Aligning tunnels

9- Mining works etc.

1.3) Theodolite: It is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of telescope by means of which distant objects can be sighted. The telescope has two distinct motions on

in the horizontal plane and the other in the vertical plane. The former being measured on a graduated Horizontal vertical circle of two verniear.

Theodolite WILD T16, SWISSERLAND

1.4) Theodolites may be classified as ;

A. Primary:

i) **Transit Theodolite:** A theodolite is called a transit theodolite when its telescope can be transited i.e revolved through a complete revolution about its horizontal axis in the vertical plane.

ii) **Non Transit Theodolite:** In this type the telescope is cannot be transited. They are inferior in utility and have now become obsolete.

Transit Theodolite & Non-Transit

B. Secondary:

i) **Vernier Theodolites:** For reading the graduated circle if verniers are used ,the theodolite is called as a Vernier Theodolite.

ii) **Micrometer Theodolites:** If a micrometer is provided to read the graduated circle the same is called as a Micrometer Theodolite.

Vernier type theodolites are commonly used.

C. Modern Theodolite: It is compact, light in weight , simple in design and can be used easily, Virtually dust and moisture proof.

1.5) Various parts of transit theodolite:

1- Telescope:

It is an integral part and is mounted on the spindle known as horizontal axis or turnon axis. Telescope is either internal or external focusing type.

2-The leveling head:

It may consists of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribranch is supported by means of three leveling screws by which the instrument may be leveled.

3) To lower plate or screw plate:

It carries horizontal circle at its leveled screw. It carries a lower clamp screw and tangent screw with the help of which it can be fixed accurately in any desired position.

4) The upper plate or vernier plate:

It is attached to inner axis and carries two vernier and at two extremities diametrically opposite.

5) Compass:

The compass box may be either of circular form or of a rough type. The former is mounted on the vernier plate between the standards while the latter is attached to the underside of the scale or lower plate or screwed to one of the standards. Modern theodolite is fitted with a compass of the tubular type and it is screwed to one of the standards.

6) Vertical circle:

The vertical circle is rigidly attached to the telescope and moves with it. It is silvered and it is usually divided into four quadrants.

7) Index bar or T-frame:

The index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its

lower extremity. The index arm and the clipping arm are together known as T-frame.

8) Clamps and tangent screws:

There are two clamps and associated tangent screws with the plate. These screws facilitate the motion of the instruments in horizontal plane. Lower clamp screw locks or releases the lower plate. When this screw is unlocked both upper and lower plates move together. The associated lower tangent screw allows small motion of the plate in locked position. The upper clamp screw locks or releases the upper vernier plate. When this clamp is released the lower plate does not move but the upper vernier plate moves with the instrument. This causes the change in the reading. The upper tangent screw allows the fine adjustment.

9) Vertical circle clamp and tangent screw (11):

Clamping the vertical circle restrict the movement of telescope in vertical plane.

10) Altitude level (2):

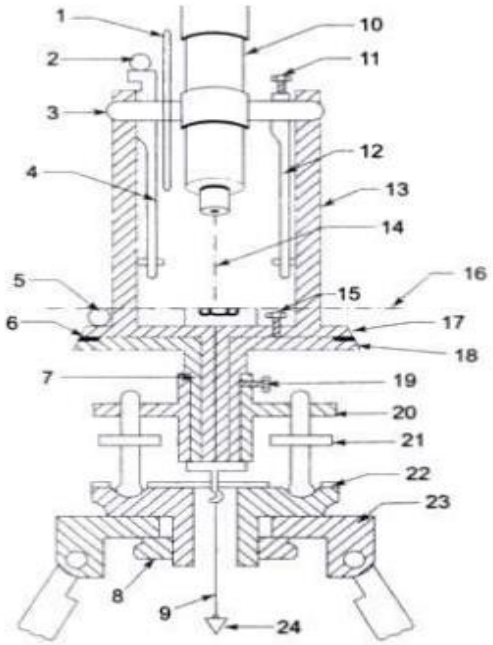
A highly sensitive bubble is used for levelling particularly when taking the vertical angle observations.

11) Plumb bob:

To center the instrument exactly over a station mark, a plumb bob is suspended from the hook fitted to the bottom of the central vertical axis.

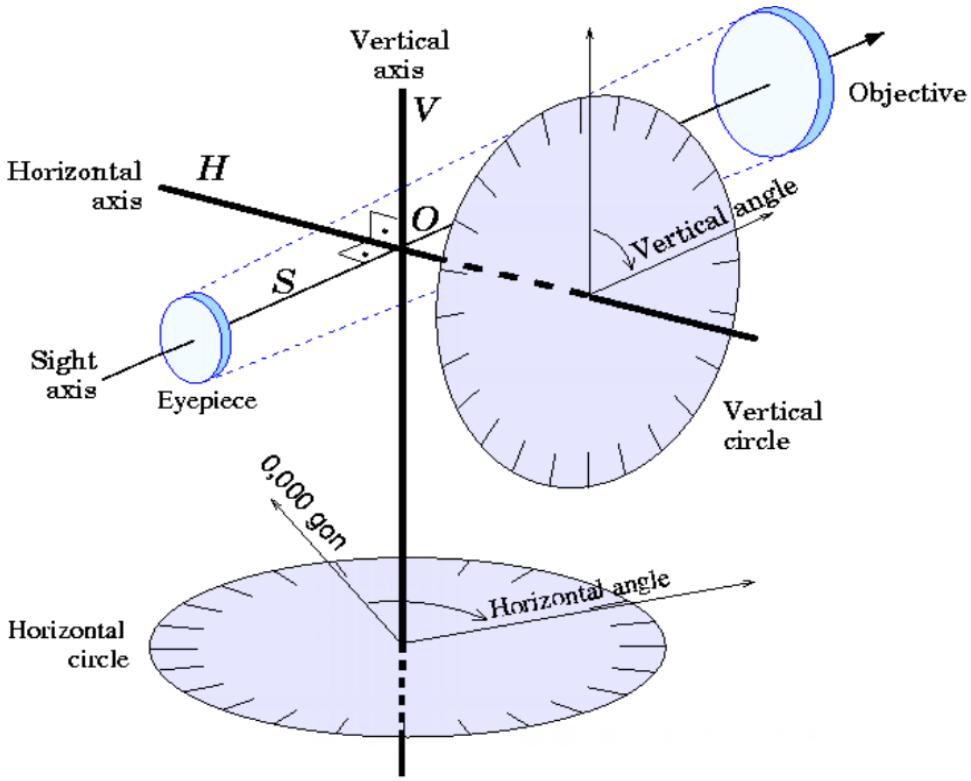
TRASIT THEODOLITE AND PARTS:

1. Vertical Circle,
2. Altitude bubble,
3. Horizontal axes,
4. Vernier Arm,
5. Plate bubble,
6. Graduated Arc,
7. Levelling Head,
8. Clamping Nut,
9. Vertical Axis,
10. Telescope,
11. Vertical circle clamping screw,
12. Arm of the vertical circle clamp,
13. Standard,



14.Line of sight,
15. Upper plate clamping screw,
16. Axis of plate bubble,
17. Upper plate(Alidade),
18. Lower plate (Horizontal circle),
19. Lower plate clamping screw,
20. Tribrach,
21. Foot screw (Leveling arrangement),
22. Trivet stage,
23. Tripod top,
24. Plumb bob.

AXIS OF VERNIER THEODOLITE



1.6) TERMS USED IN MANIPULATING A TRANSIT VERNIER THEODOLITE:

1. **Face Left :** 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.
2. **Face Right:** 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.

3. **Transiting :** Transiting is also known as plunging or reversing. It is the process of turning the telescope about its horizontal axis through 180 in the vertical plane.

4. **Changing Face :** It is the operation of bringing the vertical circle to the right of the observer ,if originally it is to the left , and vice – versa.or Revolving the telescope by 180 degree about horizontal axis in vertical plane.

5. **Line of Collimation:** It is also known as the line of sight .It is an imaginary line joining the intersection of the cross- hairs of the diaphragm to the optical centre of the object- glass and its continuation.

6. **Axis of the telescope:** It is also known an imaginary line joining the optical centre of the object- glass to the centre of eye piece.

1.7) <u>ADJUSTMENT OF A THEODOLITE:</u> The adjustments of a theodolite are of two kinds :

1. **Permanent Adjustments:** The permanent adjustments are made to establish the relationship between the fundamental lines of the theodolite.The permanent adjustments in case of a transit theodolites are :

i) **Adjustment of Horizontal Plate Levels.** The axis of the plate levels must be perpendicular to the vertical axis.

ii) **Collimation Adjustment.** The line of collimation should coincide with the axis of the telescope and the axis of the objective slide and should be at right angles to the horizontal axis.

iii) **Horizontal axis adjustment.** The horizontal axis must be perpendicular to the vertical axis.

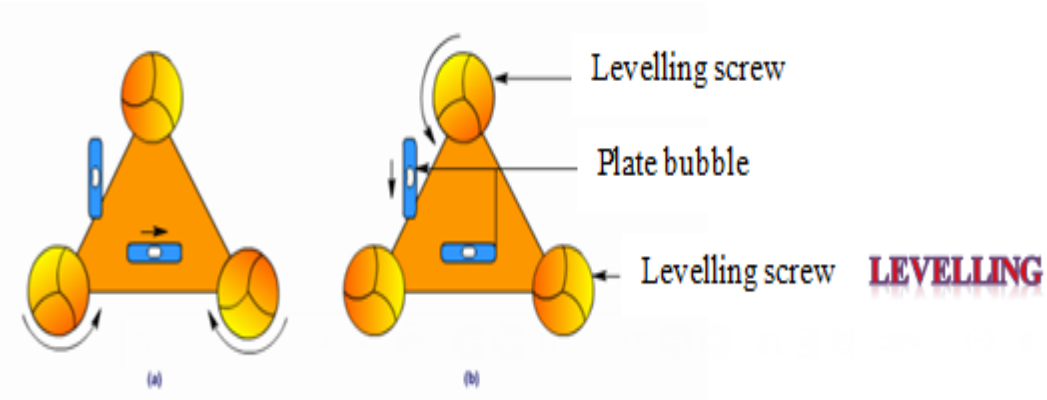
iv) **Adjustment of Telescope Level or the Altitude Level Plate Levels.** The axis of the telescope levels or the altitude level must be parallel to the line of collimation.

v) **Vertical Circle Index Adjustment.** The vertical circle vernier must read zero when the line of collimation is horizontal.

2. **Temporary Adjustments:** The temporary adjustments are made at each set up of the instrument before we start taking observations with the instrument. There are three temporary adjustments of a theodolite:

a- **Centering :** Centering means setting the theodolite exactly over an instrument. It can be done by means of plumb bob suspended from a small hook attached to the vertical axis of the theodolite.

b) **Leveling:** Leveling of an instrument is done to make the vertical axis of the instrument truly vertical. Generally, there are three leveling screws and two plate levels are present in a theodolite instrument.



3. Focussing: It is consists of focussing the eyepiece and the objective

a- Focussing the eyepiece: This operation is done to make the cross-hairs appear clearly visible.The following steps are involved:

1.The telescope is directed towards the sky or hold a sheet of white paper held in front of the object glass ,and move the eyepiece in and out until the cross hairs are seen quite distinctly and clearly (appear sharp and black).

2.The eyepiece is moved in or out until the cross hairs appear clear and distinct

b- Focussing the objective: There will be an apparent movement of the image relatively to the cross hairs when the observer moves his eyes. The apparent movement being called the parallax. To eliminate it,

1.The telescope is directed towards the obect.

2.The focussing screw is turned until the image appears clear and sharp.

6th. Week :

Traverse Survey

Objectives:

After studying this chapter,

(a) Should be able to make a traverse survey.

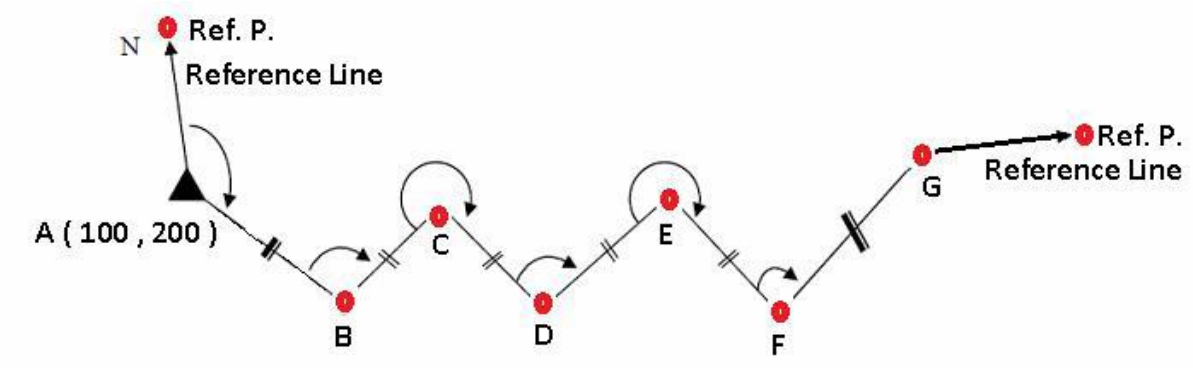
(b) Reduce the field data and plot the results graphically.

A traverse survey consists of a series of survey line connected to each other, each line having length and direction. Therefore,The vectors may or may not close to form a polygon.

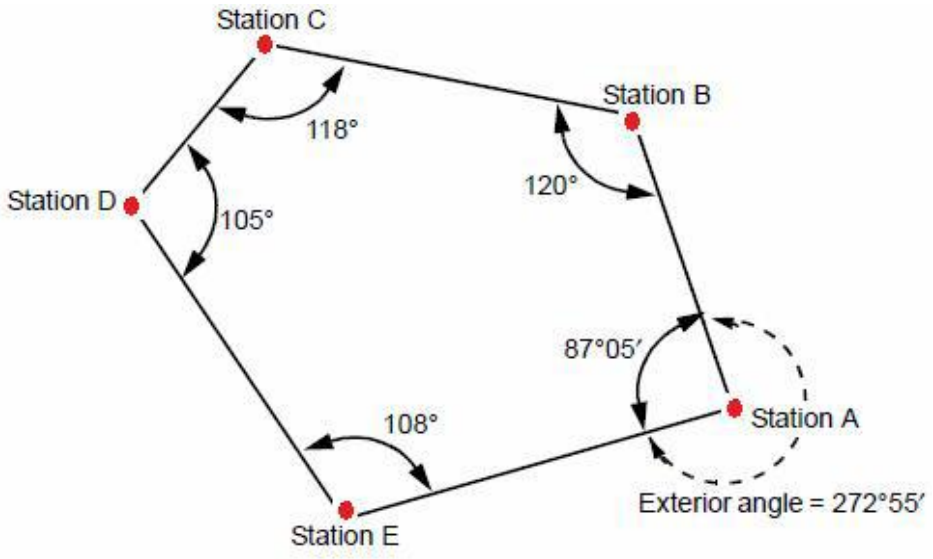
1- Types of traverse:

Theodolite traverses are classified under the following three headings.

(a) Open traverse.

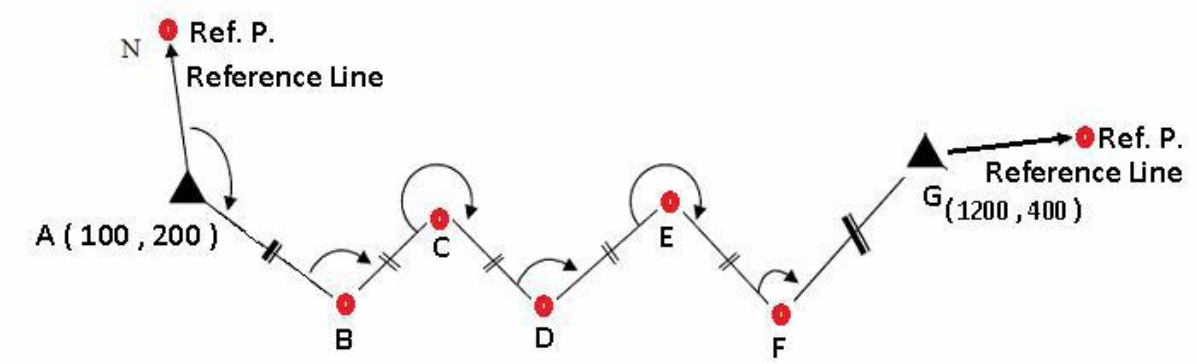


(b) Close circle traverse.



(c) Traverse closed between previously fixed points.

(Close connected traverse).



2- <u>Basic principles of traversing</u>:

In all three traverses in the figures above the survey field work consists of:

- Measuring the slope length of every line,
- Measuring the clockwise horizontal angle between adjacent lines.
- Measuring the bearing i.e. relative to north of one line of the traverse.

3- Field work:

It is generally accepted that a minimum of four surveyors is required to conduct a theodolite traverse.

Their duties are:

(a) To select suitable stations.

(b) To measure the distances between the stations.

(c) To erect, attend and move the sighting target from station to station.

(d) To measure and record the angle.

(e) To reference the stations for further use.

<u>Factors for choice of stations</u>:

The positions of stations are covered by the following factors.

1- Easy measuring conditions.

2- A voidance of short line.

3- Stations should be chosen so that the actual station mark can be sighted.

4- Stations should be chosen near some permanent objects.

Closed Traverses:

(A) Close Loop traverse computation:

The measured interior angles can be corrected by using the following formal as:

Total correction for angles:

T.C. for angles = (n – 2) * 180 – Measured sum of angles

$$\text{Correction / angle} = \frac{\text{T.C. for angles}}{n}$$

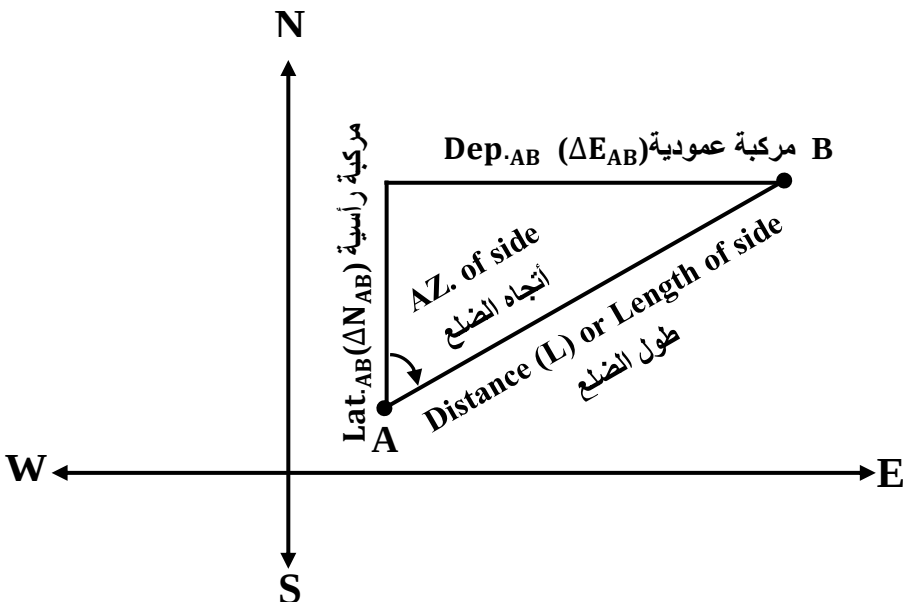
Corrected angle = Measured angle + or – Correction / angle)

Computation of R . Bearing or Azimuth as before.

-Computation of Departure or Latitude.

$$\text{Dep.}_{AB} = L * \sin Az_{AB} = \Delta E_{AB}$$

$$\text{lat.}_{AB} = L * \cos Az_{AB} = \Delta N_{AB}$$



Methods of correction for Deps & lats. Or coordinate or lengths:

a. Compass Rule or Bowdich Method.
b. Transit Rule.
c. Least, wear Method
d. The Axis Method.
e. Graphical Method.
f. Least square Method.

Week No 5:

"Measuring angles in the vertical plane"

Objectives :

After this week, the student should be able to:

(a) Select the most appropriate method of measuring vertical angles.

(b) Measure and record these angles and determined their most probable values and,

(c) Understand the errors that affect angle measurement and minimize their effects.

In the vertical plane, a theodolite can be used to measure either a vertical angle or a zenith angle. In a vertical angle, the zero angle, the zero reading of the vertical circle is in horizontal position and in measuring a zenith angle, the zero reading is in the vertical position.

Figure -2- Shows a survey line X, Y measured on a slope.

The angle of slope, measured on face left of a theodolite, set up at X, is either (15º 30' 00") vertical angle or (74º 30' 00") zenith angle.

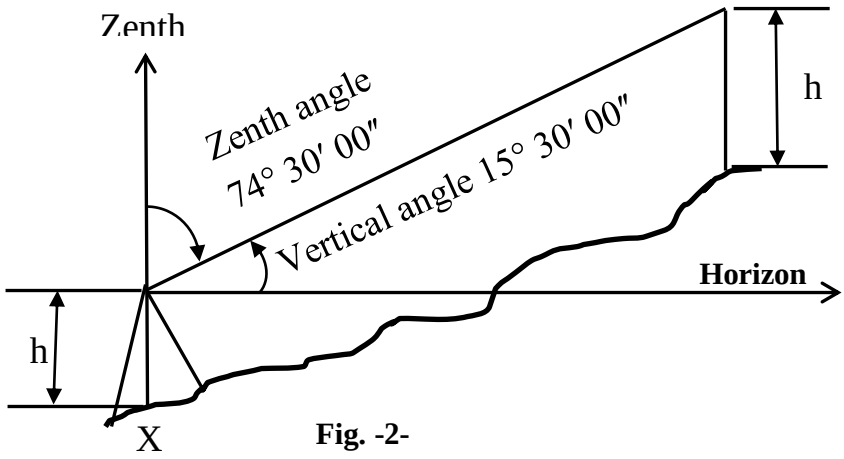
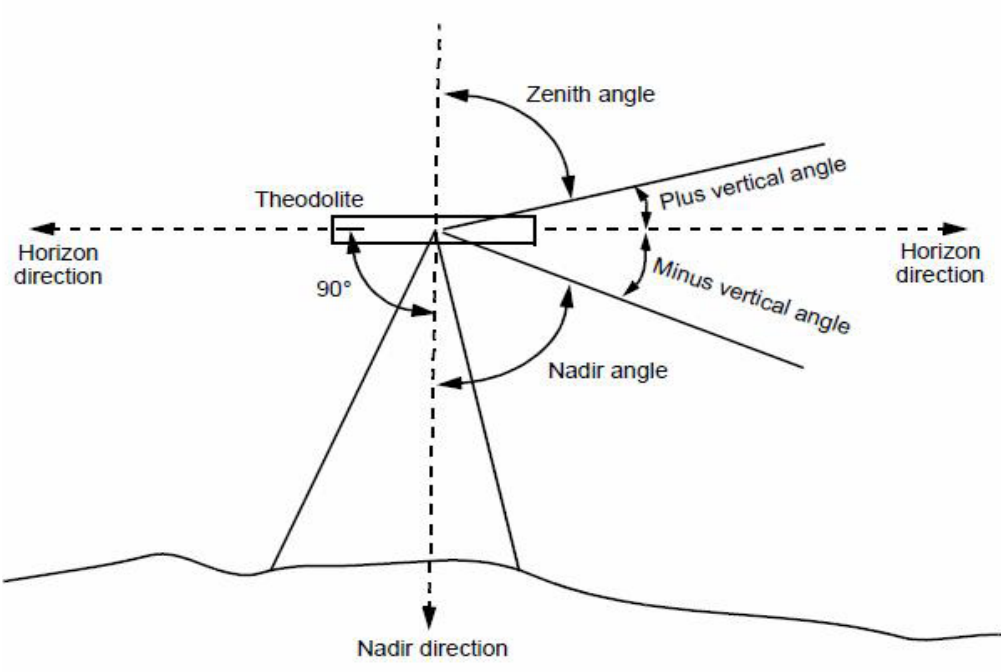


Fig. -2-

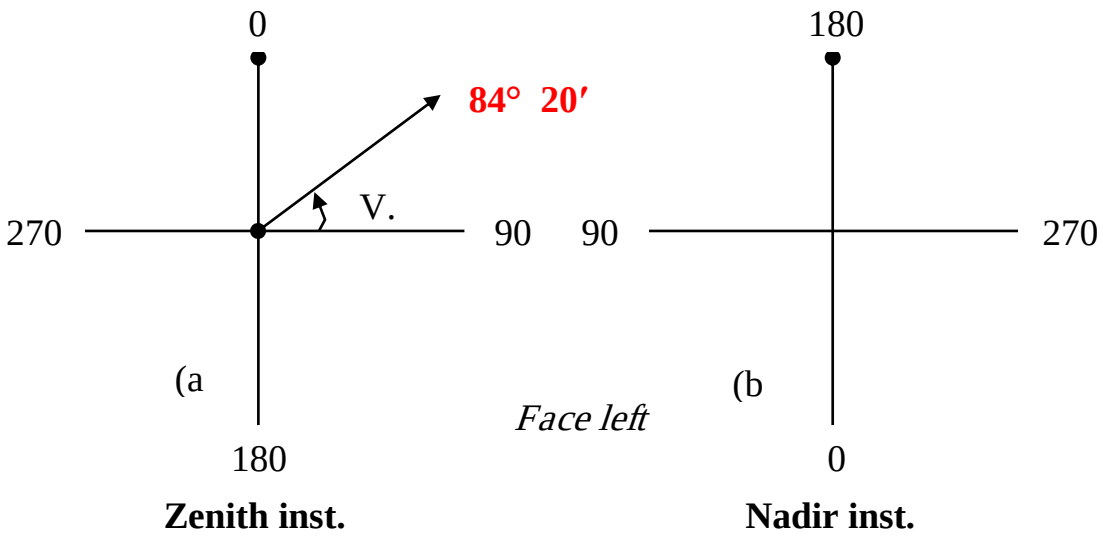


Measurement of vertical angles

It should be remembered that the construction of the theodolite is such that the vertical circle moves with the telescope and the index marker remains fixed, and all vertical angles must be measured on both face left and right. The procedure is as follows when measuring a vertical angle.

1- Set the instrument to face left.
2- Release the telescope clamp and one of the horizontal plate clamp.
3- Sight the target using the finder sights. Lock the telescope clamp and plate clamp.
4- Focus the telescope on the target. The cross – wires will not be on the target but should be close. Use the slow motion screws to bisect the target accurately.
5- Set the altitude spirit level (if fitted) to the center of its run and read the vertical circle.
6- Change the instrument to face right and repeat operations (2, 3, 4 and 5).

Figure -3- shows the method of graduating the vertical circle of two theodolites. Moreover, because of this system one reading can be obtained.



The face left reading might be:

84º 20' 35"

So that the vertical angle is:

90º 00' 00"

84º 20' 35" -

V. angle = 5º 39' 25"

And the face right reading:

275º 39' 35"

Now:

F.L. reading 84º 20' 35"

F.R. reading 275º 39' 35"

Sum = 360º 00' 10"

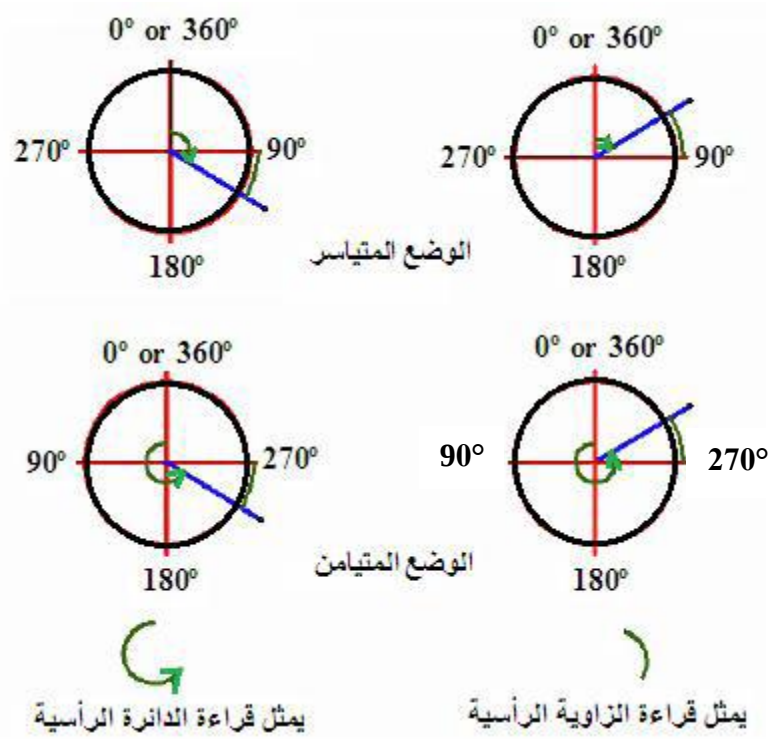
Index error = + 10"

So that :

Corrected F.L. reading = 84º 20' 30"

Corrected F.R. reading = 275º 39' 30"

Sum = 360º 00' 00"



Example:

The following readings of theodolite circle for the measurement of a vertical angle.

Face Left reading = 82º 10' 04"

Face Right reading = 277º 50' 04"

———————

Sum = 360º 00" 08"

Index error = + 08"

Now Determine the correct vertical angle:

The index error is halved and correction of (-04") is applied to both readings to bring their sum to (360º 00' 00").

∴ corr. F.L. reading = 82º 10' 00"

and corr. F.R. reading = 277º 50' 00"

———————

Sum = 360º 00' 00"

and the correct vertical angle is:

90º 00' 00"			277º 50' 00"	
- 82º 10' 00"		or	270º 00' 00"	-
Correction V. angle =	07º	50' 00"	= 07º	50' 00"

Post- Test:

The table below shows the field measurements of two angles of a traverse survey. Calculate the values of vertical angles.

Line	Face	Vertical circle reading
XY	L	79º 30' 50"
	R	280º 30' 10"
YZ	L	102º 13' 50"
	R	257º 47' 10"