

Unit 5
THEODOLITE SURVEYING

1. Differentiate between latitudes and departures. (AUC Apr/May 2011) (AUC Nov/Dec 2012)

S.No	Latitude (L)	Departure (D)
1.	It may be defined as its coordinate length measured parallel to the meridian direction.	It may be defined as its coordinate length measured at right angles to the meridian direction.
2.	The latitude of the line is positive when measured northward (upward) and is termed as northing.	The departure of the line is positive when measured eastward and is termed as easting.
3.	The latitude of the line is negative when measured southward (downward) and is termed as southing.	The departure of the line is negative when measured westward and is termed as westing.
4.	$L_1 = L_1 \cos \theta_1$	$D_1 = L_1 \sin \theta_1$

2. What are the errors eliminated in measurement of horizontal angle by method of repetition? (AUC Apr/May 2011)

- Errors due to eccentricity of verniers and centres are eliminated by taking both vernier readings.
- Errors due to inadjustments of line of collimation and the trunnion axis are eliminated by taking both face readings.
- The errors due to inaccurate graduations are eliminated by taking the readings at different parts of the circle.
- Errors due to inaccurate bisection of the object, eccentric centering etc., may be to some extent counter-balanced in different observations.

3. What is Gale's table? State its characteristic. (AUC Apr/May 2010)

Traverse computations are usually done in a tabular form is called Gale's table.

Characteristics:

- The sum of all the observed interior angles is found which should be equal to $(2n-4)$ right angle.
- If exterior angles are measured then the sum should be equal to $(2n+4)$ right angles.

- The reduced bearings of all the lines are computed based on the whole circle bearing of the lines.
- The latitude and departure of all the lines are computed.
- The independent coordinates of the lines are obtained from the corrected consecutive coordinates.

4. What kind of error can be eliminated by taking face left and face right observations?

(AUC Apr/May 2010)

- Error due to line of collimation not being perpendicular to the horizontal axis.
- Error due to horizontal axis not being perpendicular to the vertical axis.
- Error due to non-parallelism of the axis of telescope level and line of collimation.
- Error due to imperfect adjustment of the vertical circle vernier.

5. What is meant by parallax?

(AUC Nov/Dec 2011)

Parallax is a condition arising when the image formed by the objective is not in the plane of the cross hairs.

6. Name the temporary adjustments in a transit theodolite. (AUC May/June 2012, Nov/Dec 2011)

- Setting
- Levelling and
- Parallax removal.

7. What is transit theodolite?

(AUC Nov/Dec 2010)

A transit theodolite is one in which the line of sight can be reversed by revolving the telescope 180° in the vertical plane.

8. What is the use of Gale's table?

(AUC Nov/Dec 2010)

- The sum of latitudes ($\sum L$) and departures ($\sum D$) are found.
- Necessary corrections are done in closed traverse such that $\sum L = 0$ and $\sum D = 0$.
- The independent coordinates of the lines are obtained from corrected consecutive coordinates.
- The coordinates are positive and the entire traverse lie in the first quadrant.

9. What is centering of a theodolite?

(AUC Nov/Dec 2009)

The process of setting the theodolite exactly over the station mark is known as Centring.

10. What is face right observation?

(AUC Nov/Dec 2009)

If the face of the vertical circle is to the right of the observer is known as face right observation.

11. Brief how a theodolite can be used as a level.

(AUC May/June 2012)

After having centred and approximately levelled the instrument. Accurate levelling is done with the help of foot screws and with reference to the plate levels. The manner of levelling the instrument by the plate levels depends upon whether three levelling screws or four levelling screws.

12. How would you eliminate parallax in theodolite?**(AUC Nov/Dec 2012)**

Parallax is eliminated in two steps,

- Focusing the eyepiece
- Focusing the objective

PART – B (16 marks)**1. Describe briefly about temporary and permanent adjustments of a theodolite.****(AUC May/June 2013) (AUC Apr/May 2011) (AUC Nov/Dec 2010) (AUC Nov/Dec 2009)****Temporary Adjustments:**

- i) Setting
- ii) Levelling
- iii) Parallax removal

i) Setting:

The vertical axis of the instrument shall be located exactly above the survey station position marked by a peg permanently fixed in ground. The top of the peg is normally marked with a cross by permanent paint. In normal theodolites, a hook is placed in the centre of tripod stand representing the position of vertical axis of the instrument. A plumb bob is suspended from this hook with the help of a strong thread.

The instrument assembly is set on the firm ground and tripod legs are manipulated to be approximately over the station point. The legs are then moved sideways and/or radially to bring plumb bob exactly over the cross junction on peg while maintaining tribrach horizontal. In more refined theodolites, optical plummet is used for centering in place of plumb bob assembly for better accuracy. A centering plate mounted on tripod can also be used for rapidly centering the instruments.

ii) Levelling:

To ensure that the horizontal circle does lie in a true horizontal plane which is normal to vertical axis of the instrument, the theodolite is levelled. This is done with the help of leveling screws and plate bubbles. Normally, the instrument has three leveling screws and two plate bubble tubes. The upper plate of the instrument is rotated until one of the bubble tube is parallel to the line joining two leveling screws. While the second bubble tube will be normal to this line. The bubble of the first tube is brought to central position by moving the corresponding pair of leveling screws simultaneously. The third screw is then manipulated to bring bubbles in second bubble tube midway of its run. This movement may cause disturbance in position of first bubble. The process of leveling is then iterated until bubbles of both the tubes remains locked up in central position in all rotations of upper horizontal plate. This will ensure perfect horizontality of horizontal circle and makes instrument's vertical axis truly vertical.

iii) Parallax Removal:

It consists of focusing of the eyepiece and object lens so that the foci of the eyepiece and object lens coincide the cross hairs plane. As a first step, a piece of white paper is placed in front of the object lens and eyepiece screw is manipulated to move eyepiece in or out of instruments tube until the cross hairs are distinctly and clearly observable. This process ensures that eyepiece is locked in focused condition. As a next step, the telescopic tube is directed towards a distinct object and the focusing screw is turned until the object's image appears sharp and clear. This step may be required every time the distance between the object and instrument changes while making observation. This ensures that the image of object is formed in the plane of the cross hairs.

Permanent Adjustments:

As explained in Elements of Surveying (Unit 6), the fundamental axes of the theodolite can be identified as:

- vertical axis,
- axes of plate levels,
- line of collimation (also known as line of sight),
- trunnion axis (or horizontal axis or transverse axis), and
- Bubble line of the altitude level (or azimuthal axis).

For an instrument to give reliable and accurate observations, certain definitive relationships must exist between the above fundamental axes of the instrument. These relationships must also be maintained during the entire surveying exercise. It may be noted that these relationships are the properties of the instrument and do not change with survey station positions.

The relationships which must exist between fundamental axes of the instrument can be listed as follows:

- The plate levels axis is normal to vertical axis.
- The horizontal axis is normal to vertical axis.
- Line of collimation must be perpendicular to horizontal axis.
- The telescope's axis must be parallel to line of collimation.

In addition to above relations, the well adjusted theodolite should also meet following requirements to make the instrument working easily and smoothly.

- The only movement of one part relative to another should be along a circular arc. There should not be any backlash, whip or looseness.
 - The verniers of a vernier type theodolite shall be diametrically opposite to each other. The vertical circle vernier should read zero when the instrument is levelled.
 - The geometric centres of vertical circle and trunnion axis should coincide as should the geometric centres of the axis of the horizontal plates and vertical axis of the instrument.
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The new instruments are checked for all these requirements before marketing. However, old instruments get wears and tears during usage and require to be serviced by competent instrument mechanics at regular intervals if high degree of accuracy is to be maintained. Some procedures to be adopted for testing these requirements and subsequent adjustments where necessary will now be described.

2. Write short notes on balancing of traverse. List out the different methods of balancing a traverse. (AUC Apr/May 2011)

The term balancing is generally applied to the operation of applying corrections to latitudes and departures so that $\sum L = 0$ and $\sum D = 0$. This applies only when the survey forms a closed polygon. The following are common methods of adjusting traverse:

- i) Bowditch's method
- ii) Transit method
- iii) Graphical method
- iv) Axis method

i) Bowditch rule:

The basis of this method is on the assumptions that the errors in linear measurements are proportional to \sqrt{l} where l is the length of a line. The Bowditch's rule is also termed as the compass rule. It is mostly used to balance a traverse where linear and angular measurements are equal precision. The total error in latitude and in the departure is distributed in proportion to the lengths of the sides.

Bowditch Rule is

Correction to latitude (or departure) of any side

$$= \text{Total error in latitude (or departure)} \times \frac{\text{Length of that side}}{\text{perimeter of traverse}}$$

Thus if C_L = Correction to latitude of any side
 C_D = Correction to departure of any side
 $\sum L$ = total error in latitude
 $\sum D$ = total error in departure
 $\sum l$ = length of the perimeter
 l = length of any side

We have $C_L = \sum L \times \frac{l}{\sum l}$ and $C_D = \sum D \times \frac{l}{\sum l}$

ii) Transit Method:

The transit rule may be employed where angular measurements are more precise than the linear measurements. According to this rule, the total error in latitudes and departures is distributed in proportion to the latitudes and departures of the sides. It is claimed that the angles are less affected by corrections applied by transit method than by those by Bowditch's method.

The transit rule is:

Correction to latitude (or departure) of any side

$$= \text{Total error in latitude (or departure)} \times \frac{\text{Latitude(departure) of that line}}{\text{Arithmetic sum of latitudes(departures)}}$$

Where L = latitude of any line

D = departure of any line

L_T = arithmetic sum of latitudes

D_T = arithmetic sum of departure

We have, $C_L = \sum L \times \frac{L}{L_T}$ and $C_D = \sum D \times \frac{D}{D_T}$

iii) Graphical method:

For rough survey, such as a compass traverse, the Bowditch rule may be applied graphically without doing theoretical calculations. According to the graphical method, it is not necessary to calculate latitudes and departures etc. however before plotting the traverse directly from the field notes, the angles or bearings may be adjusted to satisfy the geometric conditions of the traverse.

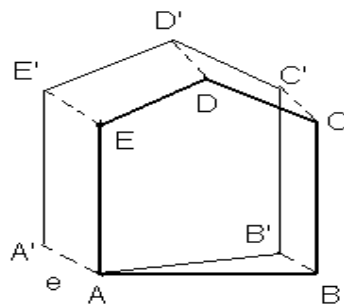


Fig (a)

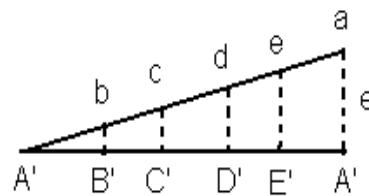


Fig (b)

The polygon $AB'C'D'E'A'$ represents an unbalanced traverse having a closing error equal to $A'A$ since the first point A and the last point A' are not coinciding. The total closing error AA' is distributed linearly to all the sides in proportion to their length by a graphical construction shown in figure. AB' , $B'C'$, $C'D'$ etc are represent the length of the sides of the traverse either to the same scale or reduced scale. The ordinate aA' is made equal to the closing error $A'A$. by constructing similar triangles, the corresponding errors bB' , cC' , dD' , eE' are found. The lines eE' , dD' , cC' , bB' respectively. The polygon $ABCDE$ so obtained represents the adjusted traverse. It should be remembered that the ordinates bB' , cC' , dD' , eE' , aA' represent the corresponding errors in magnitude only but not in direction.

iv) Axis Method:

This method is adopted when the angles are measured very accurately, the corrections being applied to lengths only. Thus the only directions of the line are unchanged and the general

shape of the diagram is preserved. To adjust the closing error aa_1 of a traverse $abcdefa_1$ the following procedure is adopted.

- Join a_1a and produce it to cut the side cd in x . the line a_1x is known as the axis of adjustment. The axis divides the traverse in two parts i.e. $a b c x$ and $a_1 f e d x$.
 - Bisect a_1a in A .
 - Join xb , xe and xf .
 - Through A , draw a line AB parallel to ab cutting xb produced in B . through B , draw a line BC parallel to bc cutting xc produced in C .
 - Similarly, through A , draw AF parallel to a_1f to cut xf in F . through F , draw FE parallel to fe to cut xe in E . through E , draw ED parallel to ed to cut xd in D .
- $ABCDEF$ (thick lines) is the adjusted traverse.

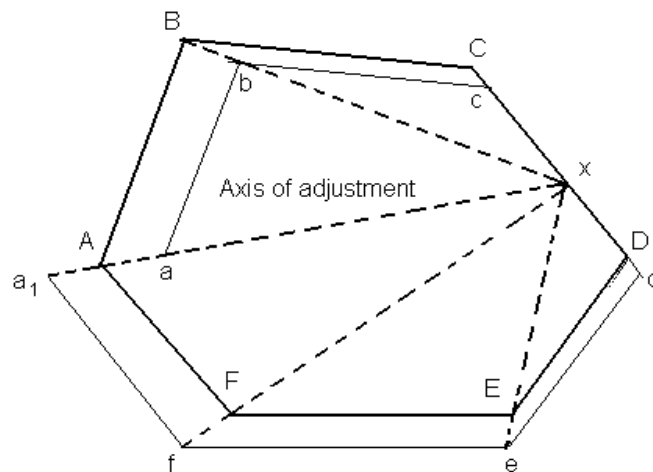


Fig. AXIS METHOD OF BALANCING TRAVERSE

$$\text{Now, } AB = \frac{Ax}{ax} ab$$

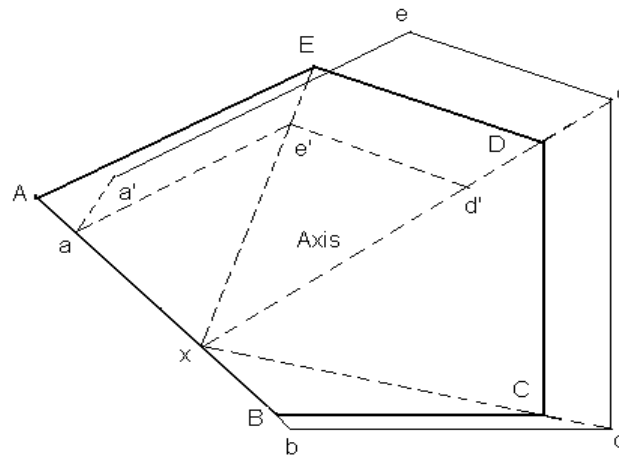
$$\begin{aligned} \text{Correction to } ab &= AB - ab = \frac{Ax}{ax} ab - ab = \frac{Aa}{ax} ab \\ &= \frac{1}{2} \frac{a_1a}{ax} ab = \frac{1}{2} \frac{ab}{ax} \times \text{closing error} \end{aligned}$$

$$\text{Similarly, correction to } a_1f = \frac{1}{2} \frac{a_1a}{a_1x} a_1f = \frac{1}{2} \frac{a_1f}{a_1x} \times \text{closing error}$$

Taking $ax \approx a_1x$ = length of axis.

We get the general rule:

$$\text{Correction to any length} = \text{that length} \times \frac{1}{2} \times (\text{closing error} / \text{Length of axis})$$



The axis a_1x should be so chosen that it divides the figure approximately into two equal parts. In some cases the closing error aa_1 may not cut the traverse or may cut it in very unequal parts. In such cases, the closing error is transferred to some other point. In figure aa_1 when produced does not cut the traverse in two parts. Through a , a line ae' is drawn parallel and equal to a_1e . through e' , a line $e'd'$ is drawn parallel and equal to ed . A new unadjusted traverse $dcbae'd'$ is thus obtained in which the closing error dd' cuts the opposite side in x , thus dividing the traverse in two approximately equal parts. The adjustment is made with reference to the axis dx . The figure $ABCDE$ shown by thick lines represents the adjusted figure.

3. During a theodolite survey the following details were noted:

Line	Length(m)	Back Bearing
AB	550	60°
BC	1200	115°
CD	?	?
DA	1050	310°

Calculate the length and bearing of the line CD.

(AUC Apr/May 2011)

Solution:

Line	Latitude		Departure	
	+	-	+	-
AB	275		476.31	
BC		507.14	1087.56	
DA	674.92			804.34
Sum	949.92	507.14	1563.87	804.34
	$\Sigma L' = 442.78$		$\Sigma D' = 759.53$	

Latitude of CD = $-\sum L^I = -442.78$ m

Departure of CD = $-\sum D^I = -759.53$ m

Since latitude and departure of CD is negative. It lies in SW quadrant.

The reduced bearing of CD (θ) is

$$\tan \theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{759.53}{442.78} = 1.72$$

$$\theta = \tan^{-1}(1.72)$$

Bearing of CD, $\theta = S 58^\circ 49' W = 238^\circ 49'$

$$\text{Length of CD} = \frac{\text{Latitude}}{\cos \theta} = \frac{442.78}{\cos(58^\circ 49')} = 855.15 \text{ m}$$

Length of CD = 855.15 m

4. In an open traverse ABCDE, it is required to find length of AE and to fix the mid point of AE.

Following is the record of readings.

(AUC Apr/May 2010)

Line	Length(m)	Bearing
AB	130.5	N20°30'E
BC	215.0	N60°15'E
CD	155.5	N30°30'E
DE	120.0	N30°30'E

- Determine the length and bearing of AE.
- Also determine the length and bearing of line joining mid point of AE and the station C.

Solution:

Line	Latitude		Departure	
	+	-	+	-
AB	122.24		45.70	
BC	106.68		186.66	
CD	133.98		78.92	
DE	103.39		60.90	
Sum	466.29		372.18	
	$\sum L^I = 466.29$		$\sum D^I = 372.18$	

Latitude of EA = $-\sum L^I = -466.29$ m

Departure of EA = $-\sum D^I = -372.18$ m

Since latitude and departure of EA is negative. It lies in SW quadrant.

The reduced bearing of EA (θ) is

$$\tan \theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{372.18}{466.29} = 0.798$$

$$\theta = \tan^{-1}(0.798)$$

Bearing of EA, $\theta = S 38^{\circ} 35' W = 218^{\circ} 35'$

$$\text{Length of EA} = \frac{\text{Latitude}}{\cos \theta} = \frac{466.29}{\cos(38^{\circ} 35')} = 596.51 \text{ m}$$

Length of EA = 596.51 m

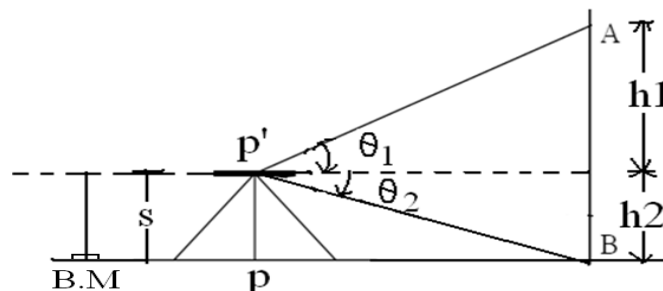
5. Explain how the height of a tower can be determined when it is inaccessible.

(AUC Apr/May 2010)

To measure the vertical angle of tower with respect to instrument station or any other point.

The Instruments used are Ranging rods, Theodolite and stand.

- To measure the Vertical angle of an object A at a station "O".
- Set up the instrument over 'O' and level it with reference to the altitude bubble.
- Set the zero of the vertical vernier exactly to the zero of the vertical circle by means of the vertical circle clamp and tangent screw.
- Bring the bubble of the altitude level to the center of its run. The line of Collimation is thus made horizontal, while the vernier reads zero.



- Loosen the vertical circle clamp, direct the telescope towards the object 'A', and sighted approximately, clamp the vertical circle and bisect 'A' exactly by turning the tangent screw.
- Read both verniers. The mean of the two readings gives the value of the required angle.
- Change the face of the instrument and repeat the process. The mean of the two vernier readings gives the second value of the required angle.
- To measure the vertical angle between the two points A and B
- Bisect 'A' as before and note the readings on the vertical circle.
- Similarly, bisect 'B' and note the readings on the vertical circle.
- The sum or difference of these readings will give the value of the angle between A & B as one of the points is above and the other below the horizontal plane.

The formula used to find the height of the tower is

$$h_1 = D \tan \theta_1$$

$$h_2 = D \tan \theta_2$$

$$\text{Height of total object, } H = h_1 + h_2$$

$$\text{R.L of top of the object} = \text{R.L of B.M} + S + h_1$$

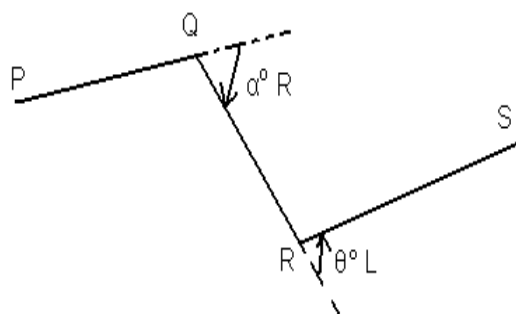
$$\text{R.L of bottom of the object} = \text{R.L of B.M} + S - h_2$$

After taking the readings find the reduced level of top and bottom of the tower. Finally by using the reduced level find the height of the tower.

6. Explain how would you measure the deflection angle using a theodolite. (AUC Apr/May 2010)

A deflection angle is the angle which a survey line makes with the prolongation of the preceeding line. It is designated as right (R) or left (L) according as it is measured to the clockwise or anti-clockwise from the prolongation of the previous line. Its value may vary from 0° to 180° . the deflection angle at Q is α° R and that at R is θ° L.

To measure the deflection angles at Q:



- i) Set the instrument at Q and level it.
- ii) With both plates clamped at 0° , take back sight on P.
- iii) Plunge the telescope. Thus the line of sight is in the direction PQ produced when the reading on vernier A is 0° .
- iv) Unclamp the upper clamp and turn the telescope clockwise to take the foresight on R. Read both the verniers.
- v) Unclamp the lower clamp and turn the telescope to sight P again. Read both the verniers.
Plunge the telescope.
- vi) Unclamp the upper clamp and turn the telescope to sight R. read both verniers. Since the deflection angle is doubled by taking both face readings, one-half of the final reading gives the deflection angle at Q.

7. It is not possible to measure the length and fix the direction of a line AB directly on account of an obstruction between the stations A and B. A traverse ACDB was therefore run and following data was obtained.

Line	Length(m)	Reduced Bearing
AC	45	N 50° E
CD	66	S 70° E
DB	60	S 30° E

Find the length and direction of line BA.

(AUC Nov/Dec 2011)

Solution:

Line	Latitude		Departure	
	+	-	+	-
AC	28.92		34.47	
CD		22.57	62.02	
DB		51.96	30	
Sum	28.92	74.53	126.49	
	$\Sigma L^1 = -45.61$		$\Sigma D^1 = 126.49$	

Latitude of BA = $\Sigma L^1 = 45.61$ m

Departure of BA = $-\Sigma D^1 = -126.49$ m

Since latitude of BA is positive and departure of BA is negative. It lies in NW quadrant.

The reduced bearing of BA (θ) is

$$\tan \theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{126.49}{45.61} = 2.77$$

$$\theta = \tan^{-1}(2.77)$$

Bearing of BA, $\theta = N 70^\circ 9' W = 289^\circ 51'$

$$\text{Length of BA} = \frac{\text{Latitude}}{\cos \theta} = \frac{45.61}{\cos(70^\circ 9')} = 134.32 \text{ m}$$

Length of BA = 134.32 m

8. Explain the various methods of horizontal angle using a theodolite.

(AUC Nov/Dec 2011) (AUC Nov/Dec 2010)

There are two methods to find the horizontal angle using a theodolite. They are

- Repetition Method
- Reiteration Method

Repetition Method:

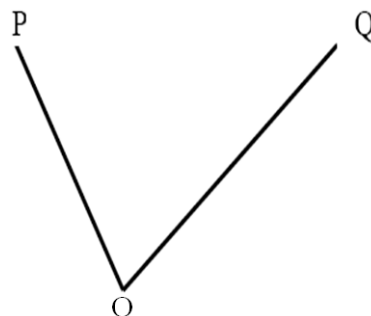
To measure a horizontal angle by repetition method.

The instruments used are

- Transit theodolite,
- Tripod and
- Ranging rods (2no.s).

Procedure:

- Set up the instrument over 'O' and level it accurately.
- With the help of upper clamp and tangent screw, set 0° reading on vernier 'A'. Note the reading of vernier 'B'.
- Release the upper clamp and direct the telescope approximately towards the point 'P'. Tighten the lower clamp and bisect point 'P' accurately by lower tangent screw.
- Release the upper clamp and turn the instrument clock-wise towards Q. Clamp the upper clamp and bisect 'Q' accurately with the upper tangent screw. Note the readings of verniers 'A' and 'B' to get the values of the angle POQ.
- Release the lower clamp and turn the telescope clockwise to sight P again. Bisect P by using the lower tangent screw.
- Release the upper clamp, turn the telescope clockwise and sight Q. Bisect Q by using the upper tangent screw.
- Repeat the process until the angle measured (required number of times is 3). The average angle with face left will be equal to final reading divided by three.
- Change face and make three more repetitions as described above. Find the average angle with face right, by dividing the final reading by three.



- The average horizontal angle is then obtained by taking the average of the two angles with face left and face right.

$$PQ = \sqrt{OP^2 + OQ^2 - 2 \cdot OP \cdot OQ \cdot \cos \theta}$$

After taking the readings calculate the horizontal angle and horizontal distance by using the formula. Then we find the exact horizontal angle and the distance between the points PQ.

Reiteration Method:

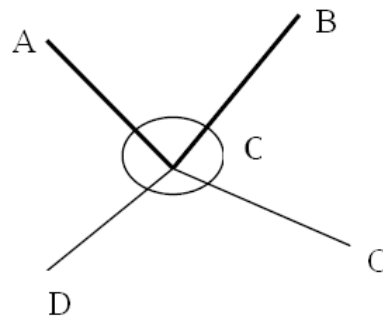
To measure a horizontal angle by reiteration method.

The instruments used are

- Transit theodolite,
- Tripod and
- Ranging rods (2no.s).

Procedure:

- It is required to measure angles AOB, BOC, and COD etc by reiteration method.
- Set the instrument over "O" and level it set the Vernier to zero and bisect point A accurately.
- Loose the upper clamp and turn the Telescope clockwise to point B. Bisect B by using the upper tangent screw.
- Read both the Verniers, the mean of the Verniers will give the angles AOB.
- Similarly, bisect successively C, D etc, thus closing the circle. Read both the Verniers at each bisection.



- Finally sight to A the reading of the vernier should be the same as the original setting reading.

Repeat the steps 02 to 04 with other face i.e. face Right.

After taking the readings then calculate the horizontal angle for each points.

9. Describe the essential parts of a transit theodolite.

(AUC Nov/Dec 2009)

Essential Parts:

Leveling head, telescope, vertical circle, index frame, A frame, lower plate, upper plate, level tubes, plumb bob.

Leveling Head:-

The leveling head consists of two parallel triangular planes known as tribrach plates. The upper tribrach has three arms, each carrying a leveling screw. The lower tribrach has three arms each carrying a leveling screw. The lower tribrach plate or foot plate has a circular hole through which plumb bob may be suspended.

Telescope:-

The telescope is an integral part of the theodolite and is mounted on a spindle known as horizontal axis or trunnion axis. In most of the transits, internal focusing telescope is used.

Vertical Circle:-

The vertical axis is a circular graduated arc attached to the trunnion axis of the telescope consequently the graduated arc rather with the telescope when the latter is turned about the horizontal axis.

Index Frame:-

The index frame is a T-shaped frame consisting of a vertical leg known as clipping arm and a horizontal bar known as vernier arm of index corn. At the two extremities of the index arm are fitted two verniers to read the vertical circle.

A Frame:-

Two standards resembling the letter A are mounted on the upper plates. The trunnion axis of the telescope is supported on these.

Lower Plate:-

The lower plate is attached to the outer spindle. The lower plate carries a horizontal circle at its leveled edge and is therefore also known as the scale plate.

Upper Plate:-

The upper plate or vernier plate is attached to the inner axis and carries two verniers with magnifiers at two extremities diametrically opposite. The upper plate supports the standards.

Plumb Bob:-

A plumb bob is suspended from the hook fitted to the bottom of the inner axis to centre of instrument exactly over the station mark.

Telescope:

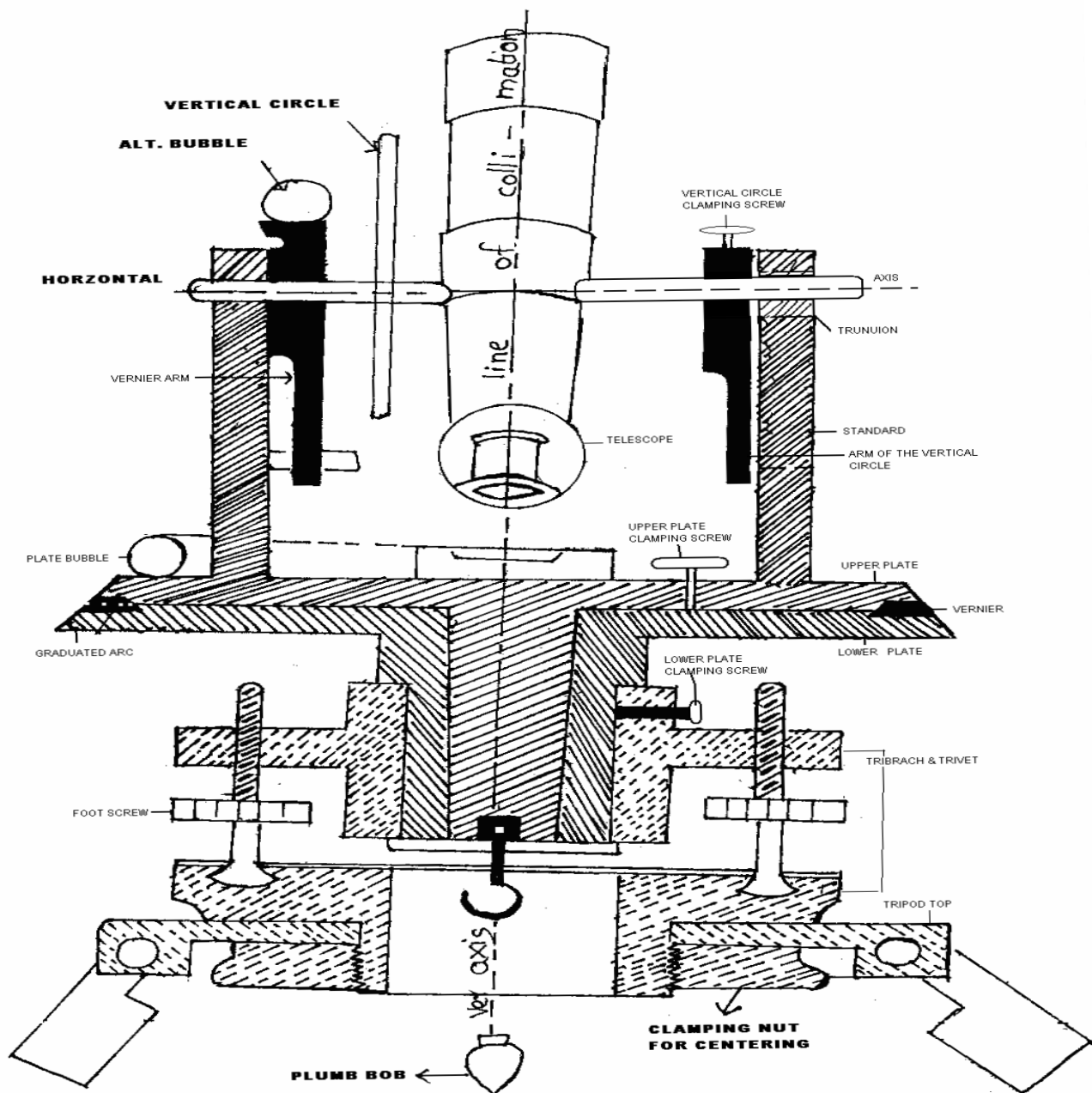
It consists of eye-piece, object glass and focusing screw and it is used to sight the object.

Vertical circle:

It is used to measure vertical angles.

Foot screws:

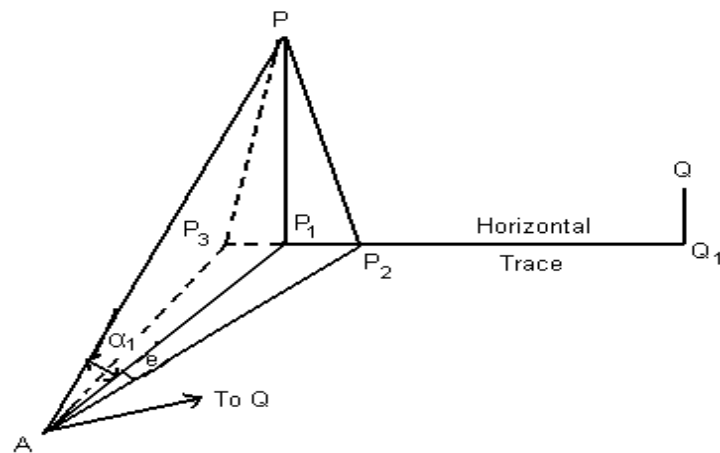
These are used to level the instrument.



10. Explain the theodolite adjustment for the line of sight.

(AUC May/June 2012)

If the line of sight is not perpendicular to the trunnion axis of the telescope, it will not revolve in a plane when the telescope is raised or lowered but instead, it will trace out the surface of a cone. The trace of the intersection of the conical surface with the vertical plane containing the point will be hyperbolic. This will cause error in the measurement of horizontal angle between the points which are at considerable difference in elevation.



In the above figure, let P and Q be two points at different elevation and let P_1 and Q_1 be their projections on a horizontal trace. Let the line AP be inclined at an angle α_1 to horizontal line AP_1 . When the telescope is lowered after sighting P the hyperbolic trace will cut the horizontal trace P_1Q_1 in P_2 if the intersection of the cross-hairs is to the left of the optical axis. The horizontal angle thus measured will be with respect of AP_2 and not with respect to AP_1 . The error 'e' introduced will thus be $e = \beta \sec \alpha_1$, where β is the error in the collimation.

On changing the face, however, the intersection of the cross-hairs will be to the right of the optical axis and the hyperbolic trace will intersect the line P_1Q_1 in P_3 . The horizontal angle thus measured will be the respect to AP_3 , the error being $e = \beta \sec \alpha_1$ to the other side. It is evident, therefore, that by taking both face observations the error can be eliminated. At Q also, the error will be $e' = \beta \sec \alpha_2$, where α_2 is the inclinations of AQ with horizontal and the error can be eliminated by taking both face observations. If however, only one face observations are taken to P and Q, the residual error will be equal to $\beta (\sec \alpha_1 - \sec \alpha_2)$ and will be zero when both the points are at the same elevation.

11. List the methods of checking in an open traverse and closed traverse. (AUC May/June 2012)

Checks in Open Traverse:

No direct check of angular measurement is available. However, indirect checks can be made as shown in below figures.

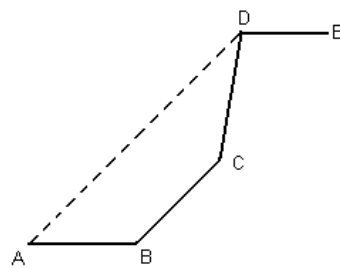


Fig (a)

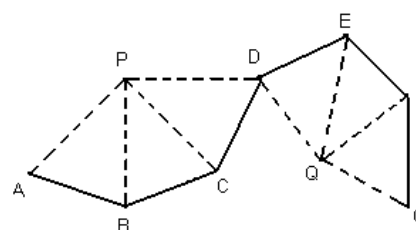


Fig (b)

In figure (a), in addition to the observation of bearing of AB at station A, bearing of AD can also be measured, if possible. Similarly, at D, bearing of DA can be measured and check applied. If the two bearings differ by 180° , the work (upto D) may be accepted as correct. If there is small discrepancy, it can be adjusted before proceeding further.

Another method, which furnishes a check when the work is plotted is as shown in figure(b) and consists in reading the bearings to any prominent point P from each of the consecutive stations. The check in plotting consists in laying off the lines AP, BP, CP, etc. and noting whether the lines pass through one point.

In case of long and precise traverse, the angular errors can be determined by astronomical observations for bearing at regular intervals during the progress of the traverse.

Checks in closed Traverse:

The errors involved in traversing are two kinds: linear and angular. For important work the most satisfactory method of checking the linear measurements consists in chaining each survey line a second time, preferably in the reverse direction on different dates and by different parties. The following are the checks for the angular work.

1) Traverse by included angles:

- The sum of measured interior angles should be equal to $(2N - 4)$ right angles, where N = number of sides of the traverse.
- If the exterior angles are measured, their sum should be equal to $(2N + 4)$ right angles.

2) Traverse by deflection angles:

The algebraic sum of the deflection angles should be equal to 360° , taking the right-hand deflection angles as positive and left-hand angles as negative.

3) Traverse by direct observation of bearings:

The fore bearing of the last line should be equal to its back bearing $\pm 180^\circ$ measured at the initial station.

12. The measured lengths and bearings of the sides of a closed traverse ABCDE run in anti-clockwise direction are tabulated below. Calculate the length of CD and DE. (AUC May/June 2012)

Line	Length(m)	Bearing
AB	298.7	$0^\circ 0'$
BC	205.7	N $25^\circ 12'$ W
CD	-	S $75^\circ 6'$ W
DE	-	S $56^\circ 24'$ E
EA	213.4	N $35^\circ 36'$ E

Solution:

Line	Latitude		Departure	
	+	-	+	-
AB	298.7		0	
BC	186.12			87.58
EA	173.52		124.23	
Sum	658.92		124.23	87.58
	$\Sigma L^I = 658.92$		$\Sigma D^I = 36.65$	

Latitude of CE = $-\Sigma L^I = -658.92$ m

Departure of CE = $-\Sigma D^I = -36.65$ m

Since latitude and departure of CE is negative. It lies in SW quadrant.

The reduced bearing of CE (θ) is

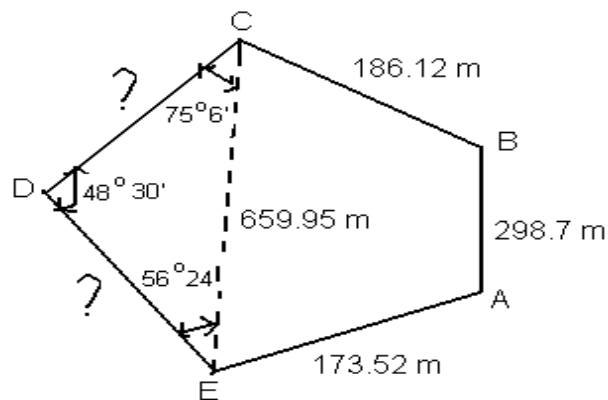
$$\tan \theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{36.65}{658.92} = 0.056$$

$$\theta = \tan^{-1}(0.056)$$

Bearing of CE, $\theta = S 3^\circ 12' W = 183^\circ 12'$

$$\text{Length of CE} = \frac{\text{Latitude}}{\cos \theta} = \frac{658.92}{\cos(3^\circ 12')} = 659.95 \text{ m}$$

Length of CE = 659.95 m



Angle DCE = $\alpha = 75^\circ 6'$

Angle CDE = $\beta = 48^\circ 30'$

Angle DEC = $\gamma = 56^\circ 24'$

$$\frac{DE}{\sin \alpha} = \frac{CE}{\sin \beta} = \frac{DC}{\sin \gamma}$$

$$\frac{DE}{\sin 75^{\circ} 6'} = \frac{659.95}{\sin 48^{\circ} 30'} = \frac{DC}{\sin 56^{\circ} 24'}$$

$$\frac{DE}{\sin 75^{\circ} 6'} = \frac{659.95}{\sin 48^{\circ} 30'}$$

$$\mathbf{DE = 851.53 \text{ m}}$$

$$\frac{DC}{\sin 56^{\circ} 24'} = \frac{659.95}{\sin 48^{\circ} 30'}$$

$$\mathbf{DC = 733.94 \text{ m}}$$

13. From the following data of a closed traverse PQRS. Calculate the length and bearing of the line SP. (AUC Nov/Dec 2012)

Line	Length(m)	WCB
PQ	85	N 83° 36' E
QR	137	N 42° 15' E
RS	67	N 63° 18' W

Solution:

Line	Latitude		Departure	
	+	-	+	-
PQ	9.47		84.47	
QR	101.41		92.11	
RS	30.10			59.85
Sum	140.98		176.58	59.85
	$\Sigma L^1 = 140.98$		$\Sigma D^1 = 116.73$	

Latitude of SP = - ΣL^1 = - 140.98 m

Departure of SP = - ΣD^1 = -116.73 m

Since latitude and departure of SP is negative. It lies in SW quadrant.

The reduced bearing of SP (θ) is

$$\tan \theta = \frac{\text{Departure}}{\text{Latitude}} = \frac{116.73}{140.98} = 0.827$$

$$\theta = \tan^{-1}(0.827)$$

Bearing of SP, $\theta = S 39^\circ 35' W = 219^\circ 35'$

$$\text{Length of SP} = \frac{\text{Latitude}}{\cos \theta} = \frac{140.98}{\cos(39^\circ 35')} = 182.92 \text{ m}$$

Length of SP = 182.92 m

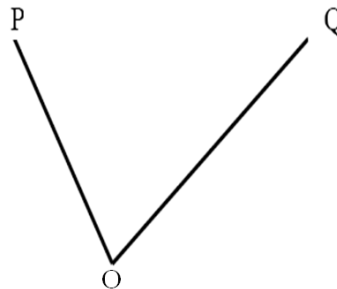
14. Explain the angle measuring procedures using theodolite.

(AUC May/June 2013)

The instruments used to measure the angles are Transit theodolite, Tripod and Ranging rods (2no.s).

The following procedures are used to find the angles,

- Set up the instrument over 'O' and level it accurately.
- With the help of upper clamp and tangent screw, set 0° reading on vernier 'A'. Note the reading of vernier 'B'.
- Release the upper clamp and direct the telescope approximately towards the point 'P'. Tighten the lower clamp and bisect point 'P' accurately by lower tangent screw.
- Release the upper clamp and turn the instrument clock-wise towards Q. Clamp the upper clamp and bisect 'Q' accurately with the upper tangent screw. Note the readings of verniers 'A' and 'B' to get the values of the angle POQ.
- Release the lower clamp and turn the telescope clockwise to sight P again. Bisect P by using the lower tangent screw.



- Release the upper clamp, turn the telescope clockwise and sight Q. Bisect Q by using the upper tangent screw.
- Repeat the process until the angle measured (required number of times is 3). The average angle with face left will be equal to final reading divided by three.
- Change face and make three more repetitions as described above. Find the average angle with face right, by dividing the final reading by three.
- The average horizontal angle is then obtained by taking the average of the two angles with face left and face right.

$$PQ = \sqrt{OP^2 + OQ^2 - 2 OP OQ \cos \theta}$$

15. Explain Bowditch rule with example.**(AUC May/June 2013)**

The basis of this method is on the assumptions that the errors in linear measurements are proportional to \sqrt{l} where l is the length of a line. The Bowditch's rule is also termed as the compass rule. It is mostly used to balance a traverse where linear and angular measurements are equal precision. The total error in latitude and in the departure is distributed in proportion to the lengths of the sides.

Bowditch Rule is**Correction to latitude (or departure) of any side**

$$= \text{Total error in latitude (or departure)} \times \frac{\text{Length of that side}}{\text{perimeter of traverse}}$$

Thus if C_L = Correction to latitude of any side

C_D = Correction to departure of any side

$\sum L$ = total error in latitude

$\sum D$ = total error in departure

$\sum l$ = length of the perimeter

l = length of any side

We have $C_L = \sum L \times \frac{l}{\sum l}$ and $C_D = \sum D \times \frac{l}{\sum l}$