TRAVERSE

A traverse consists of a series of straight lines connected successively at established points, along the route of survey. The points defining the ends of the traverse line are called traverse station or traverse points. Distance (horizontal distance) between traverse stations are known as traverse side which are measured by using a tape or electronic measuring equipment.

Traversing is the traditional surveying method which is used to determine plane coordinates (rectangular coordinates) of established traverse stations.

TRAVERSE

A traverse is currently the most common of several possible methods for establishing a series or network of monuments with known positions on the ground. Such monuments are referred to as horizontal control points and collectively, they comprise the horizontal control for the project.

This method is employed to establish horizontal control, the result is to assign rectangular coordinates to each control point within the survey. This allows each point to be related to every other point with respect to distance and direction, as well as to permit areas to be calculated when needed.

PURPOSE OF TRAVERSE STATIONS

- To determine the horizontal location of natural or artificial objects and topographic detail points on the ground to prepare plans or maps with contour lines.
- To determine the location of points of which horizontal positions are unknown by the help of other points of which positions are known by making necessary observations between traverse stations and traverse sides.
- Some measurements on scaled plans can be applied on the ground.

TRAVERSE SURVEYING

Field Work

- Reconnaissance
- Selection of Station Sites
- Marking of Stations
- Field Measurement
  - Linear Measurement
  - Angular Measurement
- Computations

Office Work

- Computation of traverse and control of computations
- Plotting map or plan

TRAVERSE SURVEYING

Reconnaissance:

Reconnaissance provides opportunity for surveyors to gather information about fieldwork such as terrain information and other potential effects on surveying.

During reconnaissance , the usability of existing stations are examined, suitable location of traverse stations are identified and the method of traversing is decided for the field conditions. Also, types of monuments to be established on the ground are determined.

TRAVERSE SURVEYING

Selection of Station Sites:

- Traverse stations must be established on the firm ground.
- Intervisibility between adjacent stations, forward and back, must be maintained for angle and distance observations.
- The stations should also be established in convenient locations that allow for easy access
- Efficient numbers of topographic detail points can be observed from selected traverse stations. Station locations must be selected to permit complete coverage of the area to be mapped.
- The traverse sides should not be intersected road or similar facilities so long as there is not a necessity.

TRAVERSE SURVEYING

Referencing Traverse Stations:

Referencing is the process of measuring the distances and directions from station points to near fixed points or objects which can be identified easily on the ground.

Traverse stations often must be found and reoccupied months or even years after they are established. They may be destroyed through construction or other activity. Therefore, it is important that they be referenced by creating observational ties to them. Therefore, they can be relocated if obscured or reestablished if destroyed.

TRAVERSE SURVEYING

a)Linear Measurements:

Distance (horizontal distance) between traverse stations are known as traverse side which are measured by using a tape, electronic measuring equipment or total stations.

Observation of traverse length with taping:

Averages of distances observed forward and back will provide increased accuracy, and the repeat readings afford a check on the observation.

S1 = the distance of AB line (forward observation) with taping

S2 = the distance of AB line (backward observation) with taping

d = tolerance (in respect of Production Regulation of Large Scale Map standards.

TRAVERSE SURVEYING

Observation of traverse length with taping:

if Absolute value (S2-S1) ≤ d

distance of AB line = (S1 + S2) / 2 (mean value of observations)

if not absolute value (S2- S1) ≤ d observations are dismissed and observations are repeated.

The maximum distance of a traverse length which is measured by using taping method is 150 meters in respect of Production Regulation of Large Scale Map standards.

TRAVERSE SURVEYING

a)Angular Measurements:

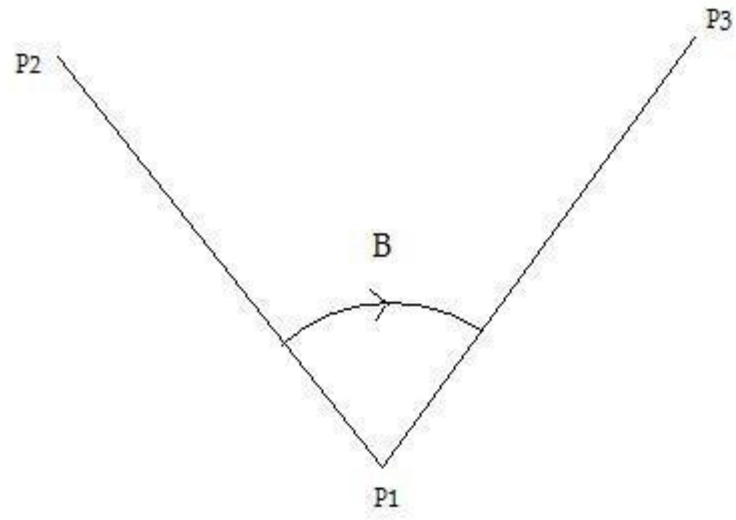


Figure: 2

P1 – station point

P2 – left target (back sight)

P3 – right target (foresight)

B : horizontal angle (clockwise)

Face I = P2 then P3 observations

Face II =P3 then P2 observations

TRAVERSE SURVEYING

a)Angular Measurements:

An *angle* is defined as the difference in direction between two convergent lines. A *horizontal angle* is formed by the directions to two objects in a horizontal plane.

- *Interior angles* are measured clockwise or counter-clockwise between two adjacent lines on the inside of a closed polygon figure.
- *Exterior angles* are measured clockwise or counter-clockwise between two adjacent lines on the outside of a closed polygon figure.
- *Angles to the right* are turned from the *back* line in a clockwise or right hand direction to the ahead line.
- *Angles to the left* are turned from the back line in a counter-clockwise or left hand direction to the ahead line.

TRAVERSE SURVEYING

a)Angular Measurements:

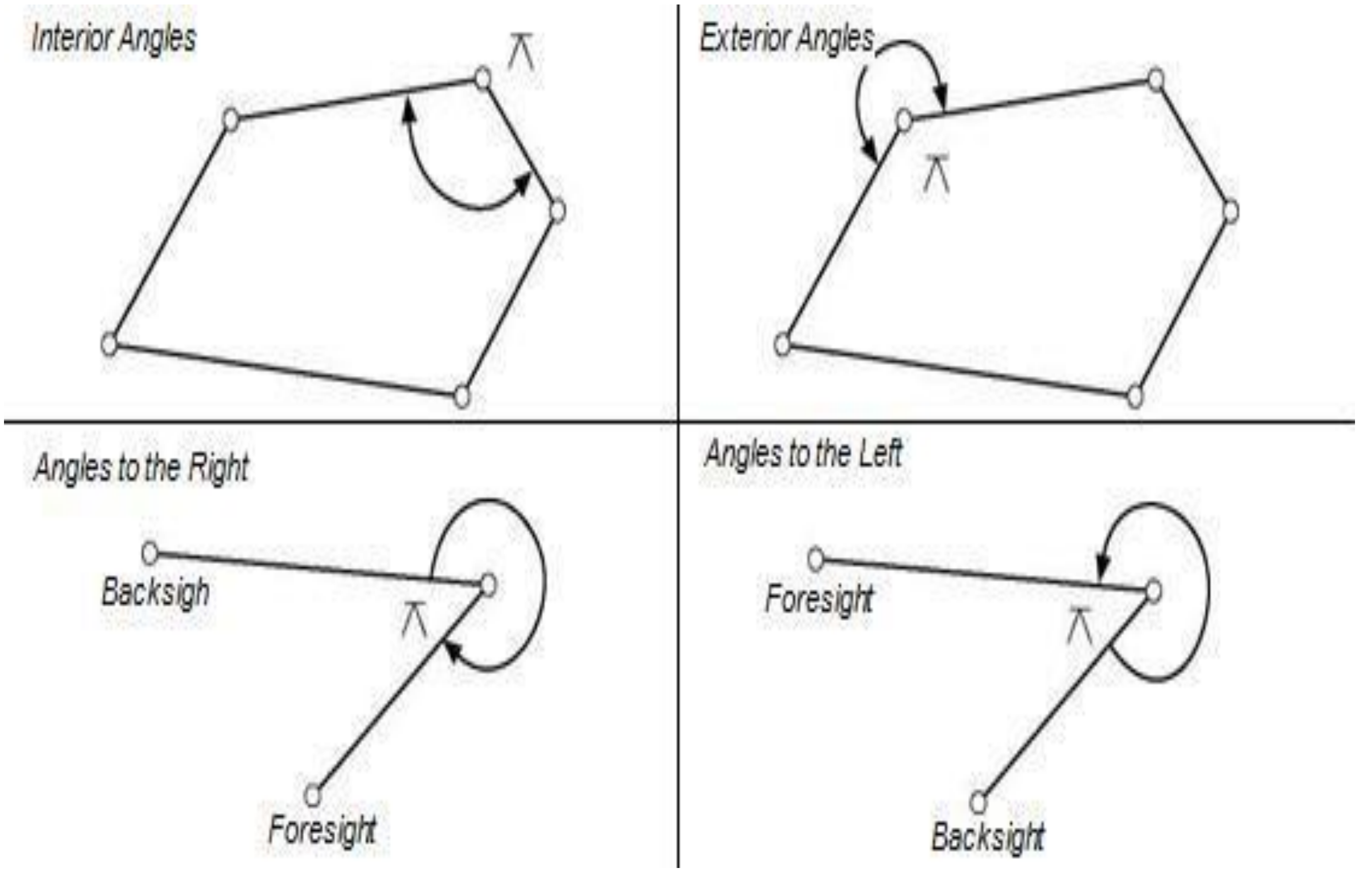


Figure:3

TRAVERSE SURVEYING

a)Angular Measurements:

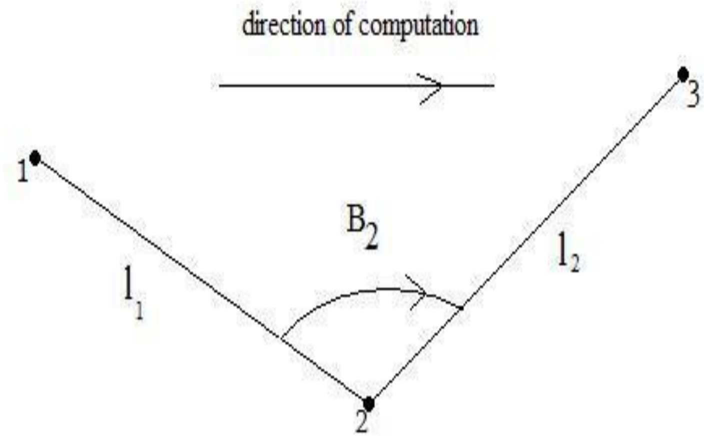


Figure:4

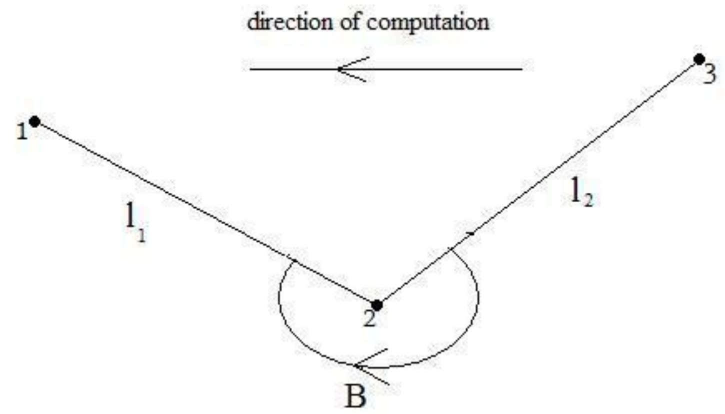


Figure:5

Traverse angle is a horizontal angle which is measured between two adjacent traverse sides. The angles which are left side of the route of survey or direction of computation are used as a traverse angle.

TRAVERSE SURVEYING

a)Angular Measurements:

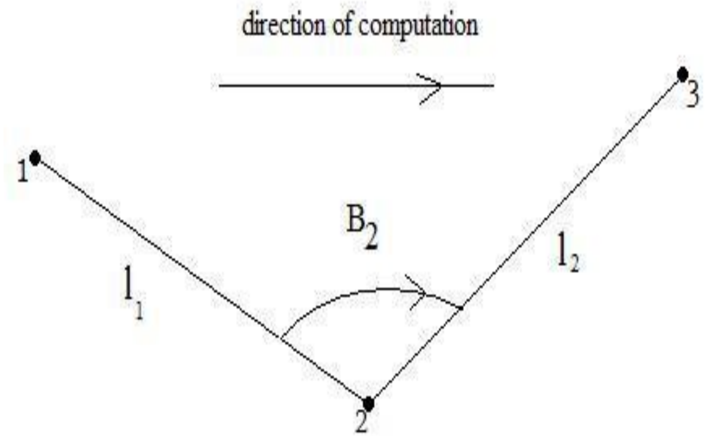


Figure:4

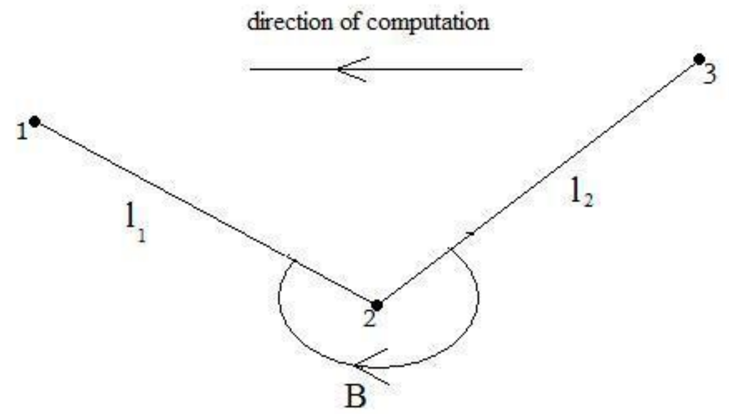


Figure:5

To reduce mistakes in reading, recording, and computing, traverse angles should always be turned clockwise from the backsight station to the foresight station. Also traverse angles are measured by using set method.

TYPES OF TRAVERSE

There are three kinds of traverses with their geometrical properties;

- Open traverse
- Closed-loop traverse
- Closed-link traverse

Open Traverse:

Open Traverse does not create a closed shape and may begin at a point of known position and ends at a point of previously unknown position. Computational check is not possible to detect error or blunder in distance and directions.

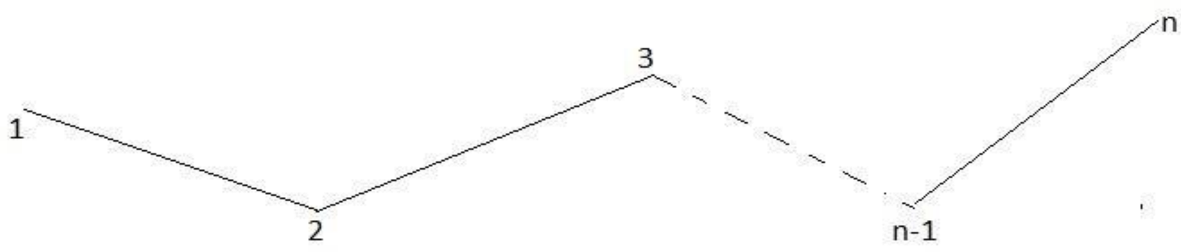


Figure:6

TYPES OF TRAVERSE

Closed-loop Traverse:

Closed Traverse creates a closed geometrical shape (polygon). A closed traverse is one that either begins and ends at the same point. Therefore the angles can be closed geometrically and the position closure can be determined mathematically.

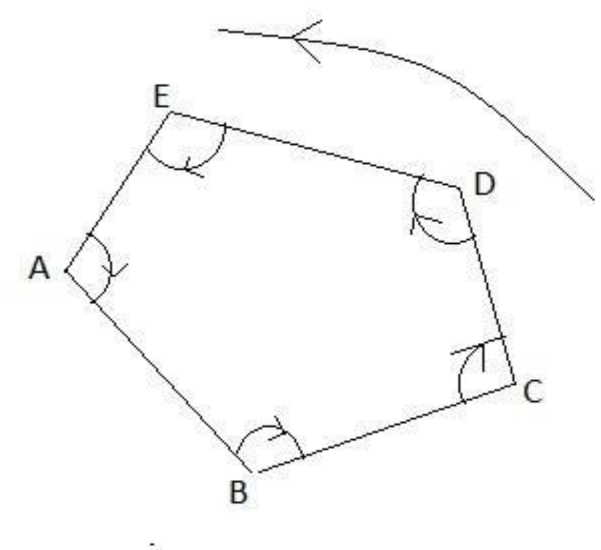


Figure:7

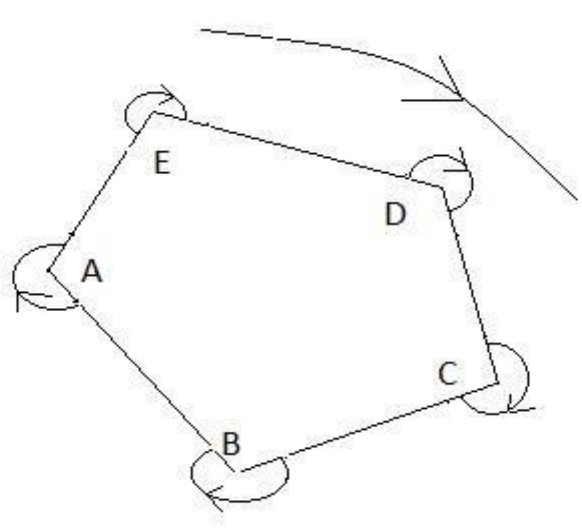


Figure:8

TYPES OF TRAVERSE

Closed-link Traverse:

A link traverse is connected to at least two points, at the beginning and at the end of traverses ,whose coordinates have been previously determined. Calculations can be made to check for errors.

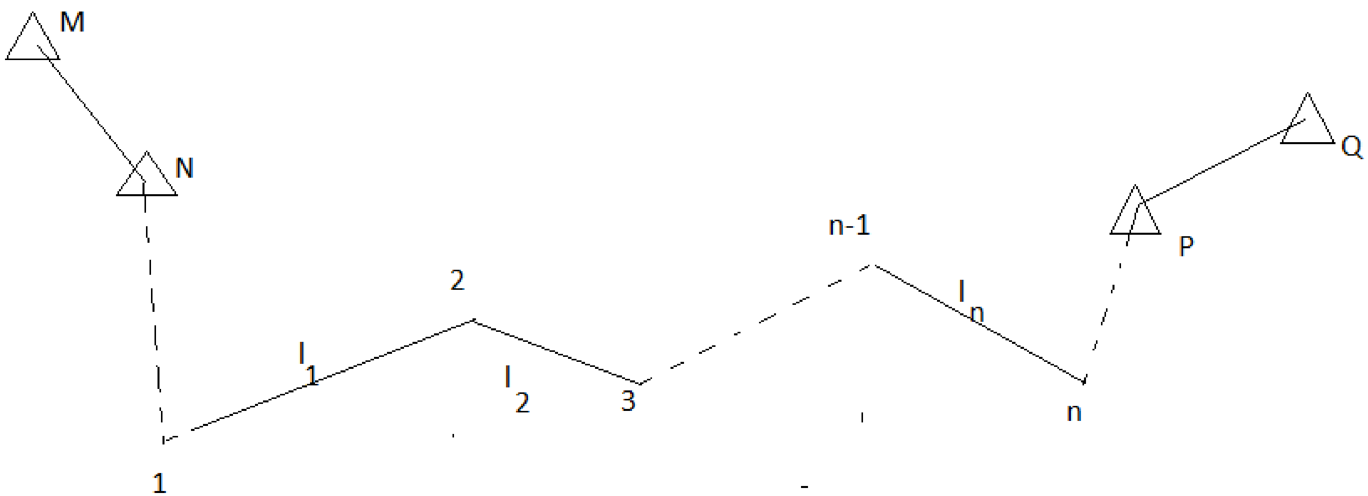


Figure:9

TRAVERSE COMPUTATION

Open Traverse Computation:

Traverse surveying in the field yields observed angles or directions and length of the traverse sides. Thus, these parameters are used in traverse computations which are performed in a plane rectangular coordinate system.

Computation of Azimuths:

Computational check is not possible to detect error or blunder in distance and directions in open traverse computation. Therefore, it is impossible to balance traverse angles .

AZIMUTHS

- The azimuth of a line on the ground is its horizontal angle measured clockwise from the meridian to the line. Azimuth gives the direction of the line with respect to the meridian. In plan surveying azimuths are generally measured from the north. Azimuths may have values between 0^g and 400^g (0 – 360 degrees).

AZIMUTH

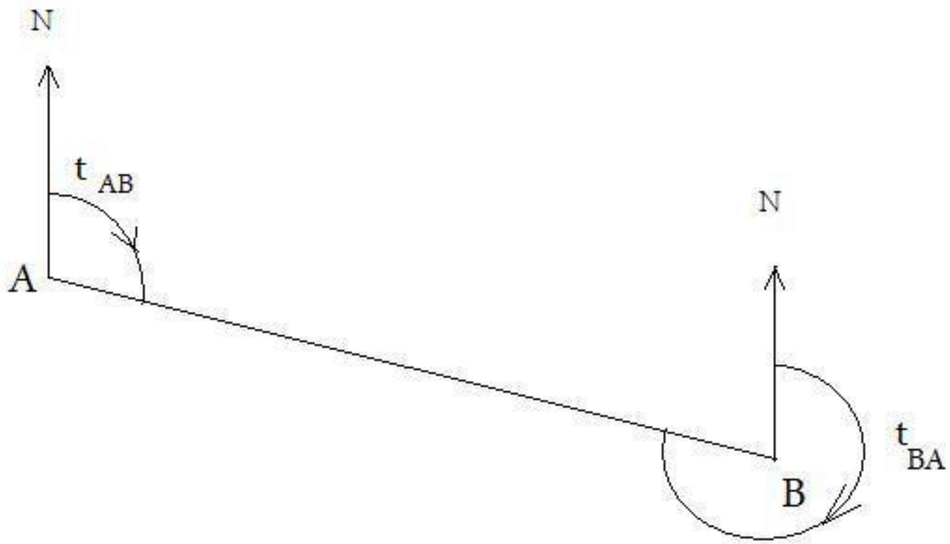


Figure:2

t_{AB} = forward azimuth of AB line

t_{BA} = back azimuth of AB line

AZIMUTH

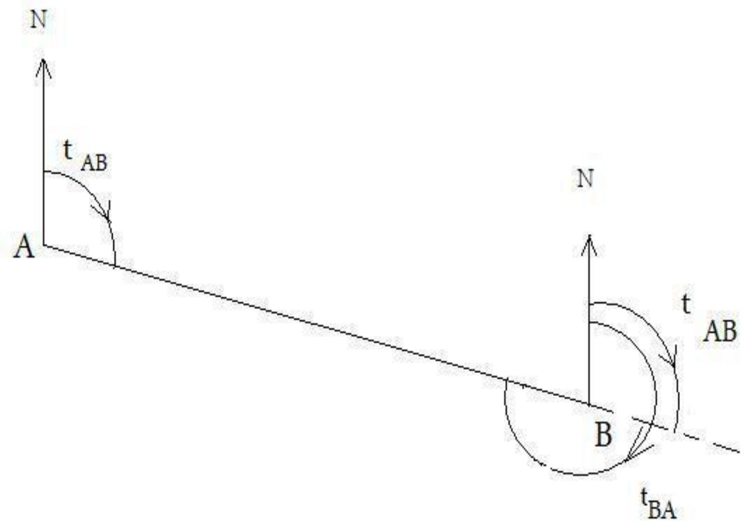


Figure:3

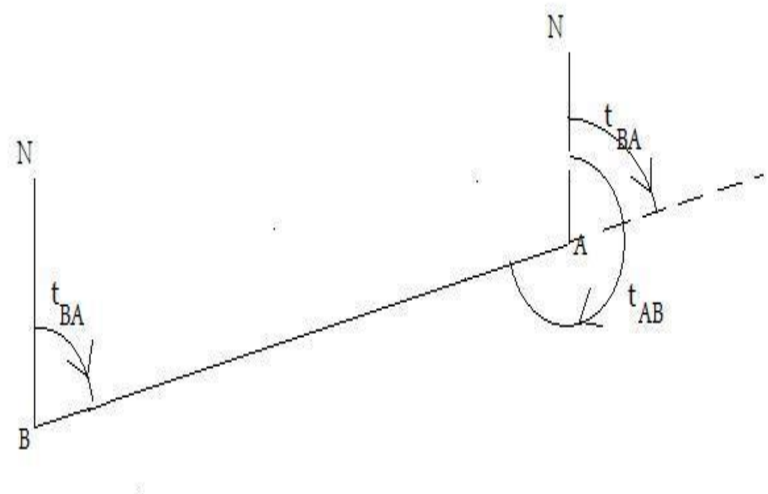


Figure:4

In plane surveying, forward azimuths are converted to back azimuths, and vice versa, by adding or subtracting 200^g .

$$t_{AB} < 200^g \longrightarrow t_{BA} = t_{AB} + 200^g$$

$$t_{AB} > 200^g \longrightarrow t_{BA} = t_{AB} - 200^g$$

RECTANGULAR COORDINATE SYSTEM

$\Delta y (departure) and\ \Delta x\ (latitude)$ indicate distances north or south and east or west between two points.

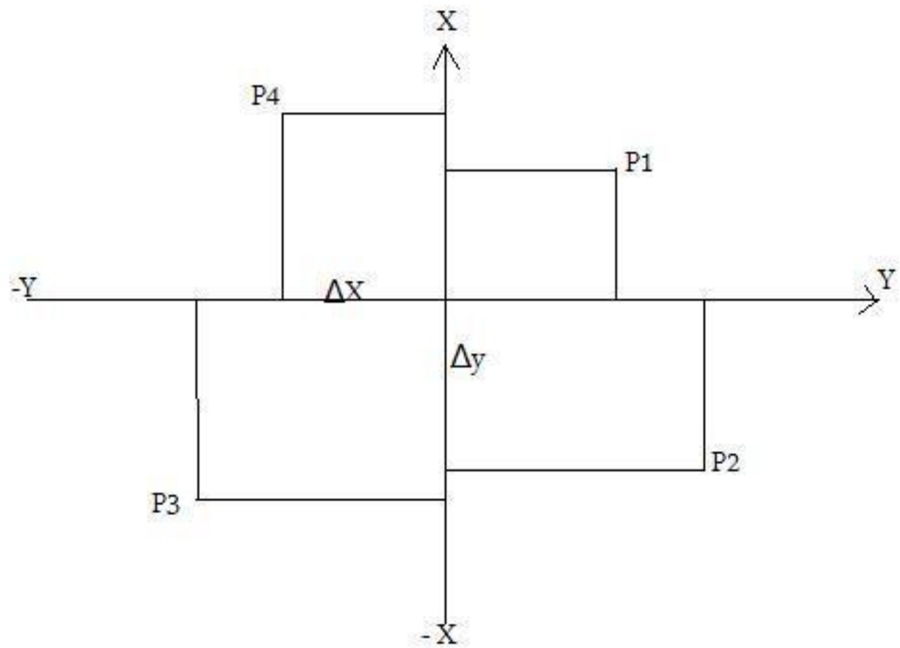


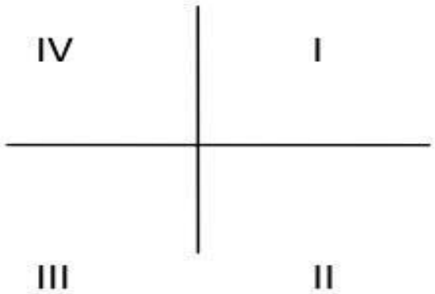
Figure:5

In plane surveys it is convenient to perform the work in a rectangular *XY* coordinate system.

Direction of +X refers to north,

Direction of +Y refers to east,

RECTANGULAR COORDINATE SYSTEM



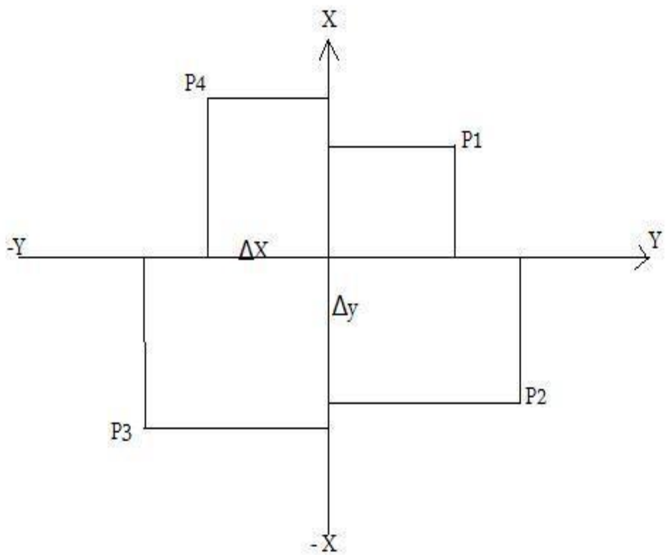
The *x* and *y* axes divide the plane into four parts. The quadrants are numbered clockwise starting with the upper right quadrant.

QUADRANT	**ΔX**	**ΔY**
I. QUADRANT	+	+
II.QUADRANT	-	+
III.QUADRANT	-	-
IV.QUADRANT	+	-

TRAVERSE COMPUTATION

Open Traverse Computation:

Computation Departure and Latitudes:



Direction of +X refers to north,

Direction of +Y refers to east,

Easting is the eastward-measured distance (or the *y*-coordinate) and northing is the northward-measured distance (or the *x*-coordinate)

TRAVERSE COMPUTATION

Closed-Loop Traverse Computation:

Traverse surveying in the field yields observed angles or directions and length of the traverse sides. Thus, these parameters are used in traverse computations which are performed in a plane rectangular coordinate system.

The usual steps followed in making elementary traverse computations are;

- Adjusting angles or directions to fixed geometric conditions
- Determining azimuths of the traverse lines.
- Calculating departures and latitudes and adjusting them for misclosure
- Computing rectangular coordinates of the traverse stations.

TRAVERSE COMPUTATION

Closed-Loop Traverse Computation:

Balancing Traverse Angles:

For closed traverses, angle balancing is done readily since the total error is known. The correction for each angle is found by dividing the total angular misclosure by the number of angles. Also another methods for balancing angles is that making larger corrections to angles where poor observing conditions were present. The first method is almost always applied.

TRAVERSE COMPUTATION

Closed-Loop Traverse Computation:

The Angular Misclosure:

The difference between total measured traverse angles and total angles which are computed for geometrical shape is described as the angular misclosure.

$f_{\beta} = \Sigma$ (measured traverse angles) - Σ (computed angles geometrically)

Maximum Angular Misclosure:

The maximum angular misclosure of a traverse angles is calculated by below formula in respect of Production Regulation of Large Scale Map standards.

$$F_B = 1.5^c \sqrt{n}$$

n = number of traverse angles

TRAVERSE COMPUTATION

Closed Loop Traverse Computation:

Departure (ΔY) and Latitude (ΔX) Closure Conditions :

For a closed-polygon traverse, It can be reasoned that if all angles and distances were measured perfectly, the algebraic sum of the departures of all courses in traverse should equal zero. Likewise, the algebraic sum of all latitudes should equal zero. Because starting and ending control points are the same point for closed-polygon traverse.

The observations are not perfect and errors exist in the angles and distances, the conditions just stated rarely occur. The amounts by which they fail to be met are termed departure misclosure and latitude misclosure. Their values are computed by algebraically summing the departures and latitudes and comparing the totals to required conditions.

TRAVERSE COMPUTATION

Closed Loop Traverse Computation:

Departure (ΔY) and Latitude (ΔX) Closure Conditions :

Control of (ΔY) and (ΔX) for Closed-Loop Traverse:

$$\Sigma \Delta Y = 0$$

$$\Sigma \Delta X = 0$$

Computation of Traverse Coordinate Misclosure :

$$f_y = 0 - \Sigma \Delta Y$$

$$f_x = 0 - \Sigma \Delta X$$

TRAVERSE COMPUTATION

Closed Loop Traverse Computation:

Departure (ΔY) and Latitude (ΔX) Closure Conditions :

$$F_{Q[m]} = 0.05 + 0.15\sqrt{S_{[km]}}$$

$$F_{L[m]} = 0.05 + 0.04\sqrt{n-1}$$

$S_{[km]}$ total length of traverse sides

$$f_Q = \frac{1}{S}(f_y[\Delta X] - f_x[\Delta Y])$$

$$f_L = \frac{1}{S}(f_y[\Delta Y] + f_x[\Delta X])$$

$$S = \sqrt{[\Delta Y]^2 + [\Delta X]^2}$$

n = number of stations

F_Q= limit of latitude error

FL=limit of departure error

fQ = error of latitude

fL = error of departure

TRAVERSE COMPUTATION

Closed Loop Traverse Computation:

Departure (ΔY) and Latitude (ΔX) Closure Conditions :

It should be;

$$\mathbf{F_Q > f_Q}$$

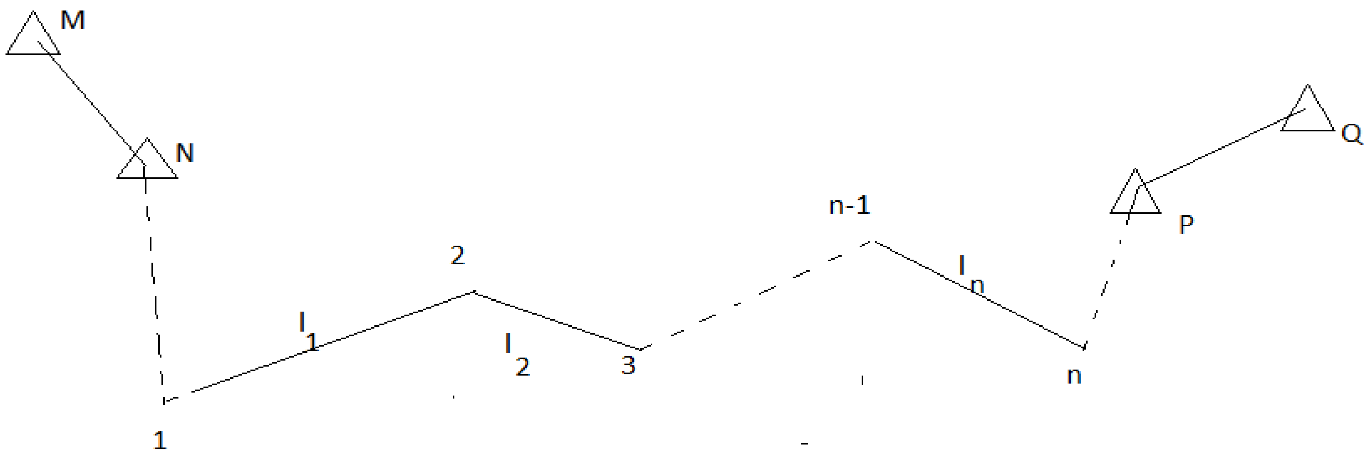
$$\mathbf{F_L > f_L}$$

it can be accepted and the departures and latitudes of traverse courses can be adjusted in proportion to their lengths.

TRAVERSE COMPUTATION

Closed Link Traverse Computation:

Balancing Traverse Angles:



Firstly, azimuth of MN traverse side and azimuth of PQ traverse side must be calculated. Az_{MN} and Az_{PQ} are calculated.

TRAVERSE COMPUTATION

Closed Link Traverse Computation:

Balancing Traverse Angles:

Angular condition:

$t_{PQ} = t_{MN} + \Sigma\beta - m.200^g$

- m= the number of station with starting and end points.

Angular misclosure:

$f_\beta = (t_{MN} + \Sigma\beta - m.200^g) - t_{PQ}$

Maximum Angular Misclosure:

The maximum angular misclosure of a traverse angles is calculated by below formula in respect of Production Regulation of Large Scale Map standards.

$F_B = 1.5^c \sqrt{n}$ n= number of the traverse angles

TRAVERSE COMPUTATION

Closed-Link Traverse Computation:

Control of angle misclosure error:

If the angle misclosure (f_β) < the maximum angle misclosure (F_β)

It can be accepted and measured traverse angles can be balanced.

The correction for each angle is found by dividing the total angular misclosure by the number of angles in respect of Production Regulation of Large Scale Map standards.

$$V_i = -(f_\beta) / n$$

Adjusted traverse angles :

$$\beta'_i = \beta_1 + v_\beta$$

TRAVERSE COMPUTATION

Closed Link Traverse Computation:

Computation Departure (ΔY) and Latitudes (ΔX) :

After balancing the angles and calculating azimuths for each line, traverse closure is checked by computing (ΔY), (ΔX) of each lines.

$$\Delta Y = S_{AB} \cdot \sin t_{AB}$$

$$\Delta X = S_{AB} \cdot \cos t_{AB}$$

Departure (ΔY) and Latitude (ΔX) Closure Conditions :

$$(Y_P - Y_N) = \Sigma \, \mathbf{\Delta Y}$$

$$(X_P - X_N) = \Sigma \, \mathbf{\Delta X}$$

TRAVERSE COMPUTATION

Closed Link Traverse Computation:

Departure (ΔY) and Latitude (ΔX) Closure Conditions

$$F_{Q[m]} = 0.05 + 0.15\sqrt{S_{[km]}}$$

$$F_{L[m]} = 0.05 + 0.04\sqrt{n-1}$$

$$f_Q = \frac{1}{S}(f_y[\Delta X] - f_x[\Delta Y])$$

$$f_L = \frac{1}{S}(f_y[\Delta Y] + f_x[\Delta X])$$

$$S = \sqrt{[\Delta Y]^2 + [\Delta X]^2}$$

F_Q= limit of latitude error

FL=limit of departure error

fQ = error of latitude

fL = error of departure

TRAVERSE COMPUTATION

<u>Closed Link Traverse Computation:</u>

<u>Departure (ΔY) and Latitude (ΔX) Closure Conditions :</u>

It should be;

$$\mathbf{F_Q > f_Q}$$

$$\mathbf{F_L > f_L}$$

can be accepted and the departures and latitudes of traverse courses can be adjusted in proportion to their lengths.

Fundamental tasks of plane surveying

- In plane surveying calculations, we can talk about a subset of tasks that are repeatedly carried out. These basic computational steps concern the calculation of a point's coordinates using a known point (a control point) and the measured distance and azimuth. The inverse of this computation, when we calculate the distance and the azimuth using the coordinates of two control points, is also essential. These two computations are therefore called the fundamental tasks of plane surveying.

The first fundamental task of surveying

Our task is to find the coordinates of the unknown point B using control point *A* with known coordinates, the azimuth (AB) and the distance S*A*B measured at the control point

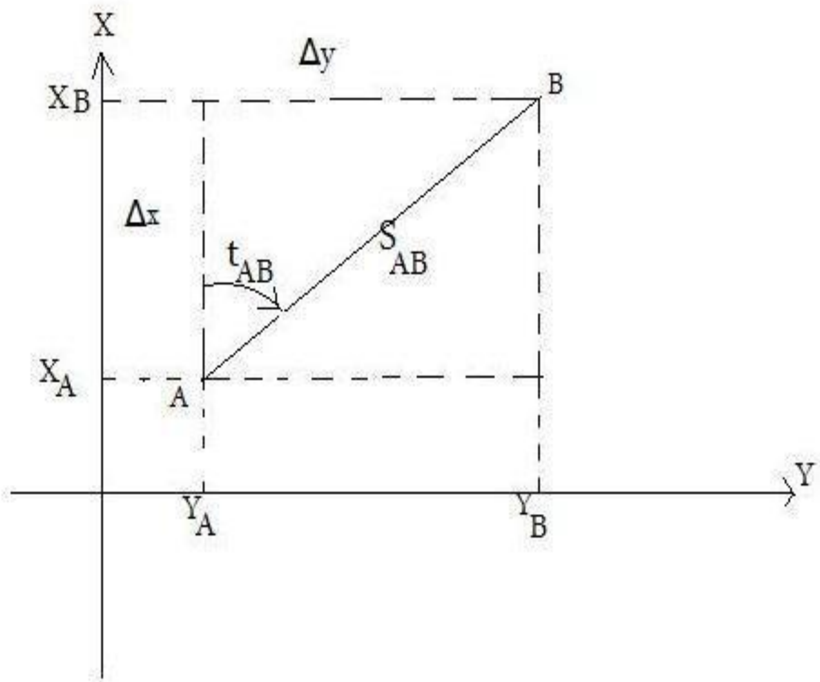
Fundamental Computation -1

Known: $A\ (X_A, Y_A)$

S_{AB}

t_{AB}

Unknown: $B\ (X_B, Y_B)$



The first fundamental task of surveying

We can calculate the coordinate difference between the control point and the unknown point using the right triangle in the figure:

Fundamental Computation -1

Formula:

$\Delta Y = S_{AB} \cdot \sin t_{AB}$

$\Delta X = S_{AB} \cdot \cos t_{AB}$

- $Y_B = Y_A + \Delta Y = Y_A + S_{AB} \sin t_{AB}$

- $X_B = X_A + \Delta X = X_A + S_{AB} \cos t_{AB}$

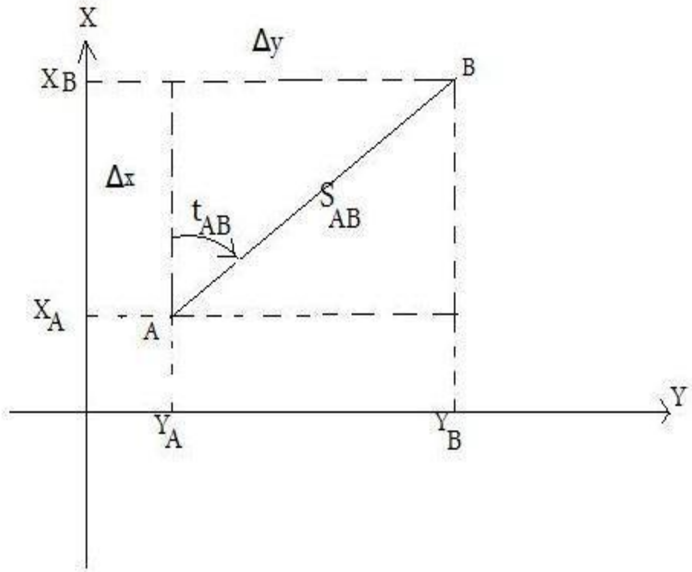


Figure:9

Now, we simply have to add the coordinate differences to the coordinates of the control point to arrive at the coordinates of point B:

Fundamental Computation -1

Question1:

Known:

- A (Y_A = 9417.41 m ; X_A = 8418.62 m)
- S_{AB} = 94.17 m , $t_{AB} = 347^g .3540$

Unknown:

B (Y_B ; X_B)

Solution:

- Y_B = 9417.41 + (94.17 * sin(347.3540)) = 9417.41 + 69.30 = 9348.11 m
- X_B = 8418.62 + (94.17 * cos(347.3540)) = 8418.62 + 63.76 = 8482.38 m

The second fundamental task of surveying

The second fundamental task is considered the inverse of the first task. In this case, the coordinates of two control points are known; our task is to compute the distance between the two points and azimuth between them.

Fundamental Computation -2

Known:

$A\ (X_A, Y_A)$

$B\ (X_B, Y_B)$

Unknown:

S_{AB}, t_{AB}, t_{BA}

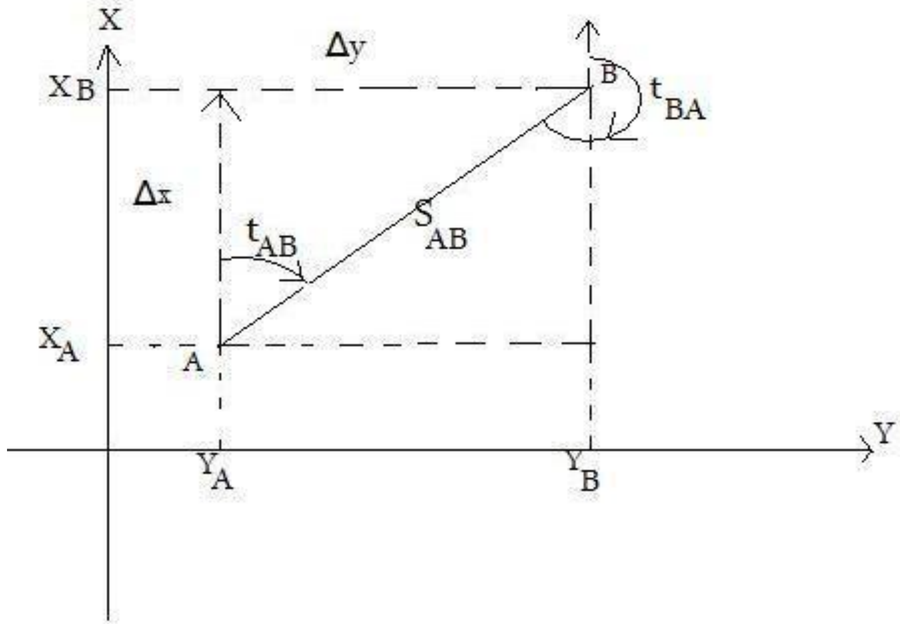


Figure: 10

The second fundamental task of surveying

We first have to calculate the coordinate differences between the two points. The order of the points in the formula is essential as the signs of the coordinate differences directly affect the value of the whole circle bearing. The rule is that if we are computing the azimuth of the direction from point A to point B, then we subtract the coordinates of point A from point B (starting point from end point):

Fundamental Computation -2

Formula:

$$\Delta Y = Y_B - Y_A$$

$$\Delta X = X_B - X_A$$

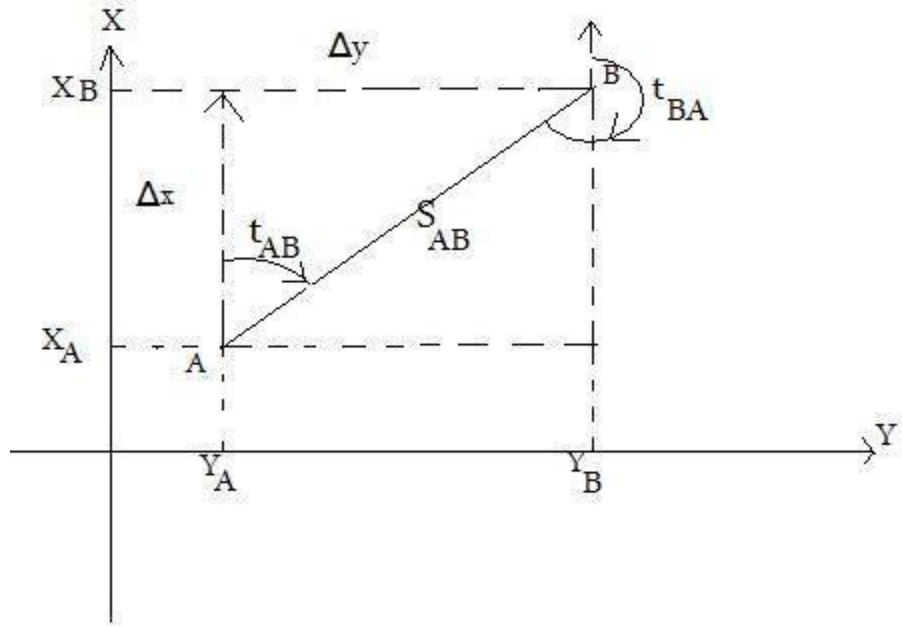


Figure: 11

Next, we can compute the distance between the two points using the Pythagoras' theorem:

$$S_{AB} = \sqrt{\Delta Y^2 + \Delta X^2}$$

Fundamental Computation -2

Formula:

$$\tan t_{AB} = \frac{\Delta Y_{AB}}{\Delta X_{AB}}$$

This equation is used for calculating the azimuth in first quadrant.

$$t_{AB} = \arctan\left(\frac{\Delta Y_{AB}}{\Delta X_{AB}}\right)$$

we compute the azimuth going from point A to point B. As the range of the inverse tangent function is between –90° and +90°, we have to use a two-step approach. We first calculate the value of an auxiliary angle

Fundamental Computation -2

Formula:

$$t'_{AB} = \arctan \frac{|\Delta Y_{AB}|}{|\Delta X_{AB}|}$$

We then use a decision matrix that gives us the correct formula for the azimuth depending on the sign of the coordinate differences:

QUADRANT	Δy / Δx	Azimuth
FIRST QUADRANT	+ / +	t = t'
SECOND QUADRANT	+ / -	$t = 200^g - t'$
THIRD QUADRANT	- / -	$t = 200^g + t'$
FOURTH QUADRANT	- / +	$t = 400^g - t'$

Fundamental Computation -2

Question2:

Known:

- A (Y_A = 1542.86 m ; X_A = 985.43 m)
- B(Y_B = 1686.22 m ; X_B = 1012.85 m)

Unknown:

S_{AB} , t_{AB}

Solution:

$\Delta Y = Y_B - Y_A$ $\quad$ $S_{AB} = \sqrt{(1686.22-1542.86)^2+(1012.85-985.43)^2}$

$\Delta X = X_B - X_A$

S_{AB} = 145.96 m

Fundamental Computation -2

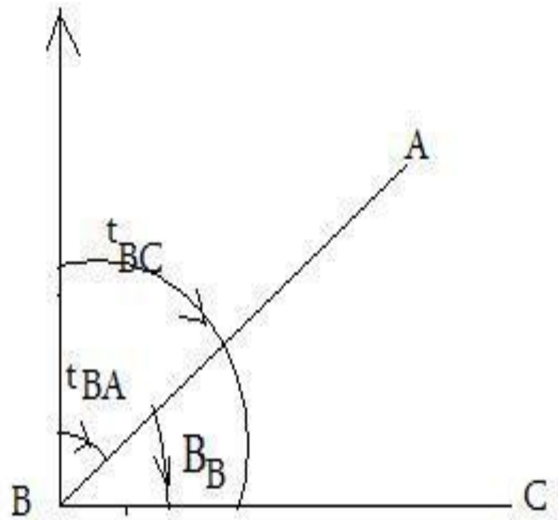
Solution:

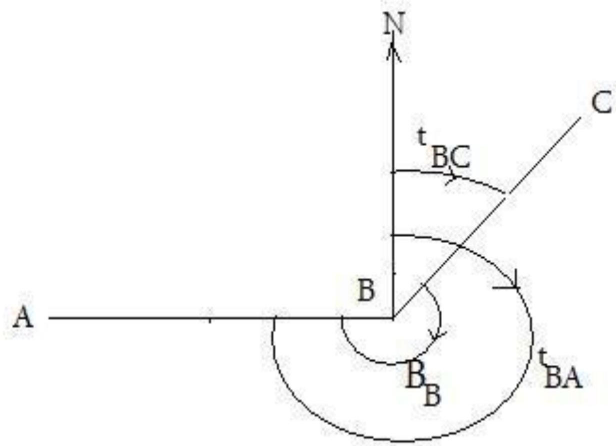
$$t'_{AB} = \arctan \frac{|\Delta Y_{AB}|}{|\Delta X_{AB}|} \qquad t' = \arctan \frac{|(+)143.36|}{|(+)27.42|} = 87^g.9689$$

QUADRANT	Δy / Δx	Azimuth
FIRST QUAD	+ / +	t = t’

$$t = t' = 87^g.9689$$

Fundamental Computation -3





Known:

- A(Y,X), B(Y,X), C(Y,X)

Unknown:

- $ß_B$

Question3:

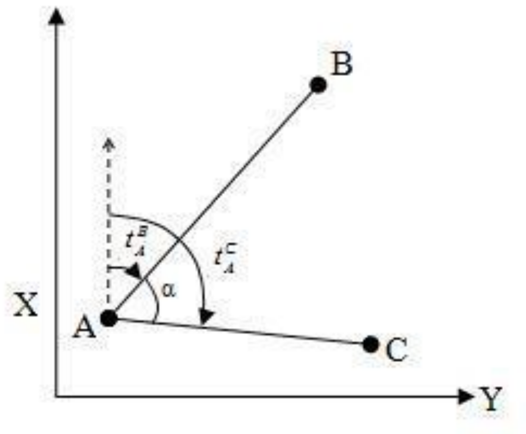


Figure:14

Known: A(Y_A =760.42m, X_A = 320.51m)

B(Y_B =840.75m, X_B = 390.62m)

C(Y_C = 910.71m, X_C =272.41m)

Unknown: α

Formula: $\alpha = t_{AC} - t_{AB}$

Fundamental Computation -3

Solution:

$$\alpha = t_A^C - t_A^B$$

$$\tan t_A'^C = \frac{|\Delta Y|}{|\Delta X|} = \frac{|Y_C - Y_A|}{|X_C - X_A|}, \quad \tan t_A'^B = \frac{|Y_B - Y_A|}{|X_B - X_A|}$$

$$t_A'^B = \text{Arctan}\left|\frac{840.75 - 760.42}{390.62 - 320.51}\right| = \quad +/+ \; \text{->} \; (\text{1.Quad}) \; \text{->} \; t_A'^B = t_A^B = 54^g.318$$

$$t_A'^C = \text{Arctan}\left|\frac{910.71 - 760.42}{272.41 - 320.51}\right| = \quad +/- \; \text{->} \; (\text{2.Quad}) \; \text{->} \; t_A'^C = 80^g.281$$

$$t_A^C = 200 - t_A'^C = 200 - 80.281 = 119^g.719$$

$$\alpha = t_A^C - t_A^B = 119.719 - 54.318 = 65^g.401$$

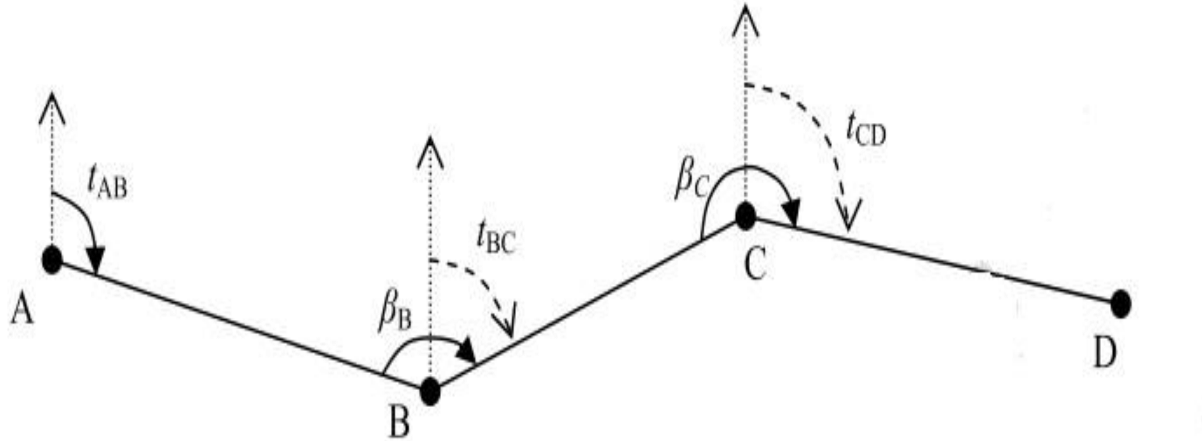
Fundamental Computation -4

Known:

t_{AB} , β_B

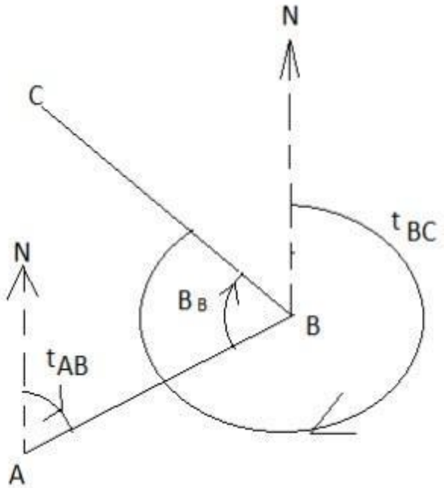
Unknown:

t_{BC}

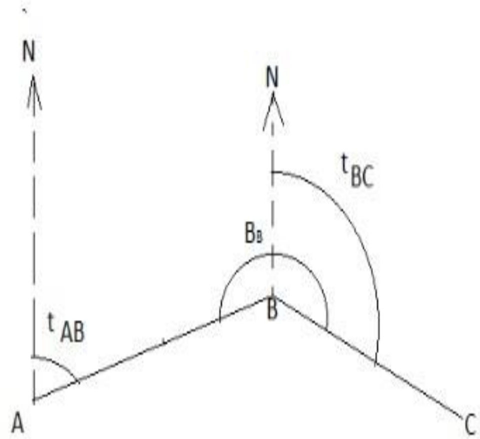


Fundamental Computation -4

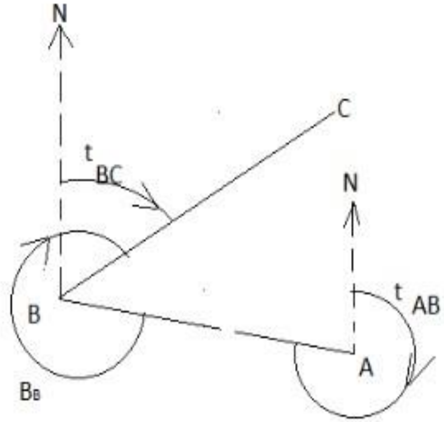
To solve this problem; three situations should be considered:



16. (a)



16. (b)



16. (c)

$$t_{BC} = t_{AB} + \beta_B + n * 200^{grad}$$

$$t_{AB} + \beta_B = K$$

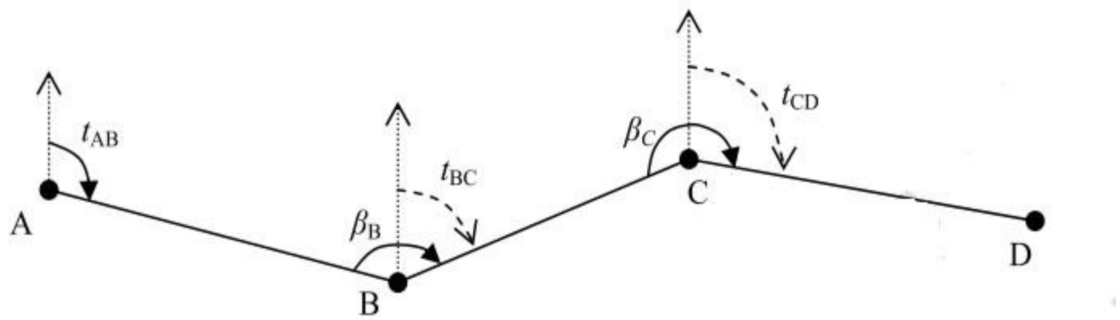
(16.a) K < 200^g ; K+ 200^g ; $t_{BC} = t_{AB} + \beta_B + 200^g$

(16.b) 200^g < K < 600^g ; K - 200^g ; $t_{BC} = t_{AB} + \beta_B - 200^g$

(16.c) K > 600^g ; K - 600^g ; $t_{BC} = t_{AB} + \beta_B - 600^g$

Fundamental Computation -4

Question4:



Known: $t_{AB} = 115^g.1420$ Unknown: t_{BC}, t_{CD}

$\beta_B = 165^g.3140$

$\beta_C = 235^g.2570$

Fundamental Computation -4

Solution:

$t'_{BC} = t_{AB} + \beta_B = 115^g .1420 + 165^g .3140 = 280^g .4560$

$*200^g < K < 600^g$; $K - 200^g$; $t_{BC} = t_{AB} + \beta_B - 200^g$

$t_{BC} = t'_{BC} - 200^g = 80^g .4560$

$t'_{CD} = t_{BC} + \beta_C = 80^g .4560 + 235^g .2570 = 315^g .7130$

$*200^g < K < 600^g$; $K - 200^g$; $t_{CD} = t_{BC} + \beta_C - 200^g$

$t_{CD} = t'_{BC} - 200^g = 115^g .7130$

Intersections

- Intersections are the group of planar surveying calculations where we use two control points (three in the case of resection) with known coordinates and certain angle/distance measurements to compute the coordinates of an unknown point.

Intersection using inner angles

- Given information: coordinates of points A and B.
- Measured quantities: α and β inner angles.

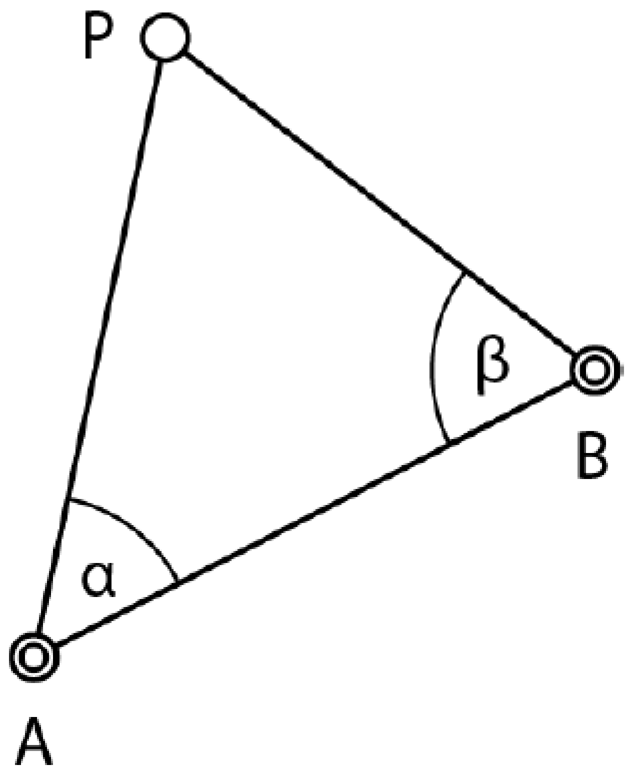


Figure 1. Intersection using inner angles.

- Computing the coordinates of the unknown point P:
- **1**. Using the II. fundamental task of surveying (abbreviated further as II. FTS), we compute the distance dAB and the azimuth (AB) and (BA).
-
- **2**. Using the measured inner angles, we compute the azimuth between the control points and the unknown point (AP)and (BP). According to the figure:

$$\mathrm{WCB}_{AP} = \mathrm{WCB}_{AB} - \alpha$$

$$\mathrm{WCB}_{BP} = \mathrm{WCB}_{BA} + \beta$$

- **3**. Using the sine theorem, we can compute the distances between the control points and point P:

$$\frac{\sin(\alpha)}{\sin(\alpha+\beta)} = \frac{d_{BP}}{d_{AB}} \Rightarrow d_{BP} = \frac{\sin(\alpha)}{\sin(\alpha+\beta)} \cdot d_{AB}$$

$$\frac{\sin(\beta)}{\sin(\alpha+\beta)} = \frac{d_{BP}}{d_{AB}} \Rightarrow d_{BP} = \frac{\sin(\beta)}{\sin(\alpha+\beta)} \cdot d_{AB}$$

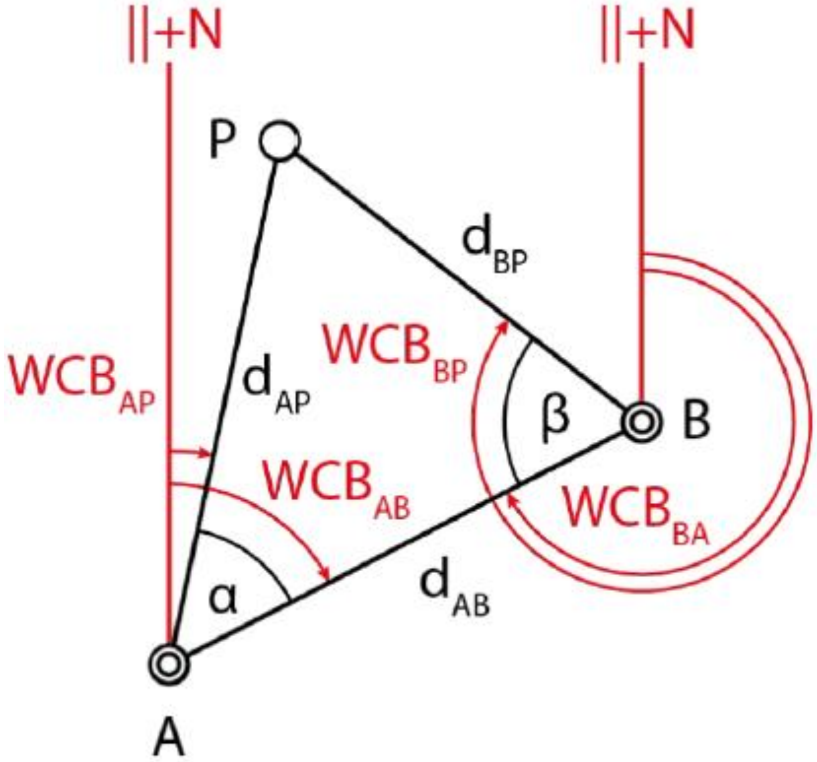


Figure 2. Computation of the WCB's.

4. We use the I. fundamental task of surveying (abbreviated further as I. FTS) to find the coordinates of the unknown point *P*. We can do this computation from using both *A* and *B*, so we can check our results:

$$E_P = E_A + d_{AP} \cdot \sin(\mathrm{WCB}_{AP})$$
$$N_P = N_A + d_{AP} \cdot \cos(\mathrm{WCB}_{AP})$$

or

$$E_P = E_B + d_{BP} \cdot \sin(\mathrm{WCB}_{BP})$$
$$N_P = N_B + d_{BP} \cdot \cos(\mathrm{WCB}_{BP})$$

Resection

- In case of the resection, we only set up the instrument on the unknown point P and measure the angles subtended by the directions from the unknown point to exactly 3 control points.

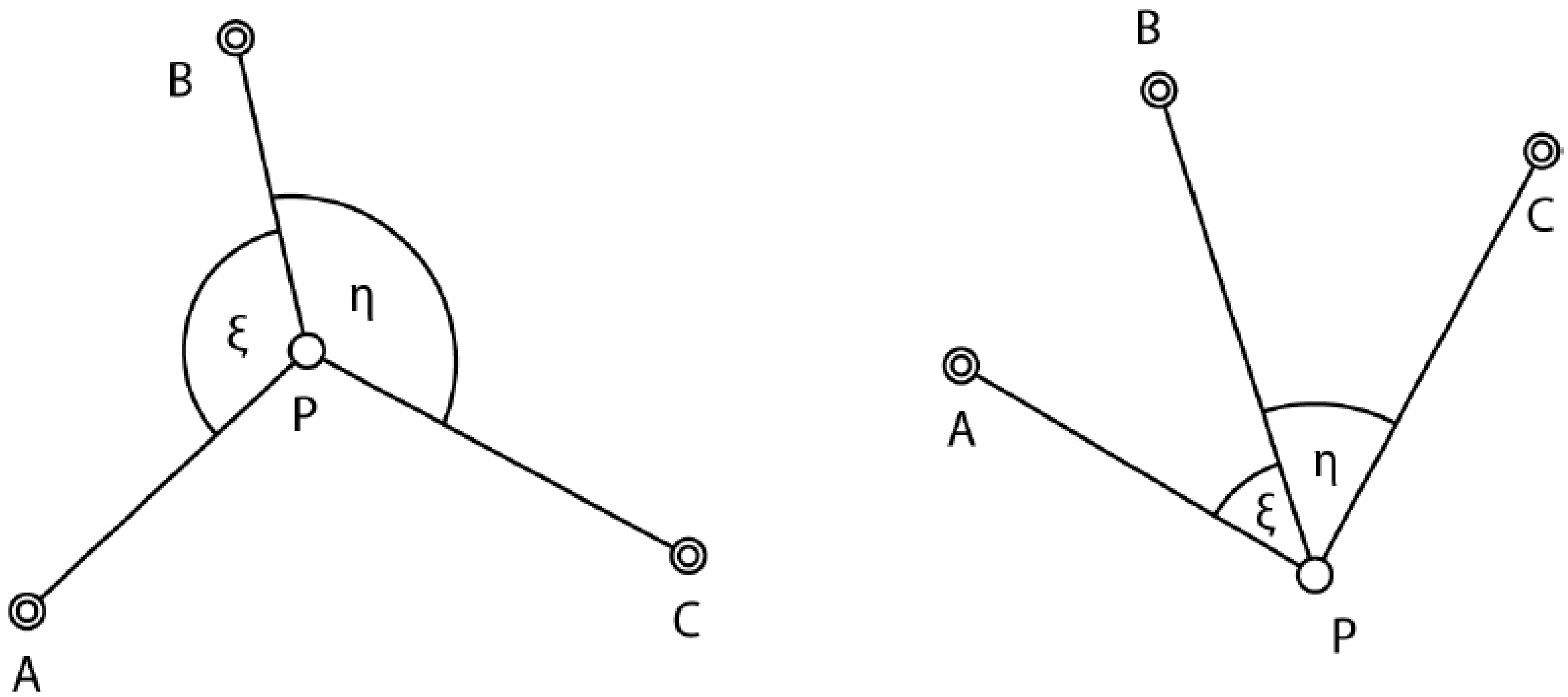


Figure 9. Two possible layouts of the points in the resection problem.

Resection

- In the figure above, the angles ξ and η are measured. There are multiple solutions to the resection problem, In the following, Collins' method is briefly introduced.

- Suppose the layout given in Figure 10 below. First, we draw a circle around the points A, C and P. The line connecting P and B intersect the circle at point S.

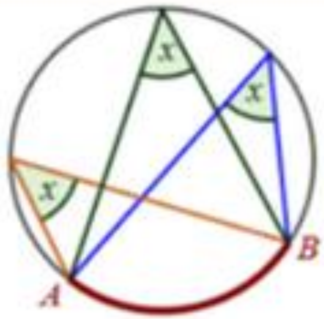
- According to the inscribed angle theorem, the angle at A in the triangle ASC is η and the angle at C in the triangle ASC is ξ. We can compute the (AS)and the (CS) azimuths as

$$\mathrm{WCB}_{AS} = \mathrm{WCB}_{AC} - \eta$$

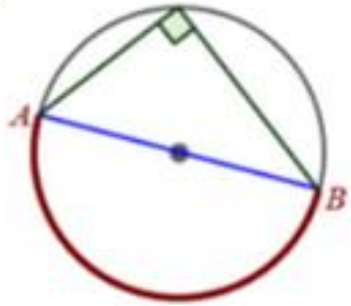
$$\mathrm{WCB}_{CS} = \mathrm{WCB}_{CA} + \xi$$

and using the control points A and C, we can find the coordinates of S

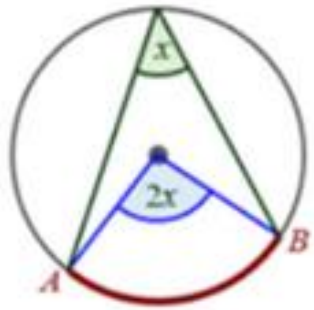
Inscribed Angle Theorems



The inscribed angles subtended by the same arc are equal.

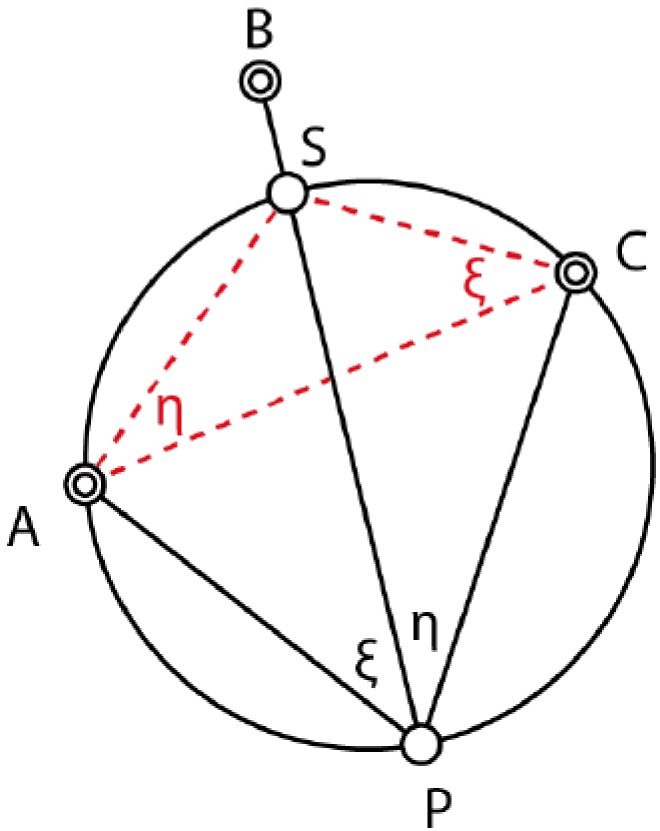


Inscribed angle in a semicircle is 90˚.



An inscribed angle is half of a central angle that subtends the same arc.

- As S is a known point now, we can compute the (BS) which is equal to (BP) as S and P are on the same line. The (AP) and (CP) can be found:



$$\mathrm{WCB}_{AP} = \mathrm{WCB}_{BP} - \xi$$

$$\mathrm{WCB}_{CP} = \mathrm{WCB}_{BP} + \eta$$

Figure 10. Computing the resection using Collins' method.

The coordinates of P can now be found as the intersection of any combination of the lines AP, BP and CP and therefore we can check our computation.

COORDINATE TRANSFORMATION

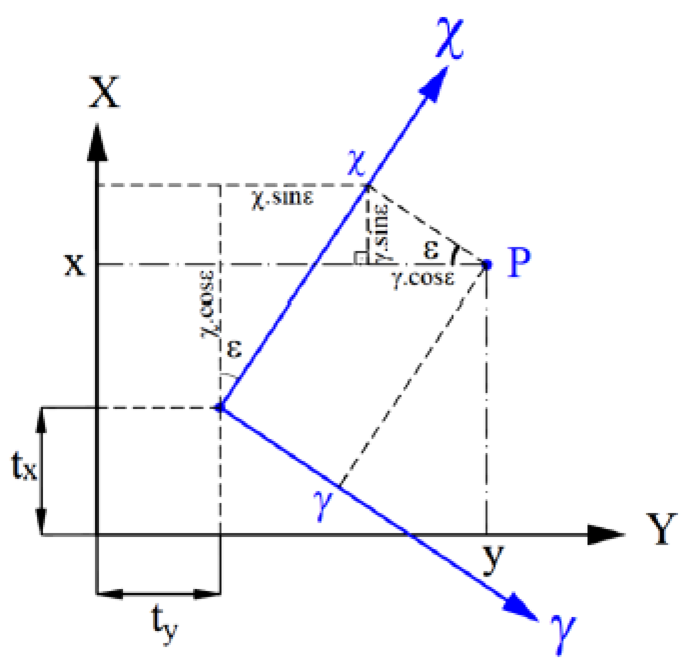
Similarity Transformation

- Coordinate transformation is one of the most common issues in geodesy. It is used to transform coordinates one datum to other by using parameters as translation terms, scale and rotation angle. The increase of application areas in engineering surveys and integration of layouts with different datum have been increased the necessity of accurate datum transformation. The problem in datum transformation is to compute the transformation parameters using common points with known coordinates into two different datum.
- The array of points that is processed through a similarity transformation undergoes the following coordinate changes:
- 1- Shifts in both coordinate directions (translation terms: tx and ty)
- 2- Rotation by an angle (rotation angle: ε)
- 3- Multiplication of the scale of a factor k such that the scale becomes equal to the one of the other system (scale factor).

COORDINATE TRANSFORMATION

Similarity Transformation

- The first system is χ, γ coordinates, and the second system is XY coordinate system. Once transformation parameters between two systems are estimated by common points, χ and γ coordinates are converted to second system namely X and Y coordinates



COORDINATE TRANSFORMATION

Similarity Transformation

- Assume that coordinates of P is changed in a ratio, namely, k. Then, coordinates of P in second system can be obtained by the above equations:

$$X = t_{\chi} + k.cos\varepsilon.\chi - k.sin\varepsilon.\gamma$$

$$Y = t_{\gamma} + k.sin\varepsilon.\chi + k.cos\varepsilon.\gamma$$

- Here, tx, ty, k and ε are the transformation parameters.
- With tx, ty: translation parameters
- k: scale factor
- ε is rotation parameter

COORDINATE TRANSFORMATION

Similarity Transformation

- Here, using points, which are common on two systems, the scale factor and rotational angle, can be estimated.

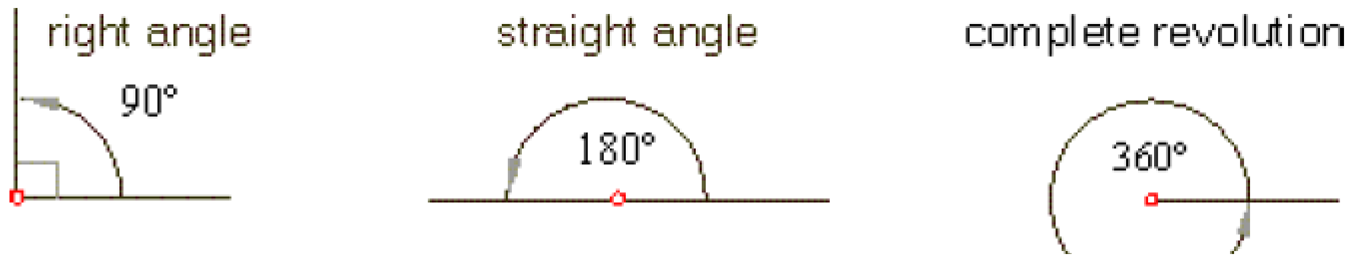
$$\text{Rotation angle: } \varepsilon = \arctan\left(\frac{a}{o}\right)$$

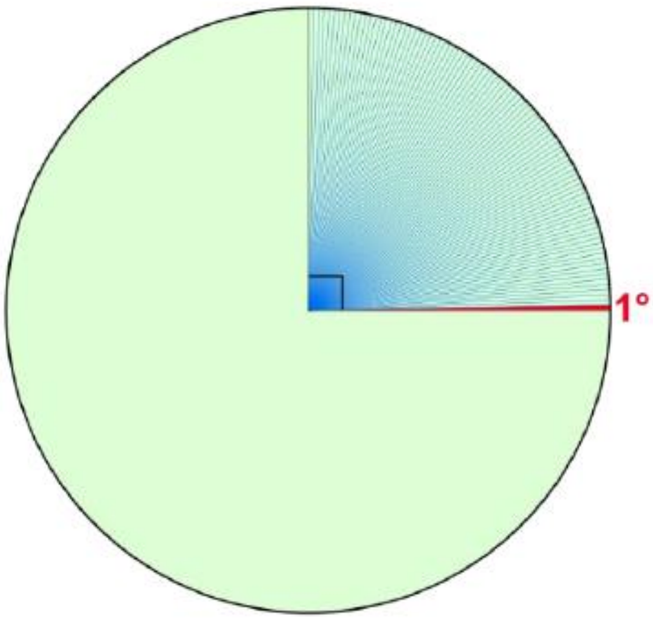
$$\text{Scale Factor: } k = \sqrt{o^2 + a^2}$$

- To estimate the transformation parameters, at least two common points should be known in both systems.

Units of Angle

- **Degree**
- Degree usually denoted by ° (the degree symbol), is a measurement of plane angle, representing 1/360 of a full rotation.

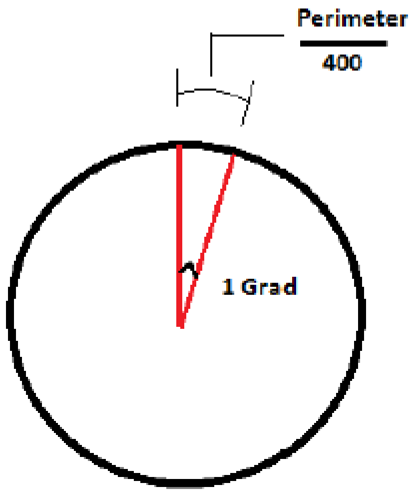




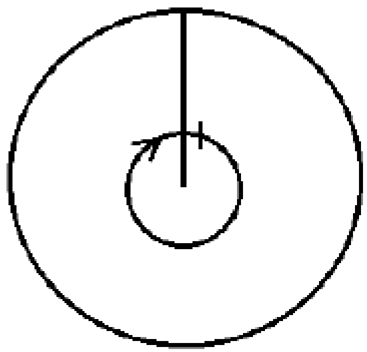
1 Degree	**1^0**	**60 minutes**	**3600 second**
1 Minute	**$1'$**	**1/60 degree**	**60 seconds**
1 Second	**$1''$**	**1/360 degree**	**1/60 minute**

$1° = 60' = 3600''$ $\qquad$ $1' = 60''$

- **Gradian (Grad/ Gon)**
- The gon is a unit of plane angle, equivalent to 1/400 of a turn.
- A grad is defined as 1/400 of a circle.
- A grad is dividing into 100 centigrad, centigrad into 100 centicentigrad.
- Grad is represented by the symbol (g) , centigrad by (c) , centicentigrad by (cc)



Definition of 1 Grad



1 full rotation= 400 grad

1^{g}	Grad	100 centigon	100^{c}
1^{c}	Centigon	100 centicentigon	100^{cc}
1^{cc}	Centicentigon	0.0001 grad	
1^{g}		100 cgon	
1^{c}		10 mgon (milligon)	

Leveling

- Leveling is the general term applied to any of the various processes by which elevations of points or differences in elevation are determined. It is a vital operation in producing necessary data for mapping, engineering design, and construction.
- Leveling results are used to
- (1) design highways, railroads, canals, sewers, and other facilities having grade lines that best conform to existing topography;
- (2) lay out construction projects according to planned
- elevations;
- (3) calculate volumes of earthwork and other materials;
- (4) investigate drainage characteristics of an area;
- (5) develop maps showing general ground configurations;
- and
- (6) study earth crustal motion.

DEFINITIONS

- Basic terms in leveling are defined in this section, some of which are illustrated in Figure 4.1.
- ***Vertical line****.* A line that follows the local direction of gravity as indicated by a plumb line.
- ***Level surface****.* A curved surface that at every point is perpendicular to the local plumb line. Level surfaces are approximately spheroidal in shape. A body of still water is the closest example of a level surface.
- Level surfaces are also known as *equipotential surfaces* since, for a particular surface, the potential of gravity is equal at every point on the surface.
- ***Level line.*** A line in a level surface—therefore, a curved line.

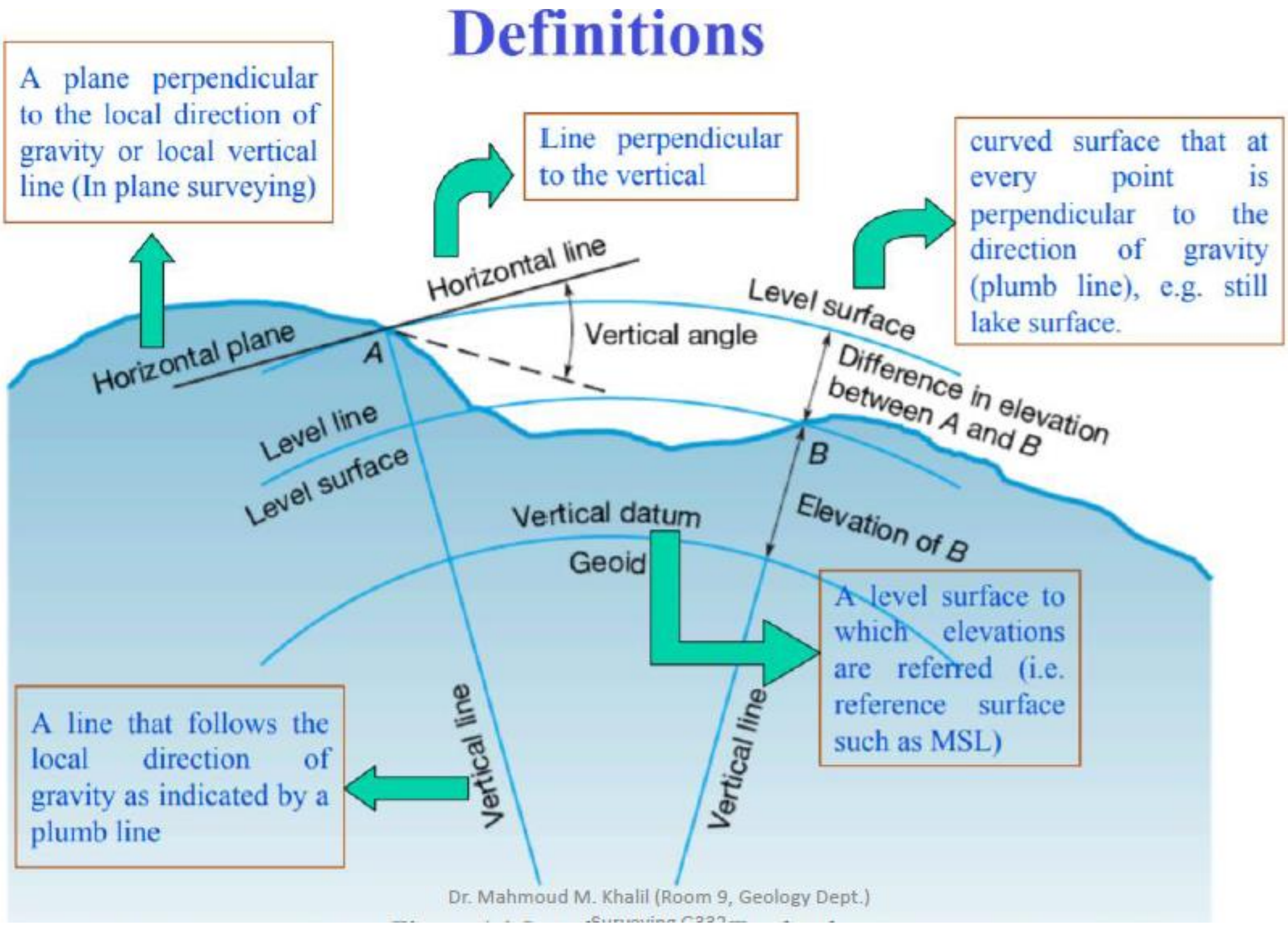


Figure 4.1
Leveling terms.

DEFINITIONS

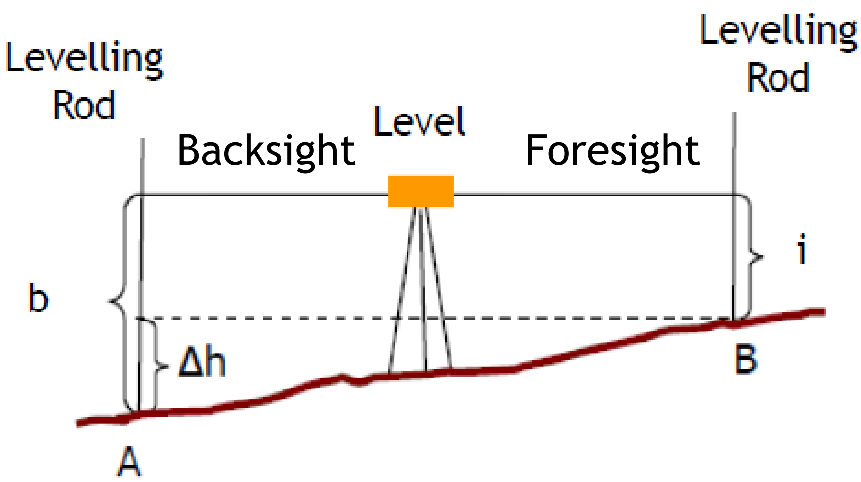
- ***Horizontal plane***. A plane perpendicular to the local direction of gravity. In plane surveying, it is a plane perpendicular to the local vertical line.
- ***Horizontal line****.* A line in a horizontal plane. In plane surveying, it is a line perpendicular to the local vertical.
- ***Vertical datum****.* Any level surface to which elevations are referenced. This is the surface that is arbitrarily assigned an elevation of zero. This level surface is also known as a reference datum since points using this datum have heights relative to this surface.
- ***Elevation****.* The distance measured along a vertical line from a vertical datum to a point or object. The elevation of a point is also called its height above the datum.
- ***Geoid****.* A particular level surface that serves as a datum for all elevations and astronomical observations.

DEFINITIONS

- ***Benchmark* (*BM*).** A relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known. Common examples are metal disks set in concrete, reference marks chiseled on large rocks, etc.
- ***Leveling***. The process of finding elevations of points or their differences in elevation.
- ***Vertical control***. A series of benchmarks or other points of known elevation established throughout an area

Differantial Levelling

- **Height** is defined as the vertical distance between the point and the reference surface along plumb line.
- Differential levelling is the measurement procedure for determining the height differences between points.



Δh = HB - HA = backsight-foresight = b-i
Δh = b-i

Levelling in practice, determining the height difference between two points

- The levelling instrument (called the level) is set up between two vertical levelling staff (A and B) at an equal distance from each staff and correctly levelled. Levelling the instrument means, that we use the circular bubble (only the circular bubble in case of an automatic level) to make the line of sight of the instrument horizontal and therefore create a horizontal plane at the height of the instrument. If the direction of the levelling is from A to B, then point A is called the backsight point (BS) and B is called the foresight point (FS).

Level instrument

Main parts:

1. Level instrument:

Level instrument

Types of Level

Dumpy level

Tilting Level

Automatic Level

Dijital Level

Level Instrument

- **2.Tripod**:A tripod is a three-legged stand used to support a level.

- <u>3. Level staff (levelling rod):</u>
- The vertical distance above or below the horizontal surface is read off a levelling staff. It may be either telescope or folding extending to a length of 4m or 5m.
- The staff must be held vertically as any leaning of the staff will result in a level staff reading which is too great. Reading can be taken by holding the staff lightly between the palms of both hands on either sides of the staff.
- The material of level staff maybe steel, wood or aluminium.

CURVATURE AND REFRACTION

- From the definitions of a level surface and a horizontal line, it is evident that the horizontal plane departs from a level surface because of curvature of the Earth. In Figure 4.2, the deviation *DB* from a horizontal line through point *A* is due to Earth's curvature.

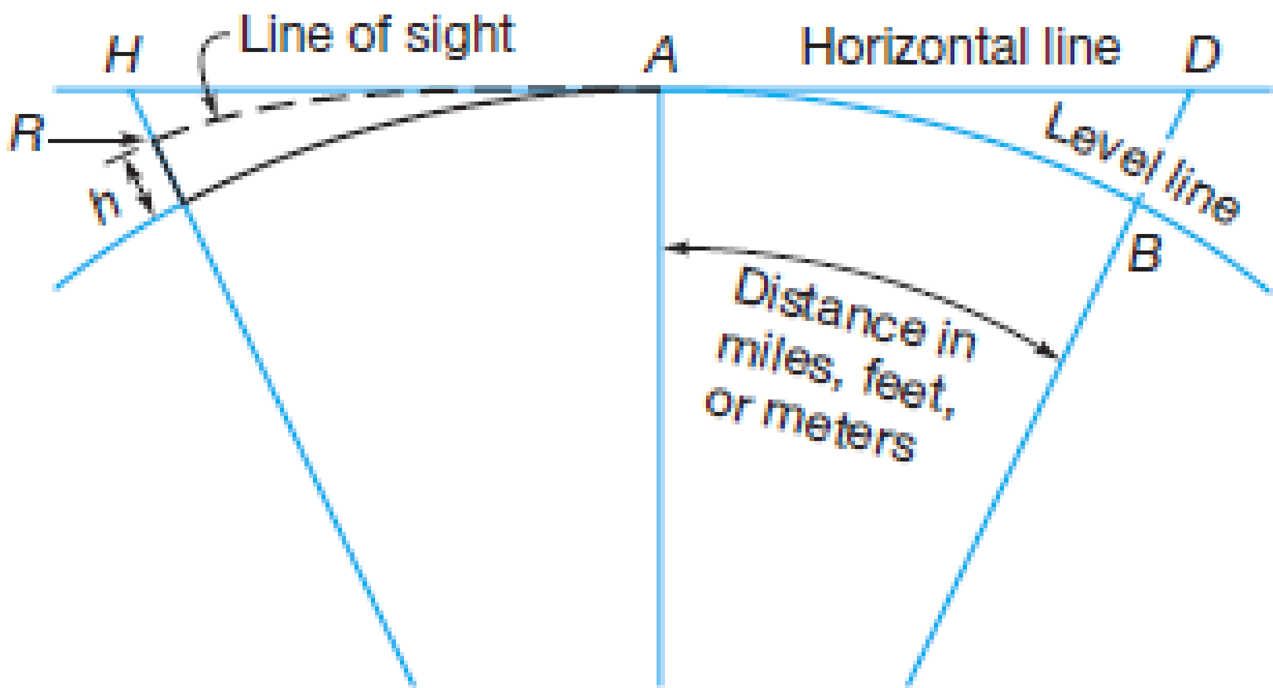


Figure 4.2
Curvature and refraction.

CURVATURE AND REFRACTION

- Since points *A* and *B* are on a level line, they have the same elevation. If a graduated rod was held vertically at *B* and a reading was taken on it by means of a telescope with its line of sight *AD* horizontal, the Earth's curvature would cause the reading to be read too high by length *BD.*

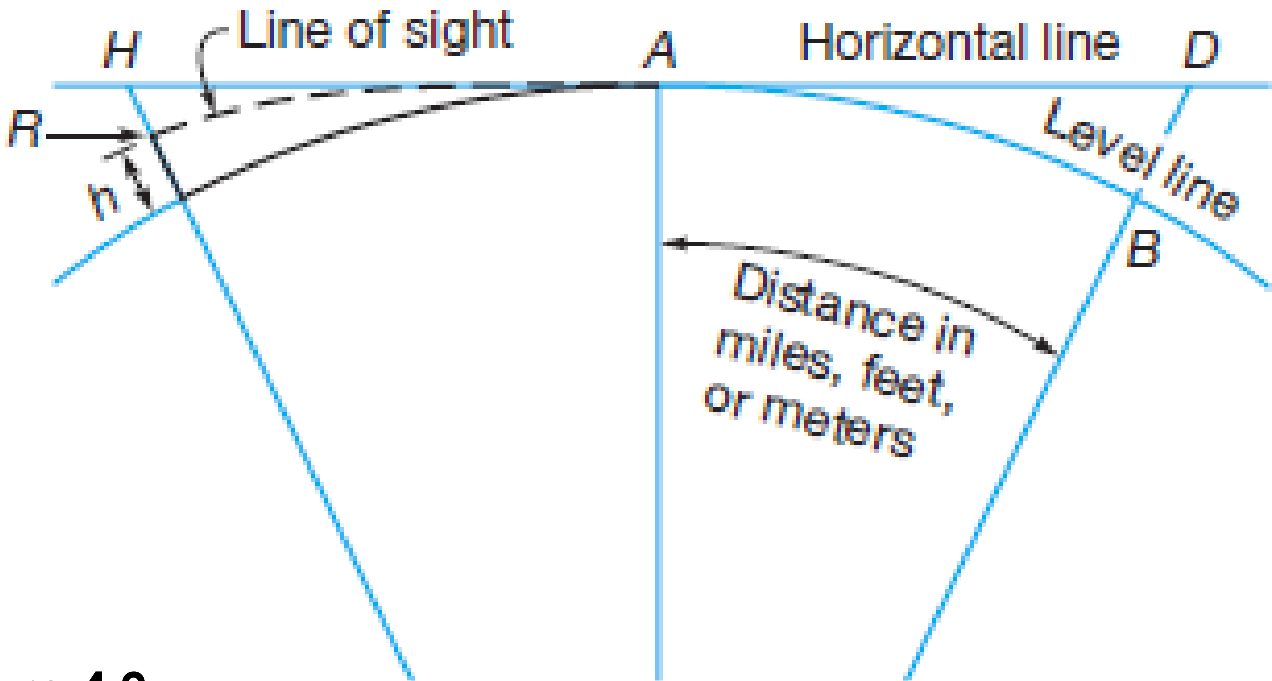


Figure 4.2
Curvature and refraction.

CURVATURE AND REFRACTION

- Light rays passing through the Earth's atmosphere are bent or refracted toward the Earth's surface. Thus a theoretically horizontal line of sight, like *AH* in Figure 4.2, is bent to the curved form *AR.* Hence, the reading on a rod held at *R* is diminished by length *RH.*

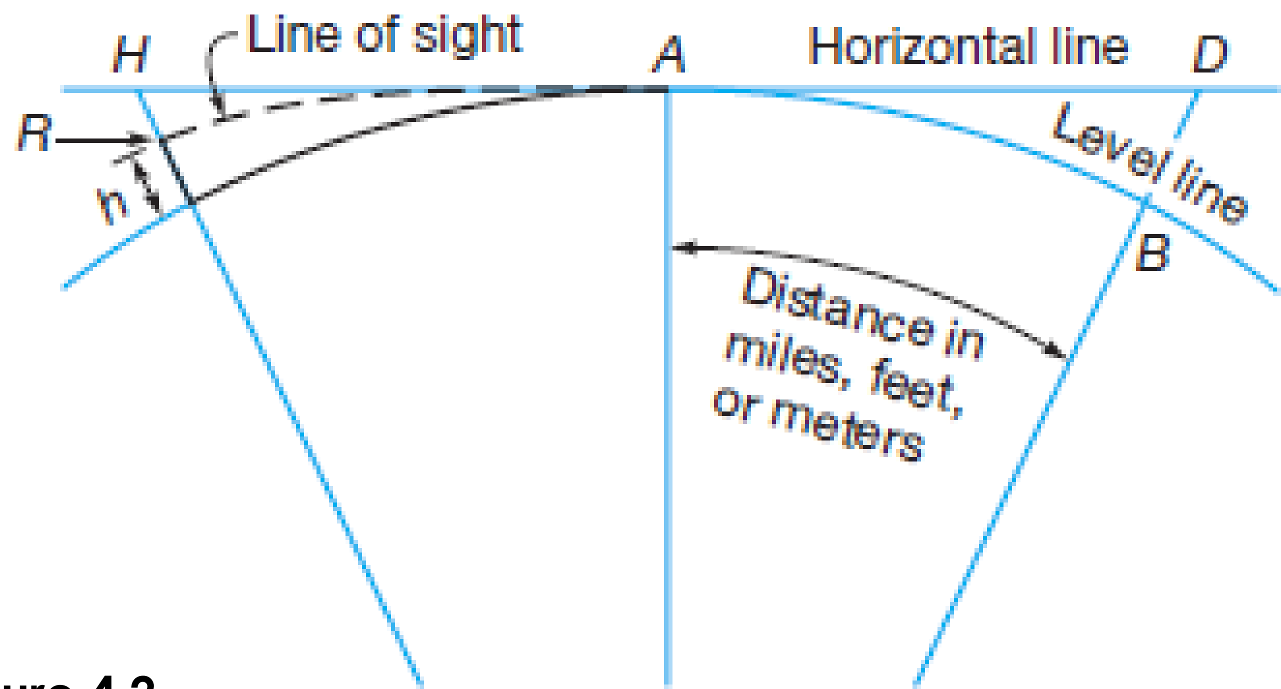


Figure 4.2
Curvature and refraction.

DETERMINING DIFFERENCES IN ELEVATION

- The basic procedure is illustrated in Figure 4.5. An instrument is set up approximately halfway between A and B points. Assume the elevation of BM (A) is known to be 100.00meters. After leveling the instrument, a backsight taken on a rod held on the BM gives a reading of 1.500m.

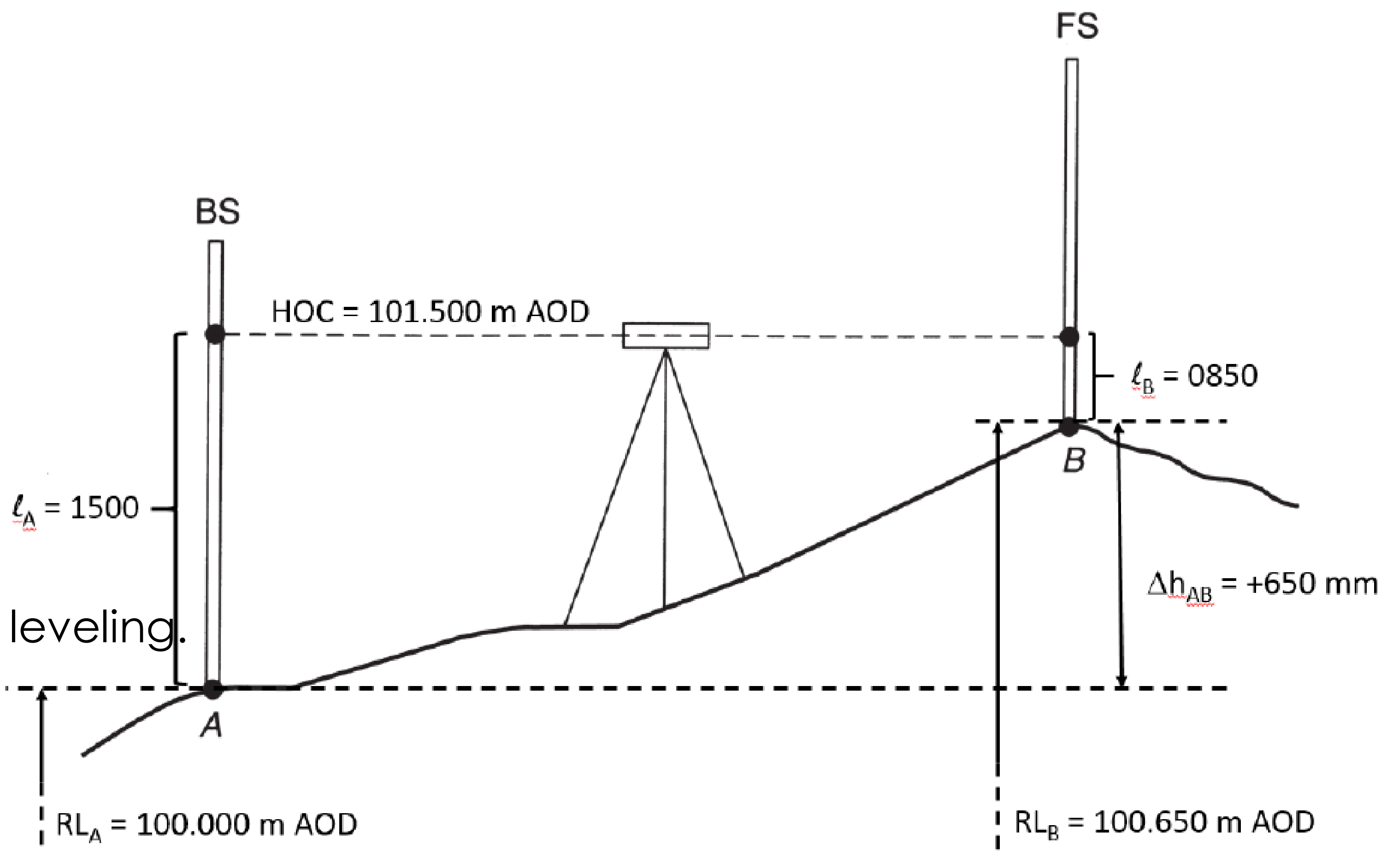
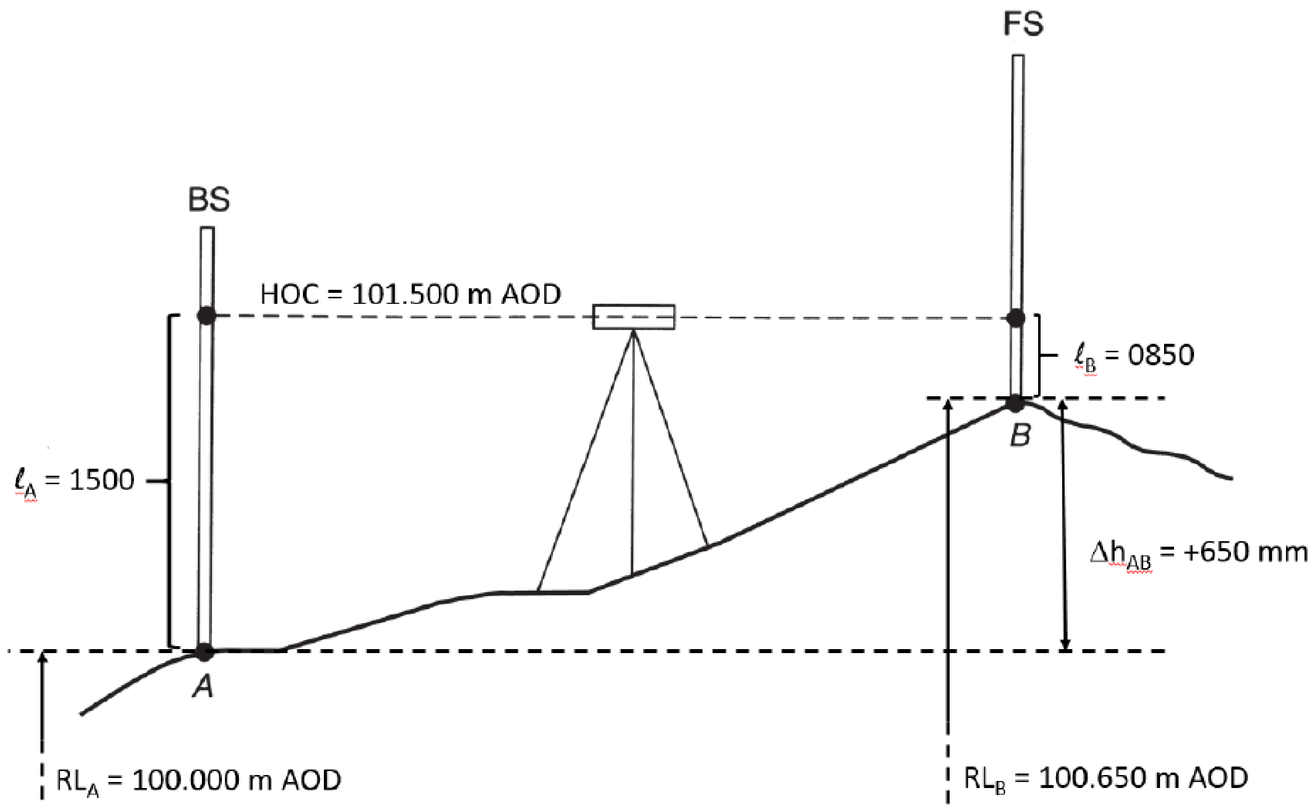


Figure 4.5
Differential leveling.

DETERMINING DIFFERENCES IN ELEVATION

- *backsight* (BS), is the reading on a rod held on a point of known or assumed elevation. This reading is used to compute the *height of instrument* (HI), defined as the vertical distance from datum to the instrument line of sight. Adding the backsight 1.500m to the elevation of point A, 100.000, gives an HI of 101.500m. Once the height of instrument is established, rod reading on point B called foresight can be taken and its elevation is calculated by simply subtracting the reading from the height of instrument.



Trigonometric Leveling

- The difference in elevation between two points can be determined by measuring (1) the inclined or horizontal distance between them and (2) the zenith angle or the altitude angle to one point from the other.

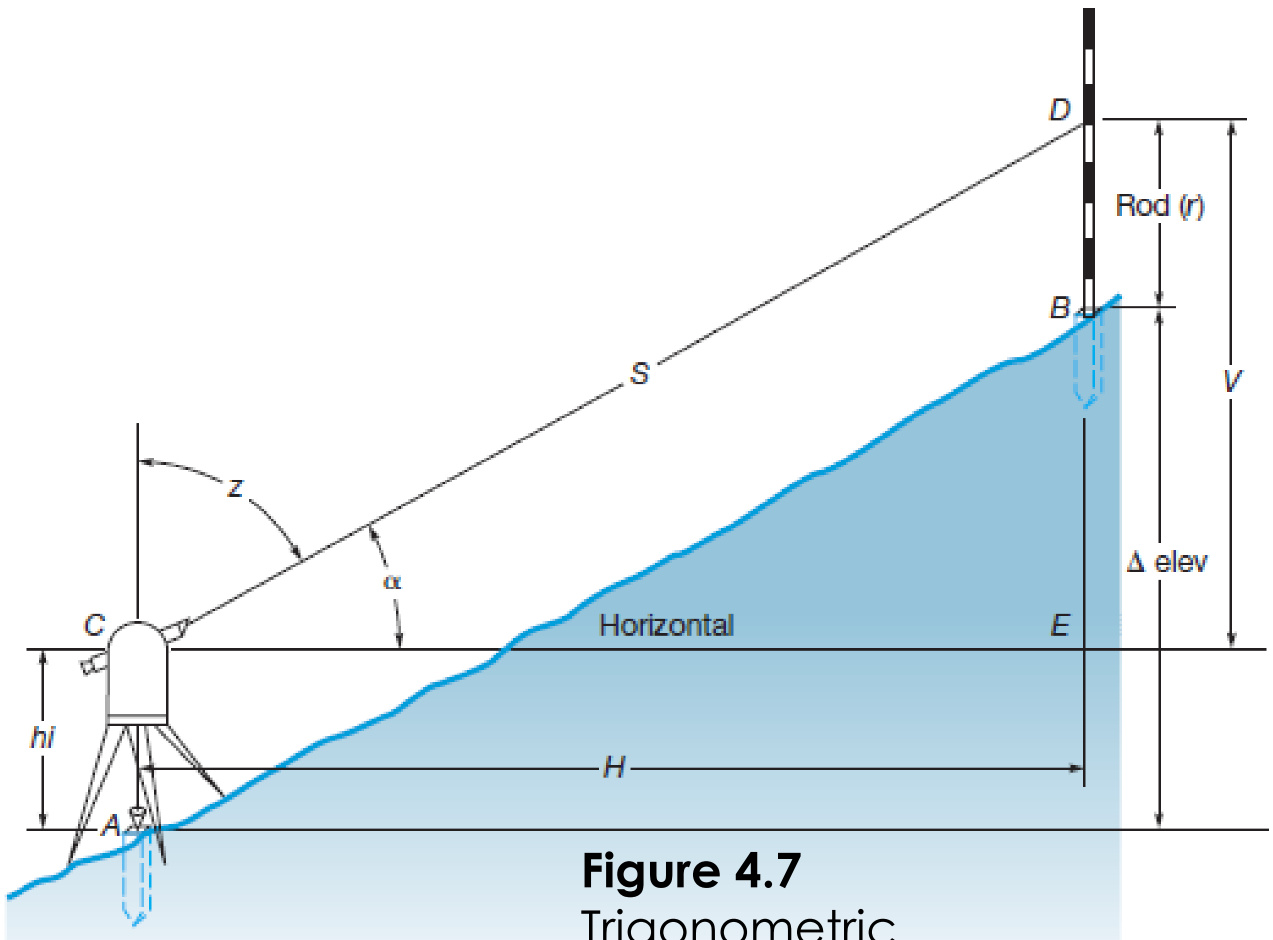


Figure 4.7
Trigonometric leveling—short lines.

Trigonometric Leveling

- Zenith angles are observed downward from vertical, and altitude angles are observed up or down from horizontal.) Thus, in Figure 4.7, if slope distance *S* and zenith angle *z* or altitude angle between *C* and *D* are observed, then *V*, the elevation difference between *C* and *D*, is

$$V = S \cos z$$

$$V = S \sin \alpha$$

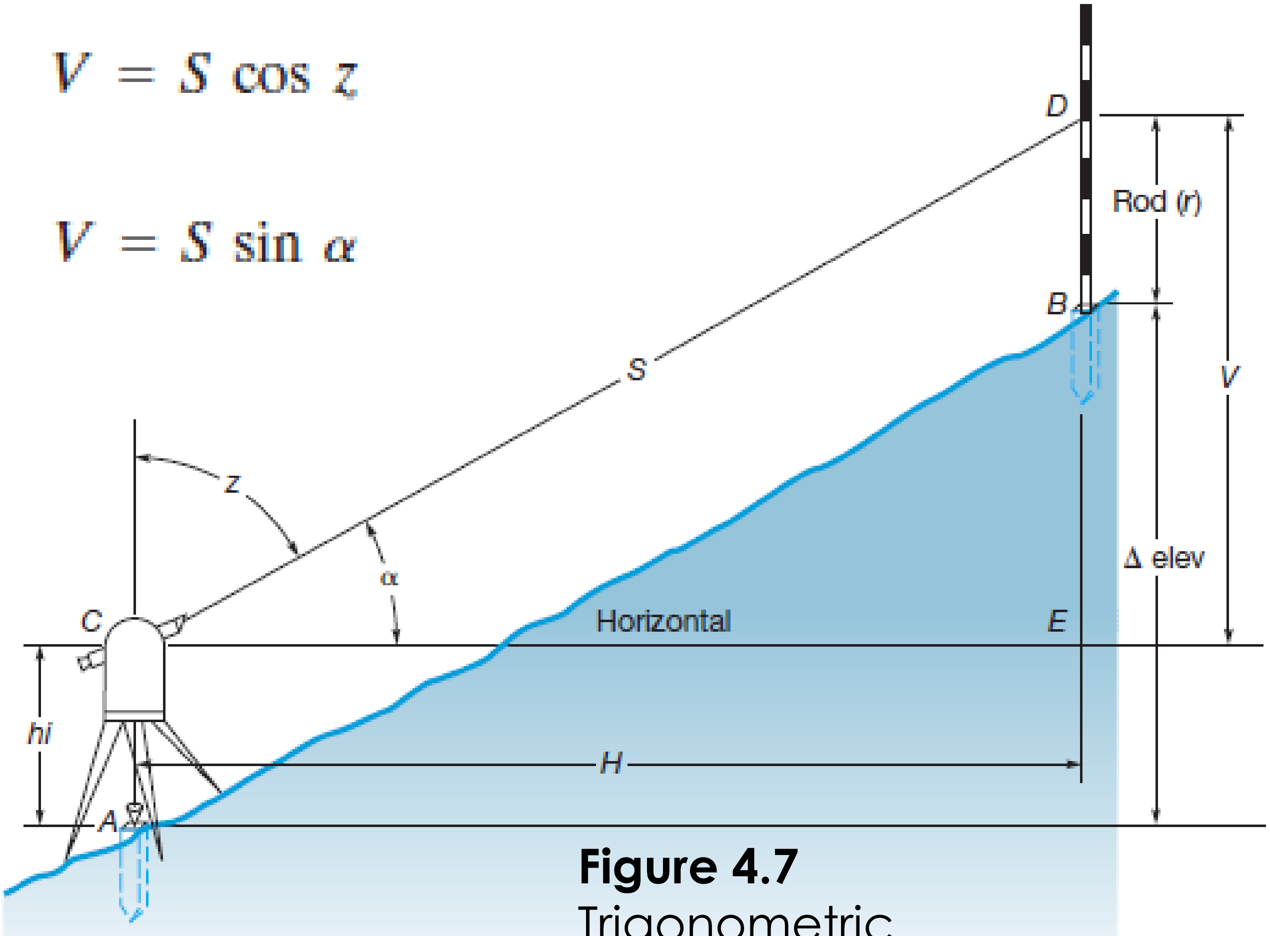


Figure 4.7
Trigonometric leveling—short lines.

Trigonometric Leveling

- Alternatively, if horizontal distance *H* between *C* and *D* is measured, then *V* is

$$V = H \cot z$$

- Or

$$V = H \tan \alpha$$

- The difference in elevation between points *A* and *B* in Figure 4.7 is given by

$$\Delta \text{elev} = hi + V - r$$

- where *hi* is the height of the instrument above point *A* and *r* the reading on the rod held at *B* when zenith angle *z* or altitude angle is read.

Trigonometric Leveling

- Note the distinction in this text between *HI* and *hi.* Although both are called height of instrument, the term *HI is the elevation of the instrument above datum*, while *hi is the height of the instrument above an occupied point*, as discussed here.

- For short lines (up to about 1000 ft in length) elevation differences obtained in trigonometric leveling are appropriately depicted by Figure 4.7 and properly computed using Equations given above. However, for longer lines Earth curvature and refraction become factors that must be considered.

Trigonometric Leveling

- Figure 4.8 illustrates the situation. Here an instrument is set up at *C* over point *A*. Sight *D* is made on a rod held at point *B*, and zenith angle z_m or altitude angle α_m is observed.

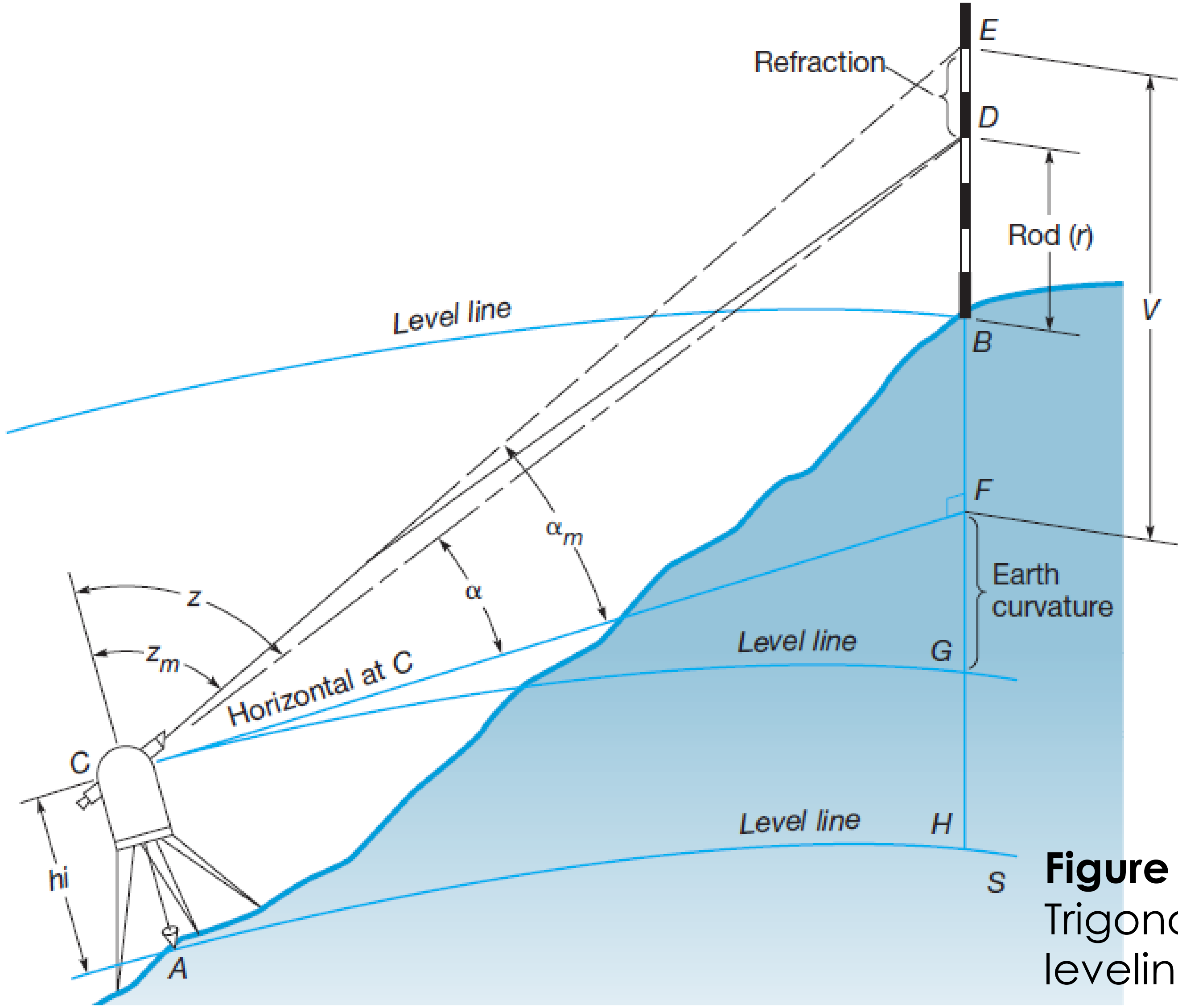
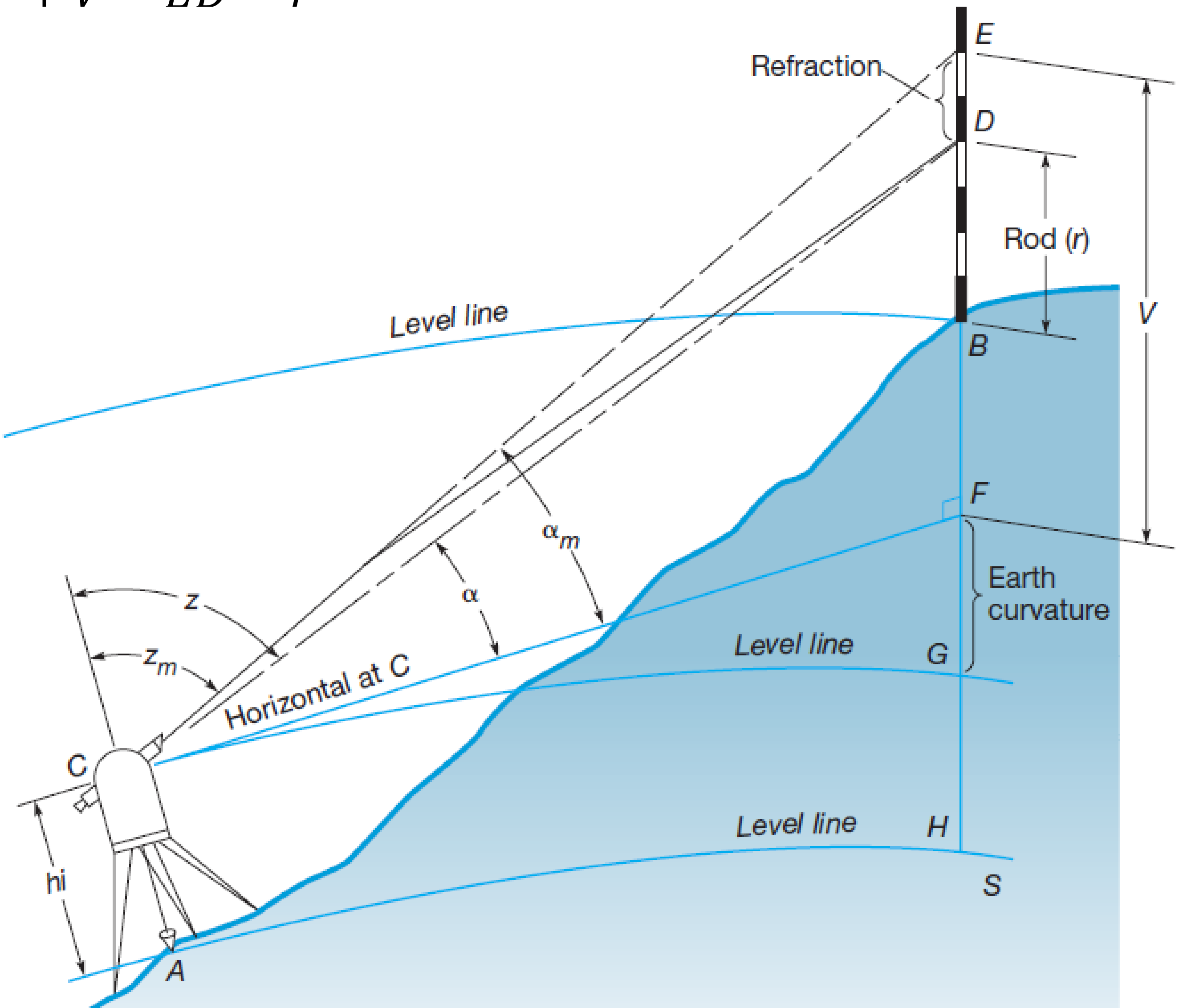


Figure 4.8
Trigonometric leveling—long line

Trigonometric Leveling

- The true difference in elevation $\Delta elev$ between *A* and *B* is vertical distance *HB* between level lines through *A* and *B*, which is equal to $HG + GF + V - ED - r$



Trigonometric Leveling

- Since *HG* is the instrument height *hi*, *GF* is earth curvature *C* , and *ED* is refraction *R*, the elevation difference can be written as

- $$\Delta\text{elev} = hi + V + h_{CR} - r \qquad (4.11)$$

- Thus, except for the addition of the curvature and refraction correction, long and short sights may be treated the same in trigonometric leveling computations. Note that in developing Equation (4.11), angle *F* in triangle *CFE* was assumed to be 90°. Of course as lines become extremely long, this assumption does not hold. However, for lengths within a practical range, errors caused by this assumption are negligible.

PROFILE LEVELING(LONGITUDINAL SECTION)

- Before engineers can properly design linear facilities such as highways, railroads, canals, sewers, they need accurate information about the topography along the proposed routes. Profile leveling, which yields elevations at definite points along a reference line, provides the needed data.

- Depending on the particular project, the reference line may be a single straight segment or straight segments joined by curves, which occur with highways and railroads.
- To stake the proposed reference line, key points such as the starting and ending points will be set first. Then intermediate stakes will be placed on line usually placed at 10-, 20-, 30-, or 40-m spacing, depending on conditions. Distances for staking can be taped, or measured using the electronic distance measuring (EDM) component of a total station instrument

PROFILE LEVELING(LONGITUDINAL SECTION)

- In route surveying, a system called *stationing* is used to specify the relative horizontal position of any point along the reference line. The starting point is usually designated with some arbitrary value, for example 1+000 or 10+000 but 0+000 could be used. In rural areas, intermediate points are normally set at 30- or 40-m increments along the line, and are again designated by their pluses. If the beginning point was 1+000 and stakes were being set at 40-m intervals, then 1+040, 1+080, 1+120 etc. would be set.

Cross-Section Leveling

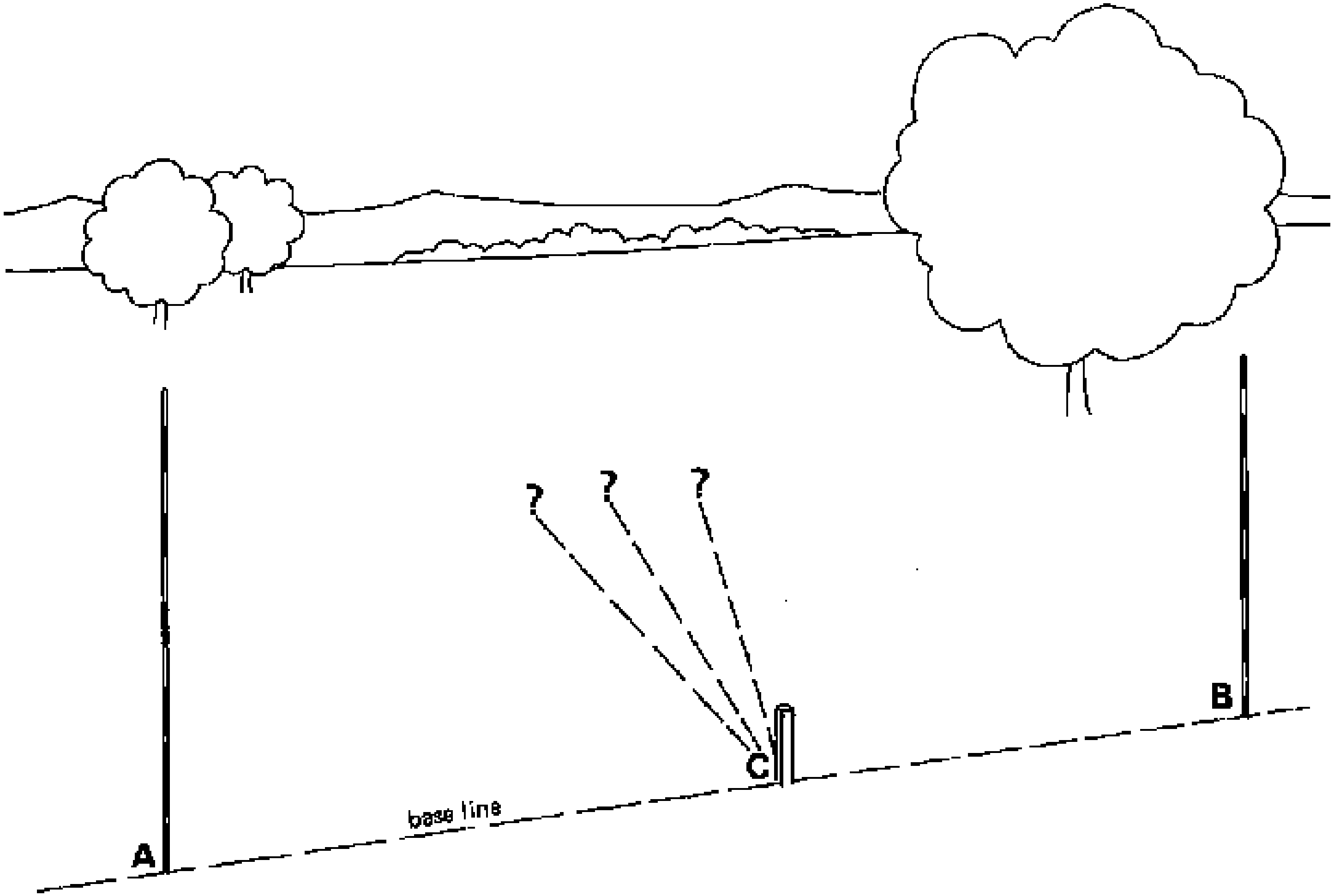
- The term cross-section generally refers to a relatively short profile view of the ground, which is drawn perpendicular to the route centerline of a highway or other types of linear projects. Cross-sectional drawings are particularly important for estimating the earthwork volumes needed to construct a roadway; they show the existing ground elevations, the proposed cut or fill side slopes, and the grade elevation for the road base.

Setting out right angles

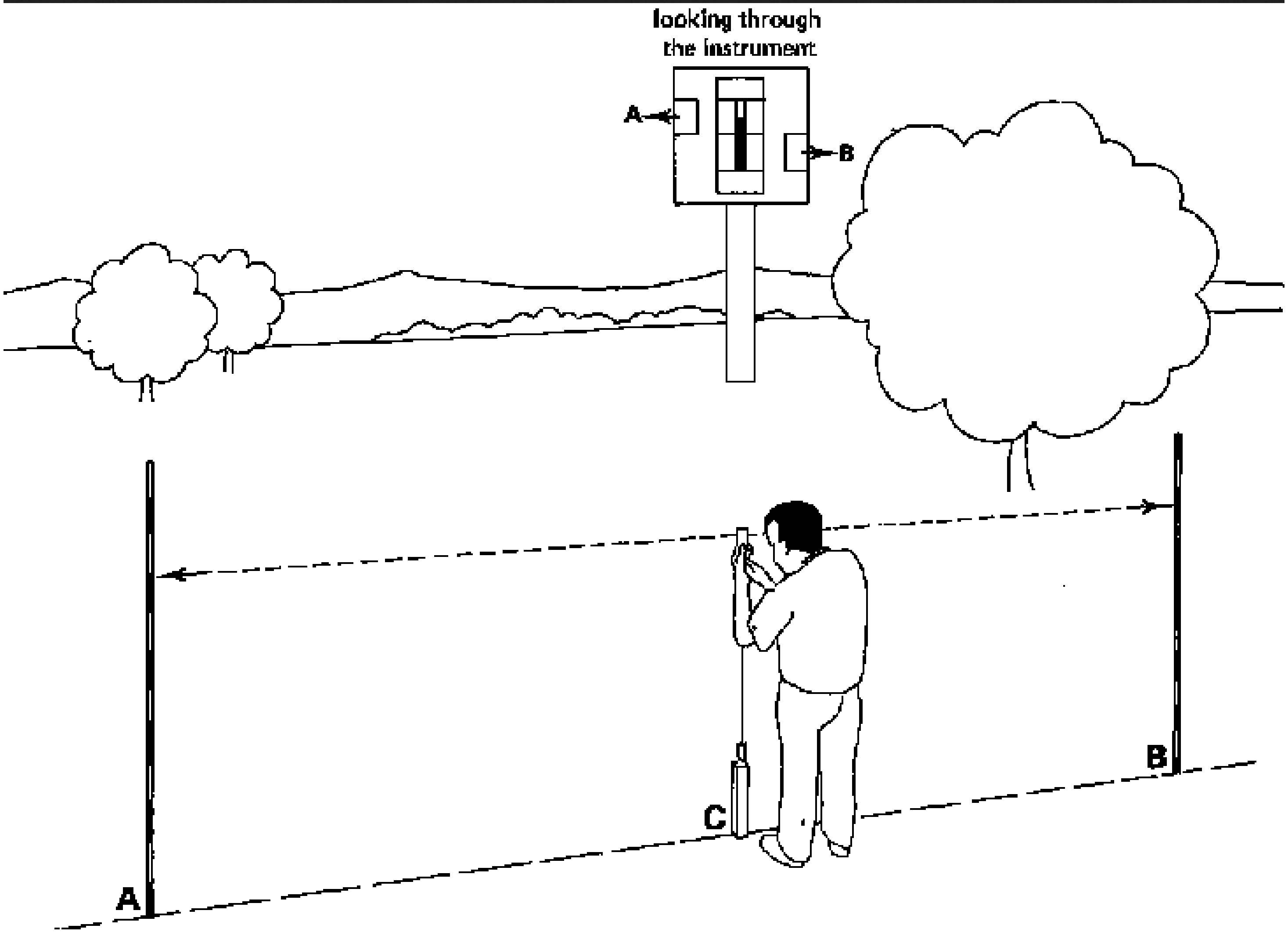
- The double prismatic square, also called double prism, has two prisms. The two prisms are placed in such a way that it is possible to look at the same time at a right angle to the left and to the right; in addition the observer can look straight ahead of the instrument through openings above and below the prisms

Setting out right angles

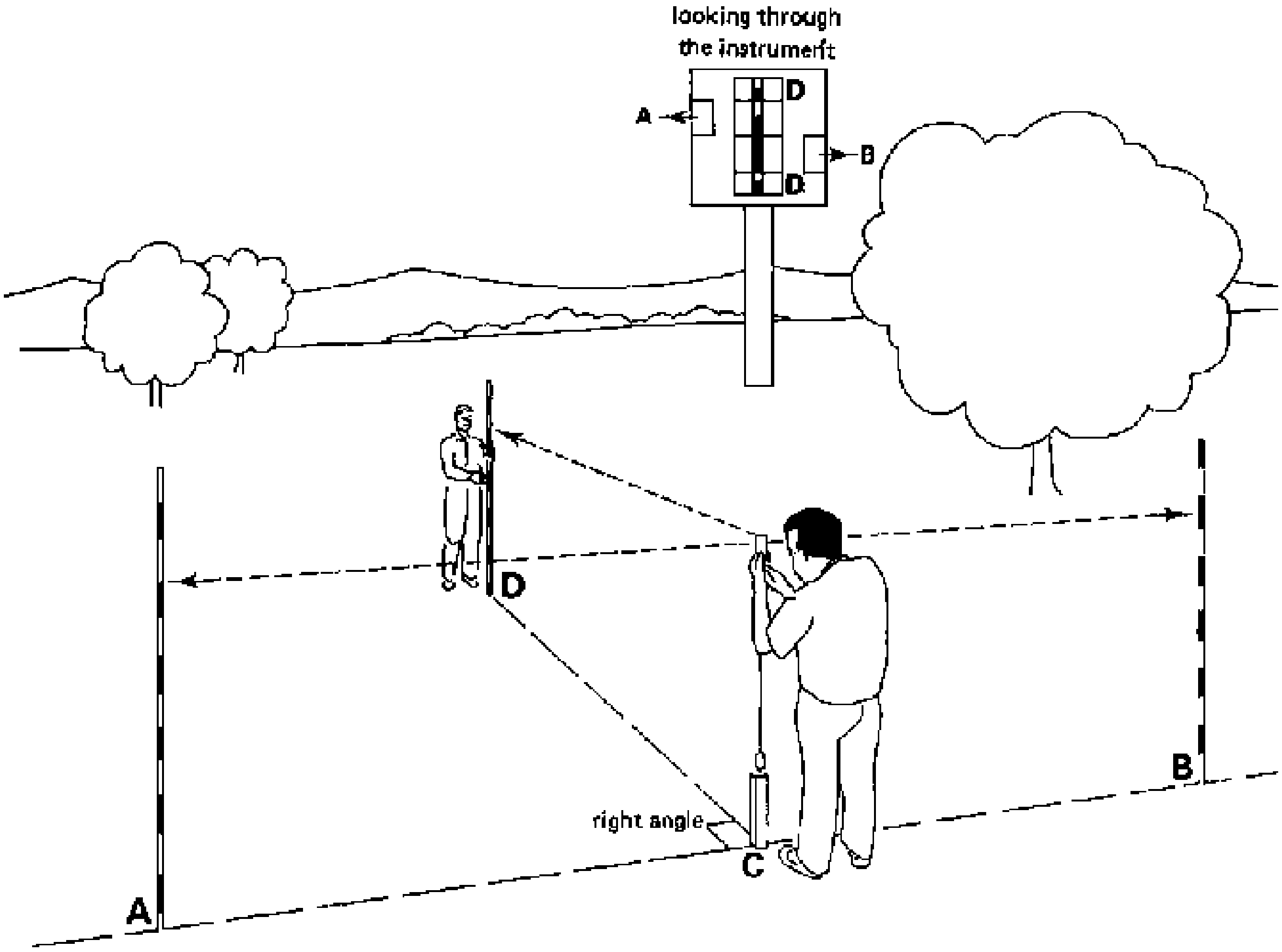
- In Fig. 27, peg (C) is on the base line connecting poles (A) and (B). A right angle has to be set out from (C).



- <u>Step 1</u>
- The observer holds the instrument vertically above peg (C) on the base line. This can be checked with the plumb bob (see Fig. 27a) The instrument is slowly rotated until the image of pole (A), is in line with the image of pole (B) (see Fig. 27a).



- <u>Step 2</u>
- The observer then directs the assistant, holding pole (D), in such a way, that seen through the instrument, pole (D) forms one line with the images of poles (A) and (B) (see Fig. 27b) The line connecting pole (D) and peg (C) forms a right angle with the base line.



ANGLES AND DIRECTIONS

Determining the location of points and orientations of lines frequently depends on measurements of angles and directions.
Angles measured in surveying are classified as either horizontal or vertical, depending on the plane in which they are observed.

Horizontal angles are the basic observations needed for determining azimuths. Vertical angles are used in trigonometric leveling, and for reducing slope distances to horizontal.

Angles are most directly observed in the field with theodolites and total stations.

ANGLES AND DIRECTIONS

An angle is defined as the difference in direction between two convergent lines. Three basic requirements determine the angle.

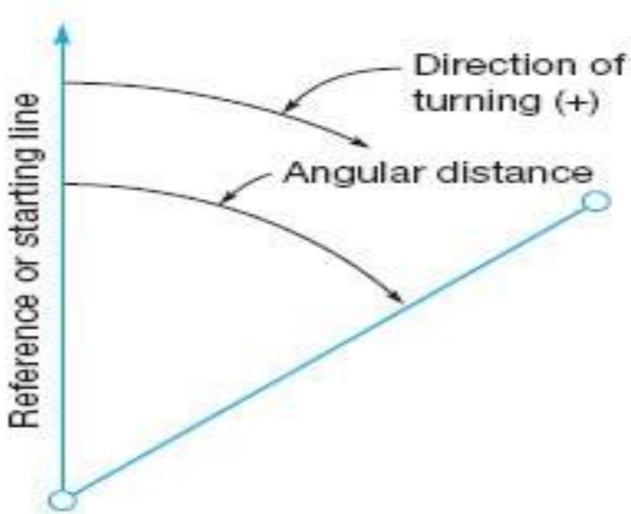


Figure:1(C.D.Ghilani & P.R.Wolf,2008)

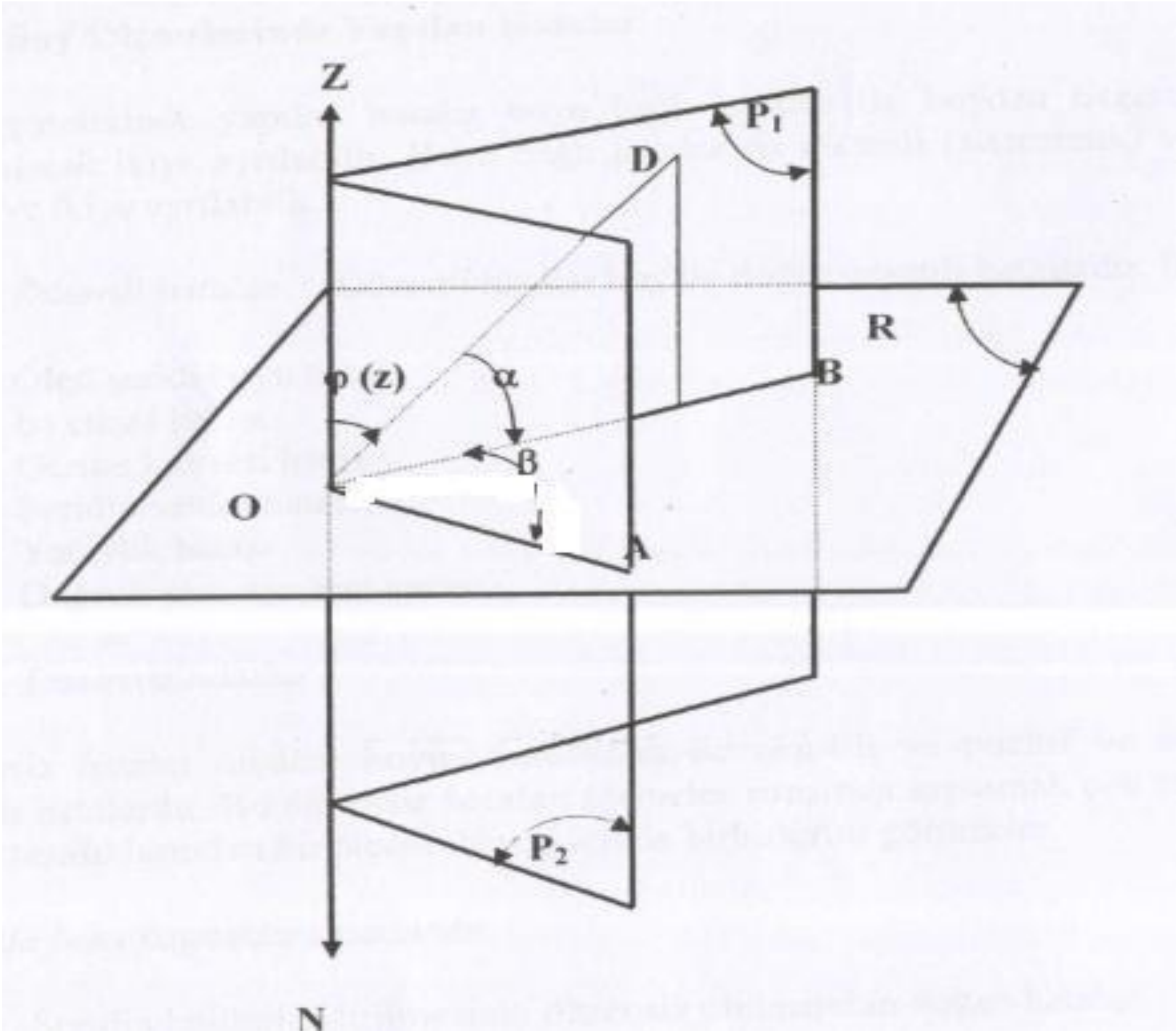
As shown in this figure:1,

(1) reference or starting line

(2) direction of turning

(3) angular distance (value of the angle).

ANGLES AND DIRECTIONS



ANGLES AND DIRECTIONS

Vertical line: is a line that follows the direction of gravity as indicated by a plumb line. (Figure2: ZN line)

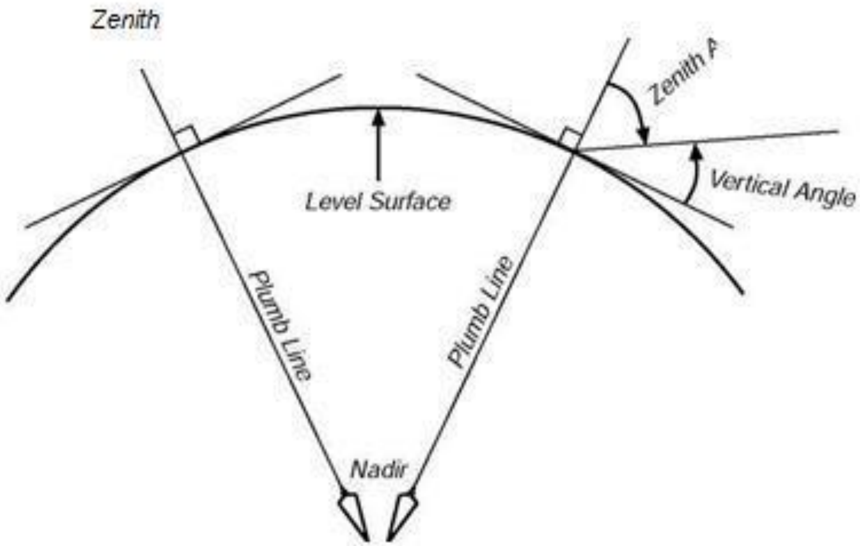
Horizontal line: is a line in a horizontal plane. In plane surveying, a line perpendicular to the vertical. (Figure2: OA and OB line)

Horizontal plane: is a plane perpendicular to the direction of gravity. In plane surveying, a plane perpendicular to the plumb line. (Figure2: R plane)

Vertical plane: is a plane, including vertical line, perpendicular to horizontal plane. (Figure2: P_1 and P_2 plane)

Horizontal angle: is formed by the directions to two objects in a horizontal plane. (Figure2: ß angle, BOA angle)

ANGLES AND DIRECTIONS



(*Basic Surveying The Theory and Practice,2000.*)

<u>Level surface:</u> is a curved surface that every point is perpendicular the plumb line.

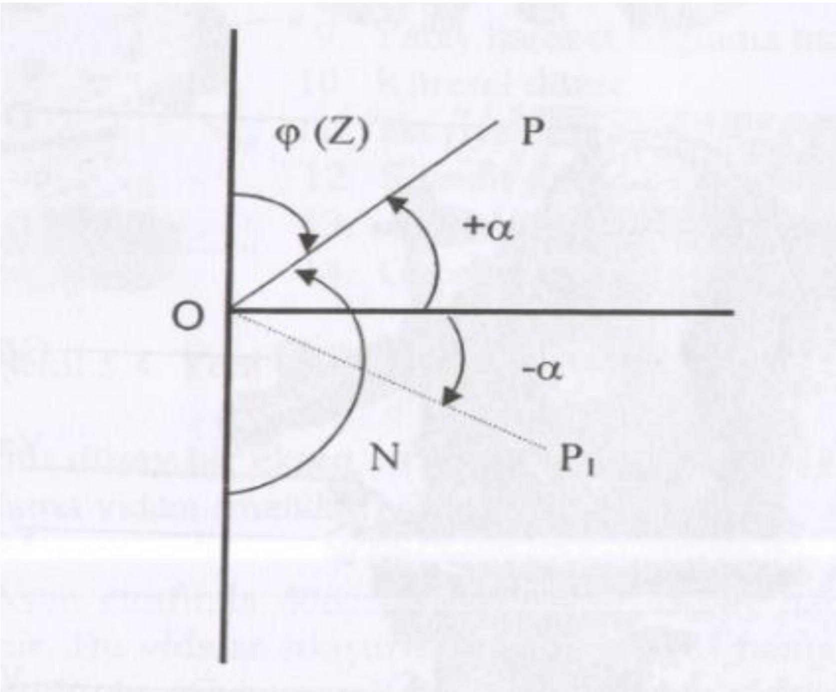
<u>Plumb line:</u> is a line that follows the direction of gravity.

<u>Zenith (vertical) angle :</u> is formed by two intersecting lines in a vertical plane, one of these lines being horizontal.

<u>Altitude angle:</u> is the complementary angle to the zenith angle and is formed by two intersecting lines in a vertical plane, one of these lines directed toward the zenith.

ANGLES AND DIRECTIONS

<u>Vertical angles:</u>



- Z : zenith angle
- N : Nadir angle
- α : slope angle
- (altitude angle)
- N : 200^g - Z
- Z + α = 100^g

ANGLES AND DIRECTIONS

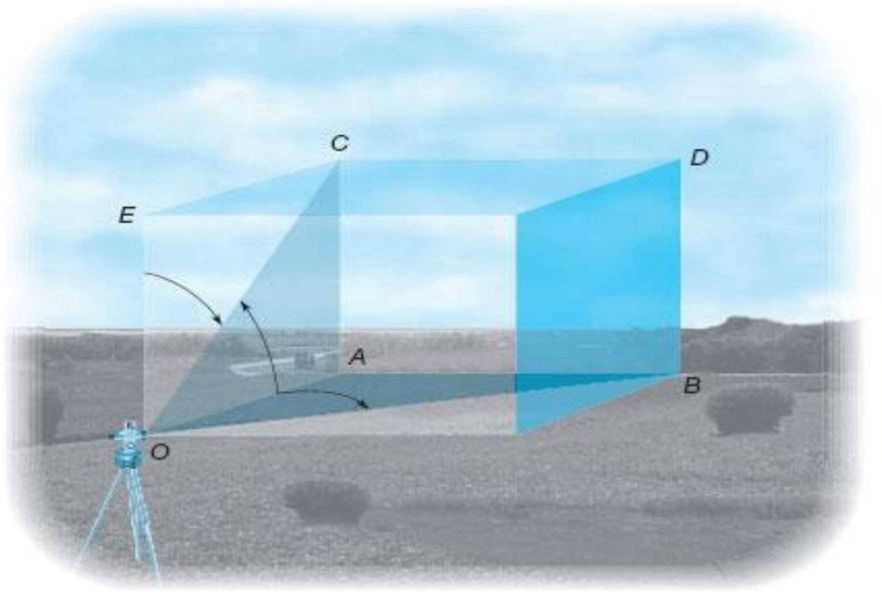


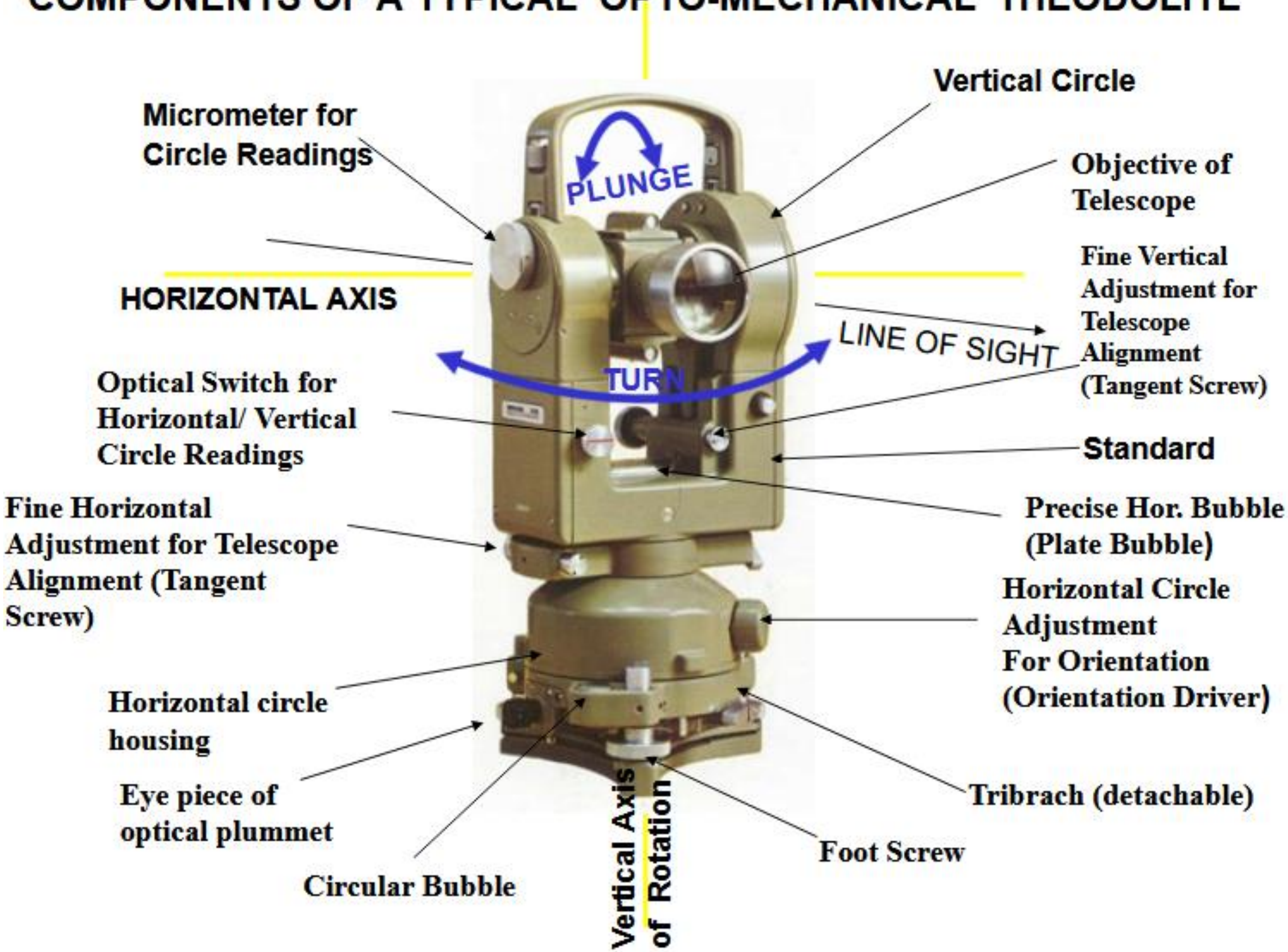
Figure:5 (C.D.Ghilani & P.R.Wolf,2008)

In the Figure:5; OAB and ECD are horizontal planes, and OACE and ABDC are vertical planes.

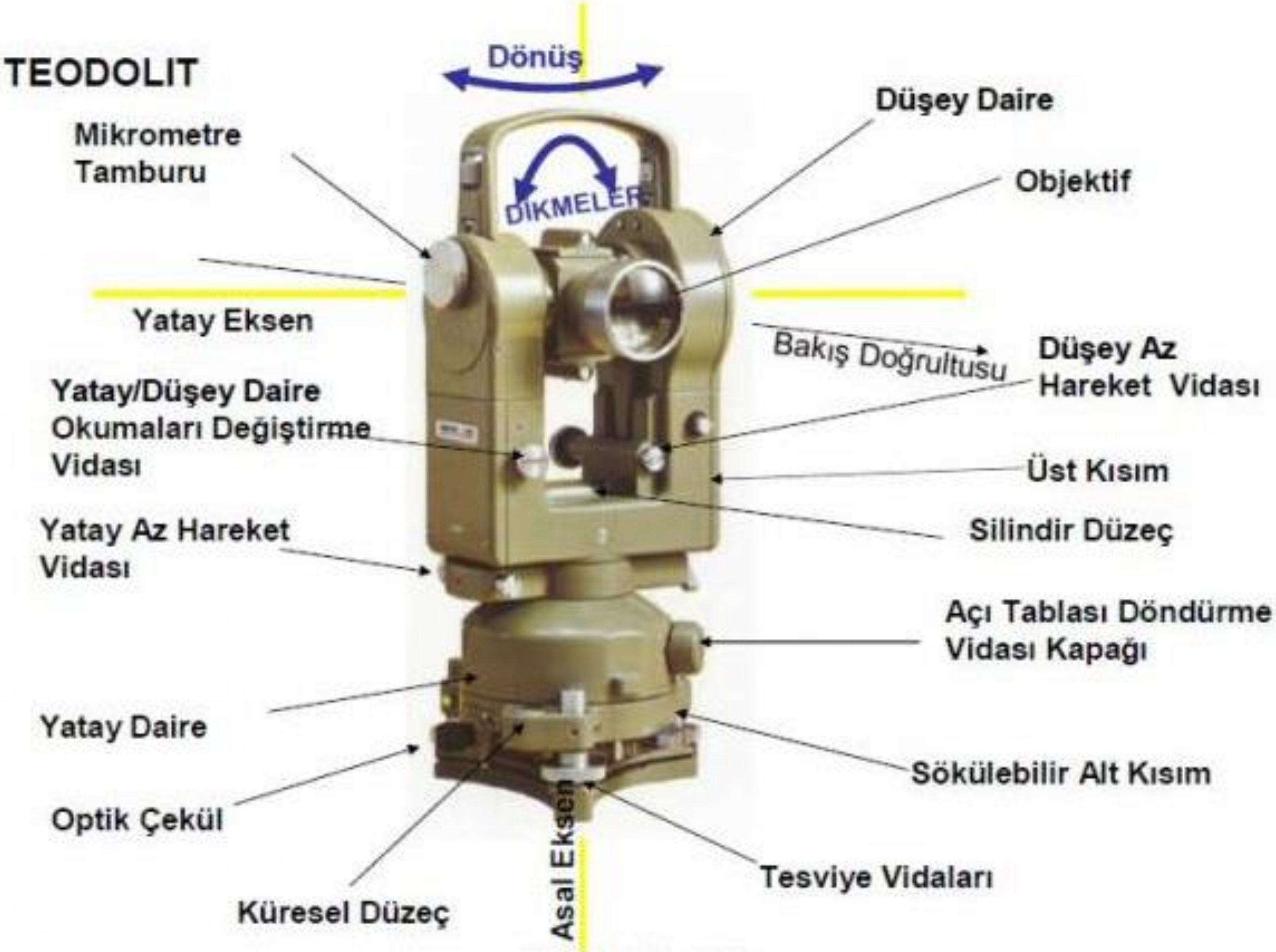
Then as illustrated, horizontal angles, such as angles AOB, and horizontal distances OA and OB , are measured in horizontal planes.

Altitude (vertical) angles, such as AOC, are measured in vertical planes; zenith angles, such as EOC, are also measured in vertical planes; vertical lines, such as AC and BD, and slope distance, such as OC, are determined along inclined planes.

COMPONENTS OF A TYPICAL 'OPTO-MECHANICAL' THEODOLITE



Teodolitin Ana Parçaları



Main Components

- **Upper Plate**: It is the base on which the standards and vertical circle are placed.
- **Vertical Scale (Circle): I**t is a full 400g scale. It is used to measure the angle between the line of sight (collimation axis) of the telescope and the vertical axis.

- **The Lower Plate**: It is the base of the whole instrument. It houses the foot screws and the bearing for the vertical axis.

- **Horizontal Scale (Circle):** It is a full 400g scale. It is often placed between the upper and lower plates. It is capable of full independent rotation about the trunnion axis.
- **Standards** are the frames which supports telescope and allow it to rotate about vertical axis.

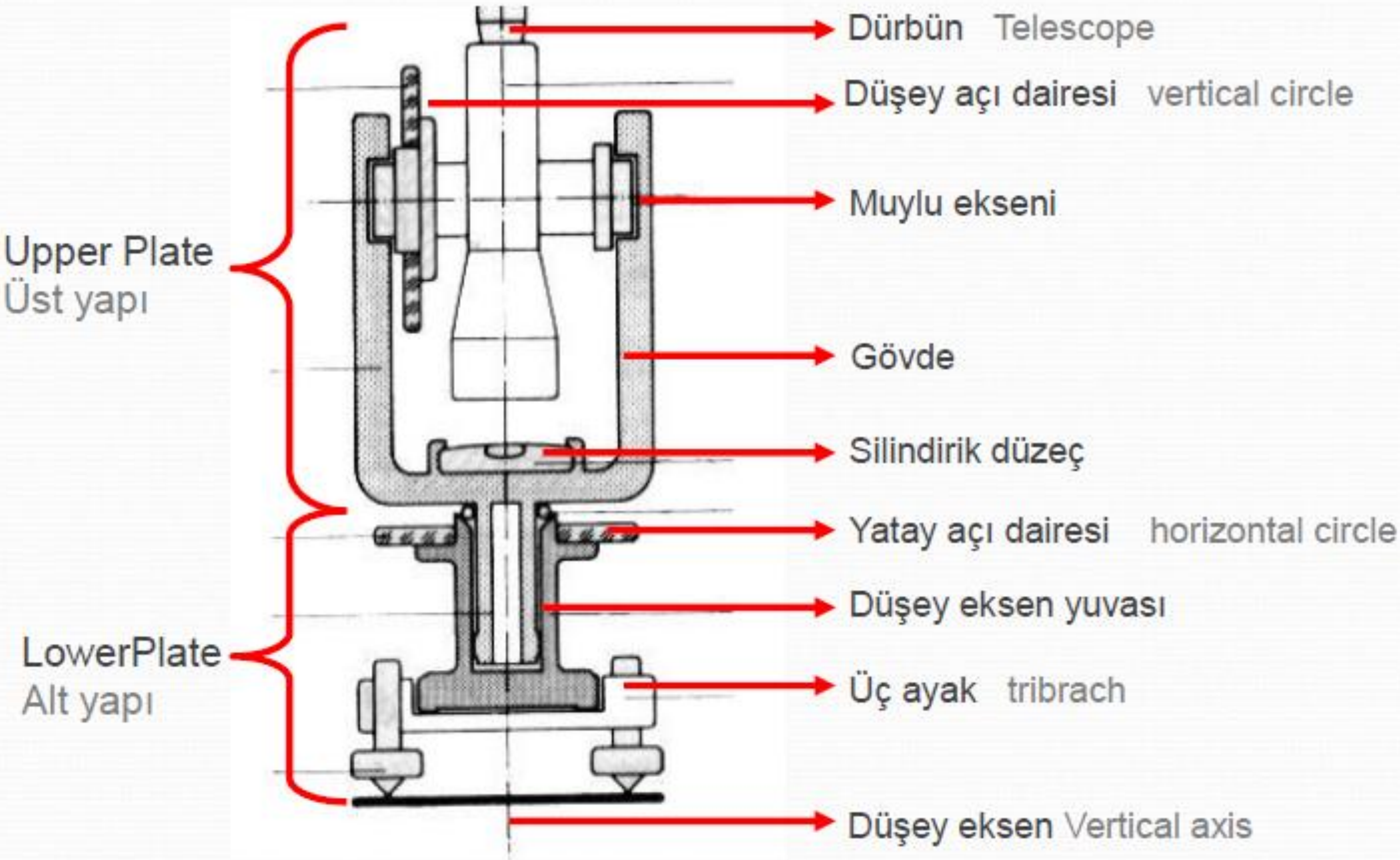
Main Components

- **Clamps and tangent screws (fine motion screw) :**
- There are two clamps and associated tangent screws.
- **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 plate. When this clamp is released the lower plate does not move but the upper plate moves with the instrument. The **upper tangent screw** allows the fine adjustment.
- **Vertical Clamp and Tangent Screw (fine motion screw)** : This allow free transiting of the telescope. When clamped, the telescope can be slowly transited using vertical tangent screw.
- **The horizontal clamp screw and fine motion screw (tangent screw)** controls locks the upper part of the theodolite in any desired position on its horizontal plane. Fine motion screw provides precise adjustment in the horizontal positioning of the telescope

- The ***tribrach*** consists of three screws, a circular level, clamping device to secure the base of the total station, and threads to attach the tribrach to the head of a tripod. As shown in Figure, some tribrachs also have optical plummets (described below) to enable centering accessories over a point without the instrument.
- An ***optical plummet***, built into either the tribrach or alidade of total station instruments, permits accurate centering over a point.

Figure Tribrach with optical plummet

Axes of Theodolite



Theodolite:

Components of theodolite:

The vertical axis of these instruments goes up through the center of the instrument and is oriented over a specific point on the earth surface. The circle assembly and alidade rotate about this axis.

Horizontal axis of the telescope is perpendicular to the vertical axis, and telescope and vertical circle tilt on it.

The line of sight (line of collimation) is a line joining the intersection of the reticle crosshairs and the center of the objective lens. The line of sight is perpendicular to the horizontal axis

Plate bubble axis is assumed to be tangent to the plate bubble.

Theodolite:

<u>Axes of theodolite:</u>

SS: Vertical (standing) axis

TT: Horizontal (Trunnion) axis

PP: Plate bubble (tubular level) axis

CC: Collimation axis(line of sight)

$CC \perp TT$
$PP \,//\, TT$
$SS \perp PP$
$SS \perp TT$

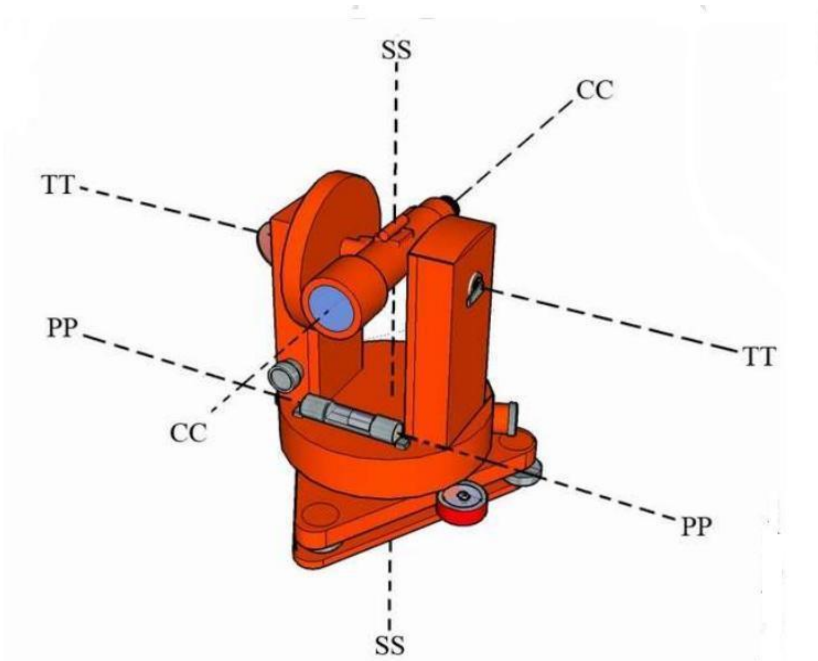


Figure:10(H.Özener , Surveying Lecture Notes

Theodolite:

Axes of theodolite:

The most important relationships are as follows:

1. The axis of plate bubble should be in a plane perpendicular to the vertical axis.(main axis order).
2. The line of sight should be perpendicular to the horizontal axis.
3. The horizontal axis should be perpendicular to the vertical axis