1.21 CHAIN AND TAPE CORRECTIONS

A. Tape Correction

1. Temperature correction (C_t) This correction is necessary because the length of the tape or chain may be increased or decreased due to rise or fall of temperature during measurement. The correction is given by the expression

$$C_t = \alpha (T_m - T_0) L$$

where,

C_t = correction for temperature, in metres
α = coefficient of thermal expansion
T_m = temperature during measurement in degrees centigrade or celsius
T_0 = temperature at which the tape was standardised, in degrees centigrade or celsius
L = length of tape, in metres

The sign of correction may be positive or negative according as T_m is greater or less than T_0.

When α for the steel tape is not given, it may be assumed to be 11×10^{-6} per degree centigrade or celsius.

2. Pull correction (C_p) During measurement, the applied pull may be either more or less than the pull at which the chain or tape was standardised. Due to the elastic property of materials, the strain will vary according to the variation of applied pull, and hence necessary correction should be applied. This correction is given by the expression

$$C_p = \frac{(P_m - P_0)\, L}{A \times E}$$

where C_p = pull correction in metres
P_m = pull applied during measurement, in kilograms
P_0 = pull at which the tape was standardised, in kilograms
L = length of tape, in metre
A = cross-sectional area of tape, in square centimetres
E = modulus of elasticity (Youngs' modulus)

The sign of correction will be positive or negative according as P_m is greater or less than P_0.

When E is not given, it may be assumed 2.1×10^6 kg/cm^2.

3. Slope correction (C_h) Slope correction is calculated as follows.

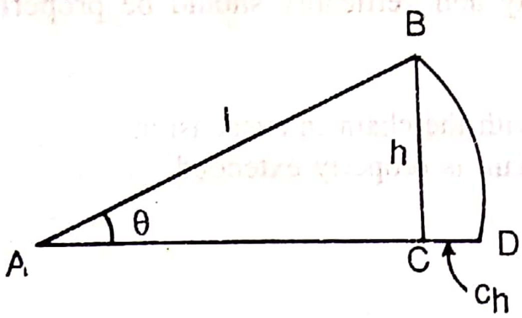


Fig. 1.22

$$C_h = l - \sqrt{l^2 - h^2} \quad \text{(exact)} \qquad (1)$$

$$= l\,(1 - \cos\theta) \quad \text{(exact)} \qquad (2)$$

$$= \frac{h^2}{2l} \quad \text{(approx)} \qquad (3)$$

This correction is always negative.

4. Sag correction (C_s) This correction is necessary when the measurement is taken with the tape in suspension (i.e. in the form of a catenary). It is given by the expression

$$C_s = \frac{L(\omega L)^2}{24 n^2 P_m^2} \qquad (1)$$

when unit weight is given

and

$$C_s = \frac{L W^2}{24 n^2 P_m^2} \qquad (2)$$

when total weight is given

where, C_s = sag correction, in metres

L = length of tape or chain, in metres
ω = weight of tape per unit length, in kilograms per metre
W = total weight of tape, in kilograms
n = number of spans
P_m= pull applied during measurement, in kilograms

The sign of correction is always negative.

5. ***Normal tension*** ***(P_n)*** The tension at which the effect of pull is neutralised by the effect of sag is known as normal tension. At this tension, the elongation due to pull is balanced by the shortening due to sag. So, equating the expressions for correction for pull and sag, we have

$$\frac{(P_n - P_0)\,L}{AE} = \frac{L\,(\omega L)^2}{24\,P_m^2} \text{ (considering } n = 1)$$

where, P_n = normal pull or tension

Here the value of P_n may be determined by trial, by forming an equation by putting the known values.

$$\frac{(P_n - P_0)\,L}{AE} = \frac{L\,(\omega L)^2}{24\,P_n^2} \text{ (considering } n = 1)$$

or

$$\frac{(P_n - P_0)}{AE} = \frac{W^2}{24\,P_n^2}$$

or

$$(P_n - P_0)\,P_n^2 = \frac{W^2 AE}{24}$$

By substituting the values of P_0, W, A and E, an equation will be obtained in the following form:

$$x\,P_n^3 \pm y P_n^2 \pm C = 0$$

Then, the value of P_n is to be determined by satisfying the equation by trial and error.

B. Chain Correction

1. Correction applied to incorrect length It is given by the expression

$$\text{True length of line (TL)} = \left(\frac{L'}{L}\right) \times \text{measured length (ML)}$$

where L = standard or true length of chain
L' = True length ± error
$= L \pm e$ (e = error in chain or tape, i.e. when it is too long or too short)

Use the positive sign when the chain or tape is too long, the negative sign when it is too short.

2. Correction of Incorrect area The correction to be applied in this case is given by the expression

$$\text{True area} = \left(\frac{L'}{L}\right)^2 \times \text{measured area}$$

3. Hypotenusal allowance This is explained in Sec. 1.15.

Hypotenusal allowance per tape = L (sec θ – 1)

where L = length of tape
θ = slope of the ground

This allowance is always added to the tape length.

1.22 WORKED OUT PROBLEMS ON CHAIN AND TAPE CORRECTIONS

Problem 1 The distance between two points, measured with a 20 m chain, was recorded as 327 m. It was afterwards found that the chain was 3 cm too long. What was the true distance between the points?

Solution Given data:

True length of chain, L = 20 m

Error in chain, e = 3 cm = 0.03 m, too long

$L' = L + e = 20 + 0.03 = 20.03$ m

Measured length = 327 m

$$\text{True length of line} = \frac{L'}{L} \times \text{ML}$$

$$= \frac{20.03}{20} \times 327 = 327.49 \text{ m}$$

Problem 2 The distance between two stations was 1,200 m when measured with a 20 m chain. The same distance when measured with 30 m chain was found to be 1,195 m. If the 20 m chain was 0.05 m too long, what was the error in the 30 m chain?

Solution Let us consider the 20 m chain.

L = 20 m L' = 20 + 0.05 = 20.05 m

Measured length = 1,200 m

$$\text{True length of line} = \frac{20.05}{20} \times 1{,}200 = 1{,}203 \text{ m}$$

Let us now consider the 30 m chain.

L = 30 m L' = ?

True length of line 1,203 m (as obtained from 20 m chain)

Measured length = 1,195 m.

From the relation

$$TL = \frac{L'}{L} \times ML$$

$$1{,}203 = \frac{L'}{30} \times 1{,}195$$

$$L' = \frac{1{,}203 \times 30}{1{,}195} = 30.20\,\text{m}$$

Now, L' is greater than L. So, the chain is too long.
Amount of error, $e = 30.20 - 30 = +\,0.20$ m

Problem 3 A line was measured by a 20 m chain which was accurate before starting the day's work. After chaining 900 m, the chain was found to be 6 cm too long. After chaining a total distance of 1,575 m, the chain was found to be 14 cm too long. Find the true distance of the line.

Solution First part:

$$L = 20\text{ m}$$

$$L' = 20 + \frac{0 + 0.06}{2} \text{ (considering mean elongation)}$$

$$= 20.03\text{ m}$$

$$ML = 900\text{ m}$$

$$TL = ?$$

$$TL = \frac{L'}{L} \times ML$$

$$= \frac{20.03}{20} \times 900 = 901.35\text{ m}$$

Second part:

$$L = 20\text{ m}$$

$$L' = 20 + \frac{0.06 + 0.14}{2} = 20.1\text{ m}$$

$$ML = 1{,}575 - 900 = 675\text{ m}$$

$$TL = \frac{20.1}{20} \times 675 = 678.375\text{ m}$$

True distance = 901.350 + 678.375 = 1,579.725 m

Problem 4 On a map drawn to a scale of 50 m to 1 cm, a surveyor measured the distance between two stations as 3,500 m. But it was found that by mistake he had used a scale of 100 m to 1 cm. Find the true distance between the stations.

Solution First method:

As the surveyor used the scale of 100 m to 1 cm,

$$\text{Distance between stations on map} = \frac{3500}{100} = 35\text{ cm}$$

As the actual scale of map is 50 m to 1 cm,

True distance on the ground = 35 × 50 = 1,750 m

Second method:

$$\text{True distance} = \frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times \text{measured length}$$

$$\text{True distance} = \frac{\dfrac{1}{100 \times 100}}{\dfrac{1}{50 \times 100}} \times 3{,}500$$

$$= \frac{50 \times 100}{100 \times 100} \times 3{,}500$$

∴ True distance = 50 × 35 = 1,750 m

Problem 5 An old map was plotted to a scale of 40 m to 1 cm. Over the years, this map has been shrinking, and a line originally 20 cm long is only 19.5 cm long at present. Again the 20 m chain was 5 cm too long. If the present area of the map measured by planimeter is 125.50 cm^2, find the true area of the land surveyed.

Solution According to the given conditions,

19.5 cm on the map was originally 20 cm.

Therefore, 1 cm on the map was originally $= \dfrac{20}{19.5}$ cm, and

1 cm^2 on the map was originally $= \dfrac{(20)^2}{(19.5)^2}$ cm^2

125.50 cm^2 was originally $= \dfrac{(20)^2}{(19.5)^2} \times 125.50 = 132.0184$ cm^2

Scale of map was 1 cm = 40 m

⇒ 1 cm^2 = 1,600 m^2

Area on the ground = 1,600 × 132.0184

= 211,229.44 m^2

Since the chain was 0.05 m too long,

$$\text{True area} = \frac{(20.05)^2}{(20)^2} \times 211{,}229.44 = 212{,}286.90 \text{ m}^2$$

= 21.2286 hectares

(1 hectare = 10,000 m^2)

Problem 6 A steel tape was exactly 30 m long at 20°C when supported throughout its length under a pull of 10 kg. A line was measured with this tape under a pull of 15 kg and at a mean temperature of 32°C and found to be 780 m long. The cross-sectional area of the tape = 0.03 cm^2, and its total weight = 0.693 kg. α for steel = 11×10^{-6} per °C and E for steel = 2.1×10^6 kg/cm². Compute the true length of the line if the tape was supported during measurement (i) at every 30 m (ii) at every 15 m.

(WBSC 1989

Solution Given data:

$L = 30$ m $\quad A = 0.03$ cm²

$T_0 = 20$°C $\quad \alpha = 11 \times 10^{-6}$ per °C

$P_0 = 10$ kg $\quad E = 2.1 \times 10^6$ kg/cm²

$P_m = 15$ kg $\quad W = 0.693$ kg

$T_m = 32$°C $\quad$ ML = 780 m

(a) When supported at every 30 m:

Total correction per tape length is to be found out first. Here, $n = 1$.

(i) Temperature correction, $C_t = \alpha(T_m - T_0)\,L$

$$= 11 \times 10^{-6}\,(32 - 20) \times 30$$

$$= 0.00396 \text{ m (+ve)}$$

(ii) Pull correction, $C_p = \dfrac{(P_m - P_0)\,L}{A \times E}$

$$= \frac{(15 - 10) \times 30}{0.03 \times 2.1 \times 10^6} = 0.00238 \text{ m (+ve)}$$

(iii) Sag correction, $C_s = \dfrac{LW^2}{24\,n^2\,P_m^2}$

$$= \frac{30 \times (0.693)^2}{24 \times (15)^2} = 0.00267 \text{ m (–ve)}$$

Total correction = + 0.00396 + 0.00238 – 0.00267

= + 0.00367 m (too long)

so $\quad L' = L + e = 30.00367$ m

$$\text{True length} = \frac{L'}{L} \times \text{ML}$$

$$= \frac{30.00367}{30} \times 780 = 780.094 \text{ m}$$

(b) When supported at every 15 m:

Here, span $n = 2$

Let us find out the correction per tape length.

(i) Temperature correction = 0.00396 m (+ve) as before

(ii) Pull correction = 0.00238 m (+ve) as before

(iii) Sag correction = $\dfrac{LW^2}{24n^2P_m^2}$

$$= \frac{30 \times (0.693)^2}{24 \times 2^2 \times (15)^2} = 0.00067 \text{ m } (-\text{ve})$$

$$\text{Total correction} = +\ 0.00396 + 0.00238 - 0.00067$$

$$= +\ 0.00567 \text{ m (too long)}$$

so $$L' = L + c = 30.00567$$

$$\text{True length} = \frac{30.00567}{30} \times 780 = 780.147 \text{ m}$$

Problem 7 A 20-m steel tape was standardised on flat ground, at a temperature of 20°C and under a pull of 15 kg. The tape was used in catenary at a temperature of 30°C and under a pull of P kg. The cross-sectional area of the tape is 0.22 cm², and its total weight is 400 g. The Young's modulus and coefficient of linear expansion of steel are 2.1×10^6 kg/cm² and 11×10^{-6} per °C respectively. Find the correct horizontal distance if P is equal to 10 kg. (WBSC 1988)

Solution Given data:

$L = 20$ m	$A = 0.02$ cm²
$T_0 = 20°C$	$\alpha = 11 \times 10^{-6}$ per °C
$P_0 = 15$ kg	$E = 2.1 \times 10^{-6}$ kg/cm²
$T_m = 30°C$	$W = 400$ g $= 0.4$ kg
$P = 10$ kg	$n = 1$

Here, applied pull $P = 10$ kg.

(a) Temperature correction, $C_t = \alpha(T_m - T_0)\, L$

$$= 11 \times 10^{-6}\ (30 - 20)\ 20$$

$$= 11 \times 10^{-6} \times 10 \times 20$$

$$= 0.00220 \text{ m } (+\text{ve})$$

(b) Pull correction, $C_p = \dfrac{(P - P_0)\, L}{A \times E}$

$$= \frac{(10 - 15)\, 20}{0.02 \times 2.1 \times 10^6}$$

$$= -\frac{5 \times 20}{0.02 \times 2.1 \times 10^6}$$

$$= -\ 0.00238 \text{ m } (-\text{ve})$$

∴ Sag correction, $C_s = \dfrac{LW^2}{24\, n^2 P^2}$ $(n = 1)$

$$= \frac{20 \times (0.4)^2}{24 \times (10)^2} = 0.00133 \text{ m } (-\text{ve})$$

Total correction $= +\ 0.00220 - 0.00238 - 0.00133 = -\ 0.00151$ m

Correct horizontal distance $= 20 - 0.00151 = 19.99849$ m

1.23 PROBLEMS ON OBSTACLES IN CHAINING

Problem 1 A survey line CD intersects a building. To overcome the obstacle a perpendicular DE, 87 m long, is set out at D. From E, two lines EF and EG are set out at angles 50° and 65° respectively with ED. Find the lengths EF and EG such that points F and G fall on the prolongation of CD. Also find the obstructed distance DF.

(WBSC 1989)

Solution

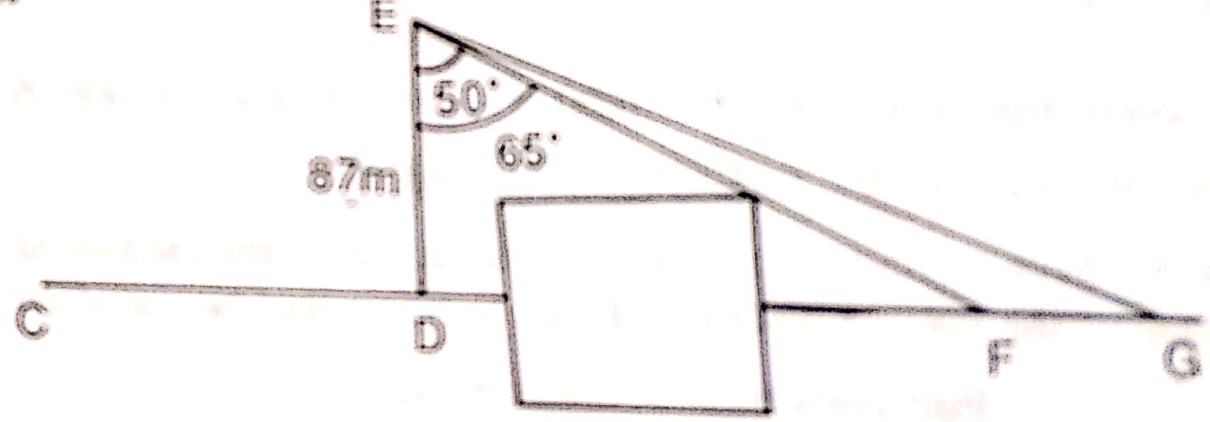


Fig. P.1.1

From Δ DEF,

$$\frac{DE}{EF} = \cos 50°$$

$$EF = \frac{DE}{\cos 50°} = \frac{87}{0.6428} = 135.345 \text{ m}$$

and

$$\frac{DF}{DE} = \tan 50°$$

$$DF = DE \tan 50° = 87 \times 1.1918 = 103.68 \text{ m}$$

From Δ DEG,

$$\frac{DE}{EG} = \cos 65^\circ$$

$$EG = \frac{DE}{\cos 65^\circ} = \frac{87}{0.4226} = 205.9 \text{ m}$$

Problem 2 P and Q are two points 367 m apart on the same bank of a river. The bearings of a tree on the other bank observed from P and Q are N 36°25′ E and N 40°35′ W, respectively. Find the width of the river if bearings of PQ are S 86°35′ E. (WBSC 1988)

Solution

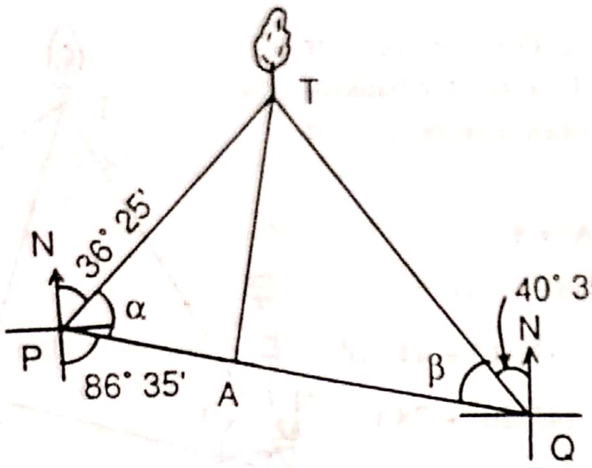


Fig. P. 1.2

Let the points P and Q be on the near side and the tree T on the far bank of the river. From T, draw a perpendicular TA to PQ. Then TA is the width of the river.

Let $\quad PA = x$

Then, $\quad AQ = 367 - x$

$$\alpha = 180^\circ - (36^\circ25' + 86^\circ35') = 57^\circ0'$$

$$\beta = 86^\circ35' - 40^\circ35' = 46^\circ0'$$

From Δ PTA,

$$\frac{TA}{PA} = \tan \alpha$$

$$TA = x \tan 57^\circ 0' \qquad (1)$$

From Δ QTA,

$$\frac{TA}{AQ} = \tan \beta$$

$$TA = (367 - x) \tan 46^\circ0' \qquad (2)$$

From (1) and (2),

$$x \tan 57^\circ 0' = (367 - x) \tan 46^\circ0'$$

or $\quad x \times 1.5399 = (367 - x) \times 1.0355$

or $\quad 2.5754\, x = 380.0285$

$$x = 147.56 \text{ m}$$

From (1),

$$TA = 147.56 \times 1.5399 = 227.229 \text{ m}$$

So, the width of the river is 227.229 m.

Problem 3 P and Q are two points 517 m apart on the same bank of a river. The bearings of a tree on the other bank observed from P and Q are N 33°40′ E and N43°20′ W respectively. Find the width of the river if the bearings of PQ are N78° E. (WBSC 1986)

Solution

Let the points P and Q be on the near bank and the tree T on the far bank of the river. From T, draw a perpendicular drawn to PQ.

Let $PA = x$

Then, $AQ = (517 - x)$

Here $\alpha = 78°0' - 33°40' = 44°20'$

$\beta = 180° - (43°20' + 78°0')$

$= 58°40'$

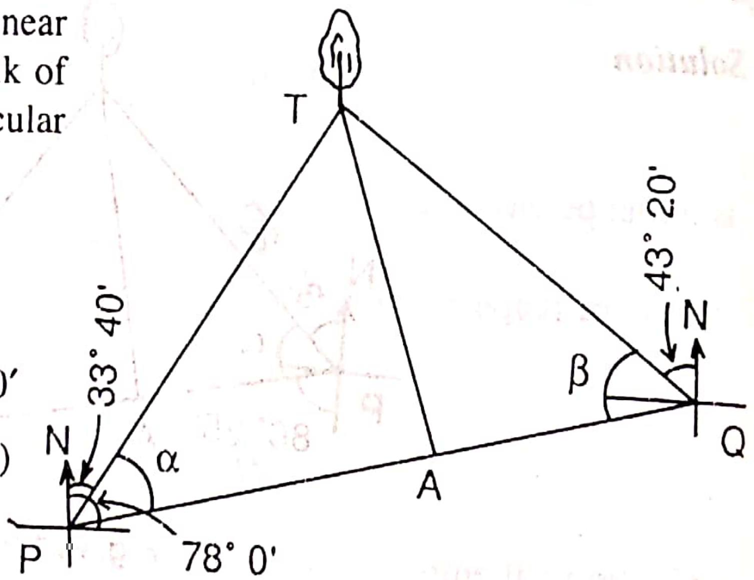


Fig. P.1.3

From triangle PTA, $\dfrac{TA}{PA} = \tan\alpha$

$$TA = x \tan 44°20' \quad (1)$$

From triangle QTA, $\dfrac{TA}{QA} = \tan\beta$

$$TA = (517 - x)\tan 58°40' \quad (2)$$

From (1) and (2), $x \tan 44°20' = (517 - x)\tan 58°40'$

or $$x \times 0.9770 = (517 - x) \times 1.6426$$

or $$2.6196\, x = 849.224$$

or $$x = 324.18 \text{ m}$$

From (1), $TA = 324.18 \times 0.9770 = 316.724$ m

So, the width of the river is 316.724 m.

1.24 PROBLEMS RELATED TO SLOPING GROUND

Problem 1 The following slope distances were measured along a chain line with a 20 m steel tape;

Slope distance (m) = 17.5, 19.3, 17.8, 13.6, and 12.9

Difference of elevation between ends (m) = 2.35, 4.20, 2.95, 1.65, and 3.25

It was noted afterwards that the tape was 2.5 cm too short. Find the true horizontal distance.

Solution

$AB = \sqrt{17.5^2 - 2.35^2} = 17.34 \text{ m}$ $\quad B_1C = \sqrt{19.3^2 - 4.2^2} = 18.84 \text{ m}$

$C_1D = \sqrt{17.8^2 - 2.95^2} = 17.56 \text{ m}$ $\quad D_1E = \sqrt{13.6^2 - 1.65^2} = 13.49 \text{ m}$

$E_1F = \sqrt{12.9^2 - 3.25^2} = 12.48 \text{ m}$

Total horizontal distance = AB + B_1C + C_1D + D_1E + E_1F

= 79.71 m

Here the steel tape was 2.5 cm too short.

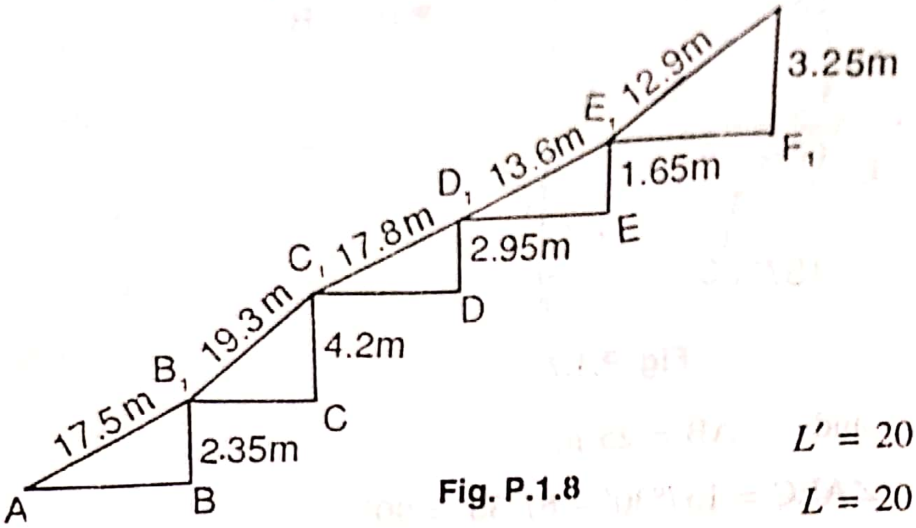


Fig. P.1.8

$L' = 20 - 0.025 = 19.975$ m

$L = 20$ m ML = 79.71 m

$$\text{True length} = \frac{19.975}{20} \times 79.71 = 79.61 \text{ m}$$

Problem 2 The length of a line measured on a slope of 15° was recorded as 550 m. But it was found that the 20 m chain was 0.05 m too long. Calculate the true horizontal distance of the line.

Solution

Horizontal distance AB = $AB_1 \cos 15°$

= 550 × 0.9659

= 531.25 m

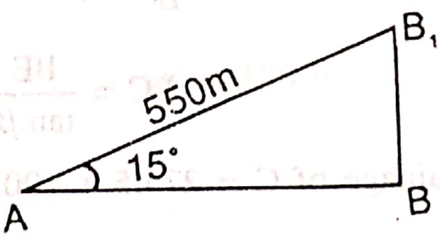


Fig. P.1.9

Again L = 20 m

$L' = (20 + 0.05)$ m = 20.05 m

ML = 531.25 m

$$\text{True length} = \frac{20.05}{20} \times 531.25$$

= 532.6 m

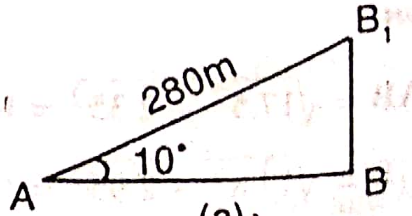
Problem 3 The distance between two points A and B measured along a slope was 280 m. Determine the horizontal distance between A and B when (a) the angle of slope is 10° (b) the slope is 1 in 10, and (C) the difference of level between A and B is 8 m.

Solution

(a)

Horizontal distance,

AB = 280 cos 10° = 275.74 m



(a);

Fig. P.1.10 (a)

(b)

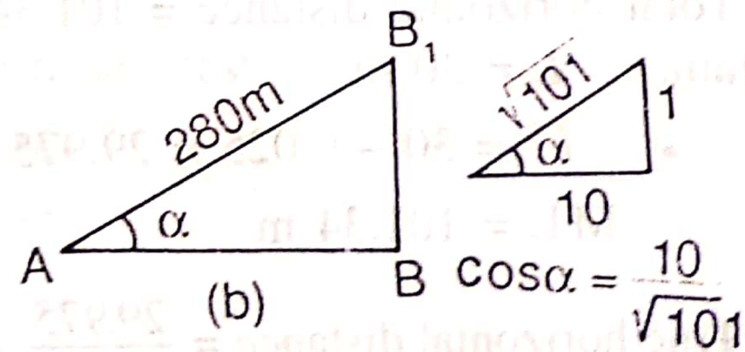


Fig. P.1.10 (b)

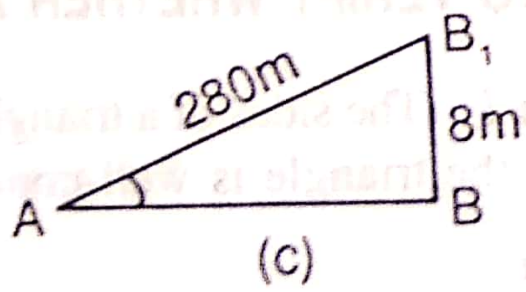
Horizontal distance, AB = 280 cos α

$$= 280 \times \frac{10}{\sqrt{101}} = 278.6 \text{ m}$$

(c)

Horizontal distance,

$$AB = \sqrt{280^2 - 8^2} = 279.9 \text{ m}$$



1.25 TO VERIFY WHETHER A TRIANGLE IS WELL-CONDITIONED

Problem 1 The sides of a triangle are 12.0, 16.5 and 23.0 m respectively. Examine whether the triangle is well-conditioned.

Solution

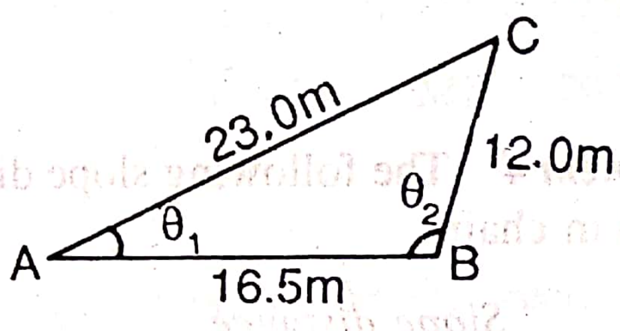


Fig. P.1.12

Let θ_1 = acute angle opposite to smallest side

θ_2 = obtuse angle opposite to greatest side

Now, $$\cos \theta_1 = \frac{23^2 + 16.5^2 - 12^2}{2 \times 23 \times 16.5}$$

$$= \frac{657.25}{759} = 0.866$$

or $$\cos \theta_1 = \cos 30°$$

$$\theta_1 = 30°$$

$$\cos \theta_2 = \frac{16.5^2 + 12^2 - 23^2}{2 \times 16.5 \times 12} = -\frac{112.75}{396} = -0.2847$$

or $$\cos \theta_2 = -\cos 73°27'$$

$$= \cos (180° - 73°27') = \cos 106°33'$$

$\therefore$ $$\theta_2 = 106°33'$$

As the obtuse angle is less than 120°, it is a well-conditioned triangle.

SHORT QUESTIONS FOR VIVA

Q.1 What is the fundamental difference between surveying and levelling?

Ans. In surveying, the measurements are taken in the horizontal plane, but in levelling they are taken in the vertical plane.

Q.2 What is the fundamental difference between plane surveying and geodetic surveying?

Ans. In plane surveying, the curvature of the earth is not considered. But in geodetic surveying, the curvature of the earth is considered.

Q.3 What do you mean by the terms 'topographical map' and 'cadastral map'?

Ans. A map which shows the natural features of a country such as rivers, hills, roads, railways, villages, towns, etc. is known as a topographical map, and one which shows the boundaries of estates, fields, houses, etc. is known as a cadastral map.

Q.4 What is the main principle of surveying?

Ans. The fundamental principle of surveying is to work from the whole to the part.

Q.5 How is a chain folded and unfolded?

Ans. In order to fold the chain, a chainman moves forward by pulling the chain at the middle so that two halves come side by side. Then he places the pair of links on his left hand with his right hand until the two brass handles appear at the top.

To unfold the chain, a chainman holds the two brass handles in his left hand and throws the bunch with his right hand. Then one chainman stands at a station holding one handle and another chainman moves forward by holding the other handle.

Q.6 In a chaining operation, who is the leader and who the follower?

Ans. The chainman at the forward end of the chain who drags the chain is known as the leader.

The one at the rear end of the chain is known as the follower.

Q.7 While chaining a line, you have to measure through a steep sloping ground. What method should you apply?

Ans. The stepping method.

Q.8 Two stations are not intervisible due to intervening high ground. How will you range the line?

Ans. The ranging is to be done by the reciprocal method.

Q.9 What do you mean by normal tension?

Ans. The tension at which the measured distance is equal to the correct distance (i.e. when sag correction is neutralised by pull correction) is known as normal tension.

Q.10 What do you mean by RF?

Ans. The ratio of the distance on the drawing to the corresponding actual length of the object is known as RF.

Q.11 What is the difference between plain scale and diagonal scale?

Ans. The plain scale represents two successive units. The diagonal scale represents three successive units.

Q.12 What is hypotenusal allowance?

Ans. When one chain length is measured on sloping ground, then it shows a shorter distance on the horizontal plane. The difference between the sloping distance and horizontal distance is known as the hypotenusal allowance.

Q.13 How many ranging rods are required to range a line?

Ans. At least three ranging rods are required for direct ranging, and at least four for indirect ranging.

Q.14 What is the length of one link in a 20 m chain?

Ans. The 20 m chain is divided into 100 links. So, one link is 0.2 m, i.e. 20 cm, long.

SHORT QUESTIONS WITH ANSWERS FOR VIVA

Q. 1 What is the principle of chain surveying?

Ans. The principle of chain surveying is triangulation.

Q. 2 What do you mean by triangulation?

Ans. The method of dividing an area into a number of triangles is known as triangulation.

Q. 3 Why is the triangle preferred to the quadrilateral?

Ans. The triangle is preferred just it is a simple figure which can be drawn by just knowing the lengths of its sides.

Q. 4 What is the disadvantage of using ill-conditioned triangles?
Ans. The apex points of an ill-conditioned triangle are not well defined and sharp. This may cause some confusion while marking the actual point correctly on the map.

Q. 5 What is reconnaissance survey?
Ans. The preliminary inspection of the area to be surveyed is known as reconnaissance survey.

Q. 6 What is an index sketch?
Ans. During reconnaissance survey, a neat hand sketch is prepared showing the framework of the survey. This sketch is known as the index sketch.

Q. 7 What is 'base line of survey'?
Ans. The base line is the backbone of the survey. The framework of the survey is prepared on this line.

Q. 8 How is the north line of the chain survey map fixed?
Ans. The north line of the chain survey map is fixed by taking the magnetic bearings of the base line by prismatic compass.

Q. 9 Suppose you are asked to conduct a chain survey in a crowded town. What would you say?
Ans. In chain survey, the whole area is to be divided into a number of triangles. But the formation of triangles is not possible in a crowded town. So, I would reject the proposal.

Q. 10 What should be the maximum length of offset?
Ans. The maximum length of offset should be within the length of the tape used. Generally, it should not be more than 15 m.

Q. 11 How is a station marked on the ground?
Ans. The station is marked on the ground by a wooden peg, and with a cross on the station point.

Q. 12 What is the need of a reference sketch?
Ans. If the station peg is removed by someone, the station can be located accurately with the help of the measurements shown in the reference sketch.

Q. 13 How will you set up a perpendicular with the help of only a chain and a tape?
Ans. By forming a triangle in the ratio 3 : 4 : 5 using the chain and tape.

Q. 14 Who are the 'leader' and 'follower' when a line is being chained?
Ans. The chain man at the forward end of the chain who drags the chain is known as the 'leader'. The one at the rear end of the chain who holds the 'zero' end at the station is known as the 'follower'.

Q. 15 Why does the field book open lengthwise?
Ans. If the field book is opened lengthwise, it become easy to maintain the continuation of a chain line.

Q. 16 Why is the scale always drawn in the map?
Ans. The paper on which the map is drawn may shrink or expand due to various reasons. If the scale is plotted on the map, then it is also reduced or enlarged proportionately. So, the distances on the map measured by this scale remain unaltered.

Q. 17 What is it necessary to provide tallies in a chain?
Ans. Tallies are provided in a chain for the facility of counting some fractional length of the chain, when the full chain length is not required.

Q. 18 What do you mean by the term 'ideal triangle'?
Ans. An equilateral triangle is said to be ideal.

5. Designation of magnetic bearing Magnetic bearings are designated by two systems:

(i) Whole circle bearing (WCB), and

(ii) Quadrantal bearing (QB).

(a) Whole Circle Bearing (WCB) The magnetic bearing of a line measured clockwise from the north pole towards the line, is known as the 'whole circle bearing, of that line. Such a bearing may have any value between 0° and 360°. The whole circle bearing of a line is obtained by prismatic compass (Fig. 3.2).

For example, in Fig. 3.2,

WCB of AB = θ_1
WCB of AC = θ_2
WCB of AD = θ_3
WCB of AE = θ_4

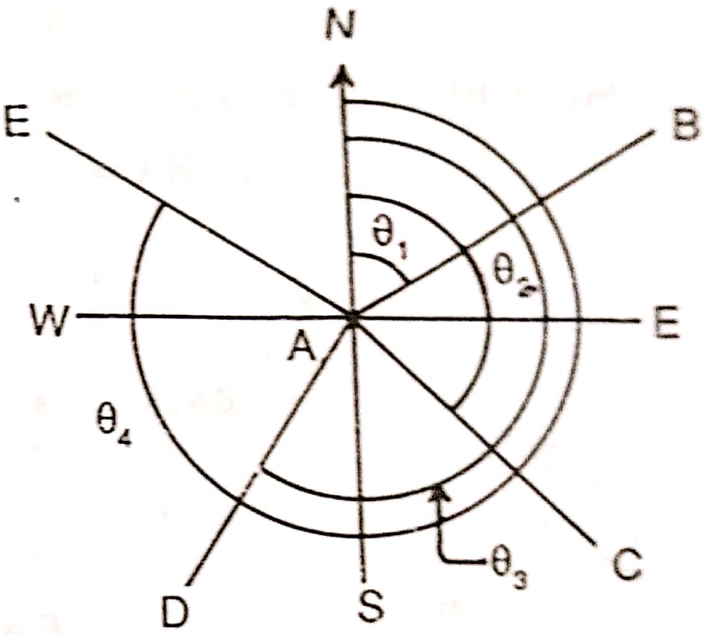


Fig. 3.2

(b) Quadrantal Bearing (QB) The magnetic bearing of a line measured clockwise or counterclockwise from the North Pole or South Pole (whichever is nearer the line) towards the East or West, is known as the 'quadrantal bearing' of the line. This system consists of four quadrants—NE, SE, SW and NW. The value of a quadrantal bearing lies between 0° and 90°, but the quadrants should always be mentioned. Quadrantal bearings are obtained by the surveyor's compass (Fig. 3.3).

For example, QB of AB = $N\theta_1$ E
QB of AC = $S\theta_2$ E
QB of AD = $S\theta_3$ W
QB of AE = $N\theta_4$ W

6. *Reduced bearing (RB)* When the whole circle bearing of a line is converted to quadrantal bearing, it is termed the 'reduced bearing'. Thus, the reduced bearing is similar to the quadrantal bearing. Its value lies between 0° and 90°, but the quadrants should be mentioned for proper designation.

The following table should be remembered for conversion of WCB to RB:

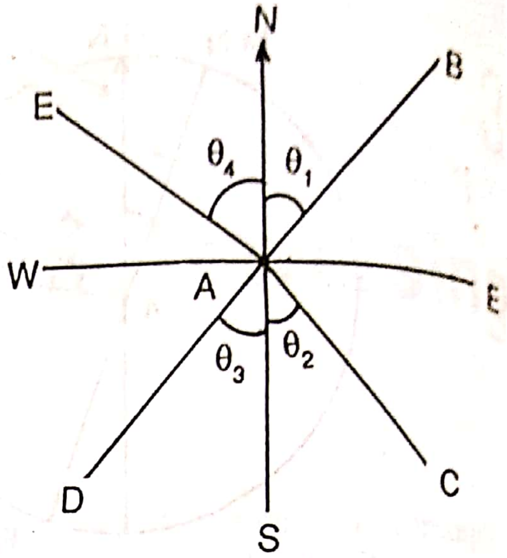


Fig. 3.3

WCB between	Corresponding RB	Quadrant
0° and 90°	RB = WCB	NE
90° and 180°	RB = 180° – WCB	SE
180° and 270°	RB = WCB – 180°	SW
270° and 360°	RB = 360° – WCB	NW

7. Fore and back bearing The bearing of a line measured in the direction of the progress of survey is called the 'fore bearing' (FB) of the line.

The bearing of a line measured in the direction opposite to the survey is called the 'back bearing' (BB) of the line (Fig. 3.4).

For example, in Fig. 3.4(a), FB of AB = θ

BB of AB = θ_1

In Fig. 3.4(b), FB of BA = θ

BB of BA = θ_1

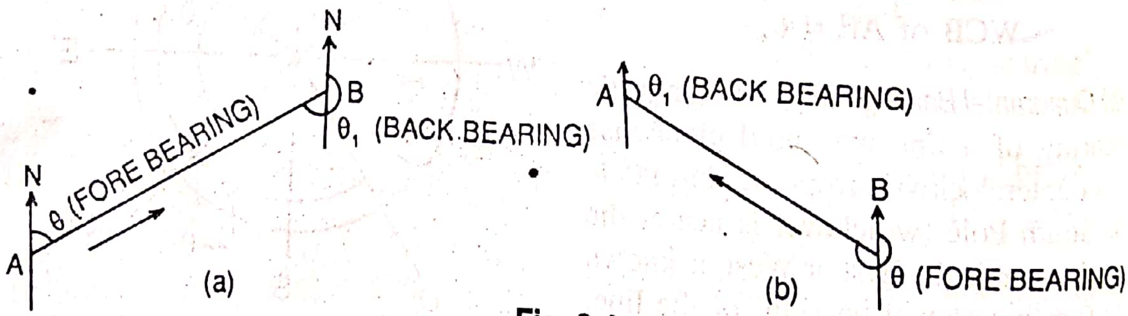


Fig. 3.4

Remember the following:

(a) In the WCB system, the difference between the FB and BB should be exactly 180°. Remember the following relation:

$$BB = FB \pm 180°$$

Use the positive sign when FB is less than 180°, and the negative sign when it is more than 180°.

(b) In the quandrantal bearing (i.e. reduced bearing) system, the FB and BB are numerically equal but the quadrants are just opposite.

For example, if the FB of AB is N 30° E, then its BB is S 30° W.

3.10 PROBLEMS ON WHOLE CIRCLE BEARING AND QUADRANTAL BEARING

Problem 1 Convert the following WCBs to QBs.

(a) WCB of AB = 45°30′
(b) WCB of BC = 125°45′
(c) WCB of CD = 222°15′
(d) WCB of DE = 320°30′

Solution

(a) QB of AB = N 45°30′ E
(b) QB of BC = 180°0′ – 125°45′ = S54°15′ E
(c) QB of CD = 222°15′ – 180°0′ = S42°15′ W
(d) QB of DE = 360°0′ – 320°30′ = N39°30′ W

Problem 2 Convert the following QBs to WCB

(a) QB of AB = S 36°30′ W
(b) QB of BC = S 43°30′ E
(c) QB of CD = N 26°45′ E
(d) QB of DE = N 40°15′ W

Solution

(a) WCB of AB = 180°0′ + 36°30′ = 216°30′
(b) WCB of BC = 180°0′ – 43°30′ = 136°30′
(c) WCB of CD = given QB = 26°45′
(d) WCB of DE = 360°0′ – 40°15′ = 319°45′

3.11 PROBLEMS ON FORE AND BACK BEARINGS

Problem 1 The FBs of the following lines are given. Find the BBs.

(a) FB of AB = 310°30′

(b) FB of BC = 145°15′
(c) FB of CD = 210°30′
(d) FB of DE = 60°45′

Solution

(a) BB of AB = 310°30′ – 180°0′ = 130°30′
(b) BB of BC = 145°15′ + 180°0′ = 325°15′
(c) BB of CD = 210°30′ – 180°0′ = 30°30′
(d) BB of DE = 60°45′ + 180°0′ = 240°45′

Problem 2 FBs of the following lines are given. Find the BBs.

(a) FB of AB = S 30°30′ E
(b) FB of BC = N 40°30′ W
(c) FB of CD = S 60°15′ W
(d) FB of DE = N 45°30′ E

Solution

(a) BB of AB = N 30°30′ W
(b) BB of BC = S 40°30′ E
(c) BB of CD = N 60°15′ E
(d) BB of DE = S 45°30′ W

Problem 3 BBs of the following lines are given. Find the FBs.

(a) BB of AB = 40°30′
(b) BB of BC = 310°45′
(c) BB of CD = 145°45′
(d) BB of DE = 215°30′

Solution

(a) FB of AB = 40°30′ + 180° 0′ = 220°30′
(b) FB of BC = 310°45′ – 180° 0′ = 130°45′
(c) FB of CD = 145°45′ + 180° 0′ = 325°45′
(d) FB of DE = 215°30′ – 180° 0′ = 35°30′

Problem 4 BBs of the following lines are given. Find the FBs.

(a) BB of AB = N 30°30′ W
(b) BB of BC = S 40°15′ E
(c) BB of CD = N 60°45′ E
(d) BB of DE = S 45°30′ W

Solution

(a) FB of AB = S 30°30′ E
(b) FB of BC = N 40°15′ W
(c) FB of CD = S 60°45′ W
(d) FB of DE = N 45°30′ E

3.12 PROBLEMS ON MAGNETIC DECLINATION

Remember the following:

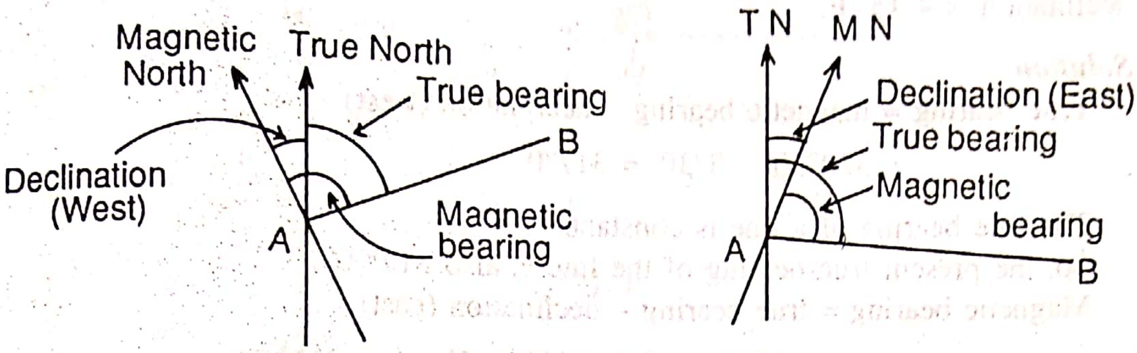


Fig. P-3.1

Determination of true bearing and magnetic bearing:

(a) True bearing = magnetic bearing ± declination

Note [use the positive sign when declination east, and the negative sign when declination west.]

(b) Magnetic bearing = true bearing ± declination

Note [Use the positive sign when declination west, and the negative sign when declination east.]

Problem 1 (a) The magnetic bearing of a line AB is 135°30′. What will be the true bearing, if the declination is 5°15′ W.

(b) The true bearing of a line CD is 210°45′. What will be its magnetic bearing, if the declination is 8°15′ W.

Solution

(a) True bearing of AB = magnetic bearing – declination

= 135°30′ – 5°15′ = 130°15′

(b) Magnetic bearing = true bearing + declination

= 210°45′ + 8°15′ = 219°0′

Problem 2 The magnetic bearing of a line CD is S 30°15′ W. Find its true bearing, if the declination is 10°15′ E.

Solution First convert the RB to WCB, and then follow the usual procedure to find the true bearing in WCB. Finally, convert the true bearing to RB.

RB of CD = S 30°15′ W

WCB of CD = 180°0′ + 30°15′ = 210°15′

Now TB = MB + declination (east)

= 210°15′ + 10°15′ = 220°30′

Required true bearing = 220°30′ – 180° = S 40°30′ W

3.14 PROBLEMS ON LOCAL ATTRACTION

Problem 1 The following are the observed bearings of the lines of a traverse ABCDEA with a compass in a place where local attraction was suspected.

Line	FB	BB
AB	191°45′	13°0′
BC	39°30′	222°30′
CD	22°15′	200°30′
DE	242°45′	62°45′
EA	330°15′	147°45′

Find the correct bearings of the lines. (WBSC 1969)

Solution *First method—By calculating interior angles*

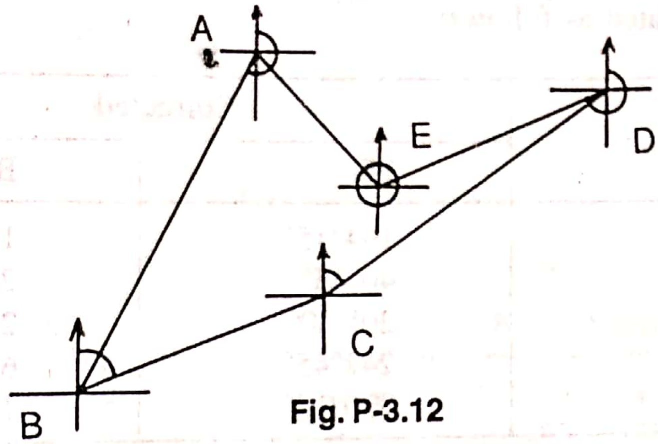


Fig. P-3.12

(a) Calculation of interior angle

Interior ∠A = FB of AB – BB of EA = 191°45′ – 147°45′ = 44°00′
Interior ∠B = FB of BC – BB of AB = 39°30′ – 13°00′ = 26°30′
Exterior ∠C = BB of BC – FB of CD = 222°30′ – 22°15′ = 200°15′
Interior ∠C = 360°00′ – 200°15′ = 159°45′
Interior ∠D = FB of DE – BB of CD
= 242°45′ – 200°30′ = 42°15′
Interior ∠E = FB of EA – BB of DE
= 330°15′ – 62°45′ = 267°30′

Sum of interior angles = 44°00′ + 26°30′ + 159°45′ + 42°15′ + 267°30′
= 540°00′

which is equal to $(2N - 4) \times 90° = 540°00'$

So, the calculated angles are correct.

(b) Calculation of corrected bearing

The line DE is free from local attraction. So,

FB of DE = 242°45′ (correct)

and FB of EA = 330°15′ (correct)

FB of AB = BB of EA + ∠A
= (330°15′ – 180°0′) + 44°00′
= 150°15′ + 44°00′ = 194°15′

FB of BC = BB of AB + ∠B
= (194°15′ – 180°0′) + 26°30′
= 14°15′ + 26°30′ = 40°45′

FB of CD = BB of BC – exterior ∠C
= (40°45′ + 180°00′) – 200°15′
= 220°45′ – 200°15′ = 20°30′

FB of DE = BB of CD + ∠D
= (20°30′ + 180°0′) + 42°15′
= 200°30′ + 42°15′
= 242°45′ (checked)

The result is tabulated as follows:

Line	Corrected	
	FB	BB
AB	194°15′	14°15′
BC	40°45′	220°45′
CD	20° 30′	200°30′
DE	242°45′	62°45′
EA	330°15′	150°15′

Second method—Directly applying correction

Procedure (a) On verifying the observed bearing it is found that the FB and BB of line DE differ by exactly 180°. So, the stations D and E are free from local attraction and the observed FB and BB of DE are correct.

(b) The observed FB of EA is also correct.

(c) The actual BB of EA should be

330°15′ – 180°0′ = 150°15′

But the observed bearing is 147°45′.
So, a correction of (150°15′ – 147°45′) = + 2°30′ should be applied at A.

(d) Correct FB of AB = 191°45′ + 2°30′ = 194°15′
Therefore, the actual correct BB of AB should be

194°15′ – 180°00′ = 14°15′

But Observed bearing = 13°0′

So, a correction of (14°15′ – 13°0′) = + 1°15′ should be applied at B.

(e) Correct FB of BC = 39° 30′ + 1°15′ = 40°45′

∴ Correct BB of BC should be = 40°45′ + 180°0′ = 220°45′

But Observed bearing of BC = 222°30′

So, a correction of

(220°45′ − 222°30′) = − 1°45′ should be applied at C.

(f) Correct FB of CD = 22°15′ − 1°45′ = 20°30′

Therefore, the BB of CD should be

$$20°30′ + 180°0′ = 200°30′$$

which tallies with the observed BB of CD.

So, D is free from local attraction, which also tallies with the remark made at the beginning.

The result is tabulated as follows:

Table for Correction

Line	Observed		Correction	Correct		Remarks
	FB	BB		FB	BB	
AB	191°45′	13°00′	+ 2°30′ at A	194°15′	14°15′	
BC	39°30′	222°30′	+ 1°15′ at B	40°45′	220°45′	
CD	22°15′	200°30′	− 1°45′ at C	20°30′	200°30′	
DE	242°45′	62°45′	0° at D	242°45′	62°45′	Station D is free from local attraction
EA	330°15′	147°45′	0° at E	330°15′	150°15′	Station E is also free from local attraction

SHORT QUESTIONS WITH ANSWERS FOR VIVA

Q. 1 What is the principle of compass surveying?

Ans. The principle of compass surveying is traversing, which means that the area i enclosed by series of connected lines. The magnetic bearings of these lines ar taken with the compass and the distances of sides are measured by chain.

Q. 2 What is the difference between triangulation and traversing?

Ans. Triangulation involves dividing an area into a number of well-conditioned triangles But traversing involves the consideration of a series of connected lines.

Q. 3 What does the term 'chain angle' mean?

Ans. When the angle between any two adjacent sides is fixed by chain and tape only by taking tie line. The angle is said to be the chain angle.

Q. 4 What is a 12 cm compass?

Ans. The size of a compass is designated by its diameter. Therefore, a 12 cm compass is a compass of diameter 12 cm.

Q. 5 What is the fundamental difference between the prismatic compass and the surveyor's compass?

Ans. The prismatic compass shows the whole circle bearing of a line, whereas the surveyor's compass shows the quadrantal bearing of a line.

Q. 6 How would you detect the presence of local attraction in an area.

Ans. When the FB and BB of a line differ by exactly 180°, then the line is free from local attraction. The presence of local attraction is established when the FB and BB do not differ by 180°.

Q. 7 The FB of a line is 96°30′ and BB is 276°0′. How will you adjust the bearings?

Ans. Here, FB of line is 96°30′.

So, BB of this line = 96°30′ + 180°0′ = 276°30′

as local attraction.

Q. 9 What is declination?

Ans. The horizontal angle between the true meridian and magnetic meridian is known as declination.

Q. 10 What are isogonic and agonic lines?

Ans. The line passing through points of equal declination is known as the isogonic line, and the one passing through points of zero declination is called the agonic line.

Q. 11 What do you mean by azimuth?

Ans. The true bearing of a line is also known as its azimuth.

Q. 12 The FB of a line is 145°30′. What is its BB?

Ans. BB of the line = 145°30′ + 180°0′ = 325°30′

Q.13 The FB of a line is S 45°30′ W? What is its B.B.?

Ans. BB of the line = N 45°30′ E

Q. 14 What are the precautions to be taken while shifting a prismatic compass from one station to another?

Ans. The sight vane must be folded.

Q. 15 A compass was properly balanced at the equator. What will be the effect on the needle if it is taken to the northern hemisphere?

Ans. The north end of the needle will be inclined towards the North Pole.

Q. 16 What is the angular check of a closed traverse?

Ans. The sum of the interior angles should be equal to $(2N - 4) \times 90°$, where N is the number of sides of traverse.

Q. 17 How would you check the accuracy of open traverse?

Ans. The accuracy of open traverse is checked by taking cut-off lines or an auxiliary point.

5.11 METHODS OF CALCULATION OF REDUCED LEVEL

The following are the two systems of calculating reduced level:

1. The collimation system or height of instrument system (HI)
2. The rise-and-fall system.

1. The collimation system The reduced level of the line of collimation is said to be the height of the instrument. In this system, the height of the line of collimation is found out by adding the backsight reading to the RL of the BM on which the BS is taken. Then the RL of the intermediate points and the change point are obtained by subtracting the respective staff readings from the height of the instrument (HI).

The level is then shifted for the next se tup and again the height of the line of collimation is obtained by adding the backsight reading to the RL of the change point (which was calculated in the first set up).

So, the height of the instrument is different in different setups of the level. Two adjacent planes of collimation are correlated at the change point by an FS reading from one setting and a BS reading from the next setting.

It should be remembered that, in this system, the RLs of unknown points are to be found out by deducting the staff readings from the RL of the height of the instrument.

Consider Fig. 5.24.

(a) RL of HI in 1st setting = 100.000 + 1.255 = 101.255
RL of A = 101.255 – 1.750 = 99.505
RL of B = 101.255 – 2.150 = 99.105

(b) RL of HI in 2nd setting = 99.105 + 2.750 = 101.855
RL of C = 101.855 – 1.950 = 99.905

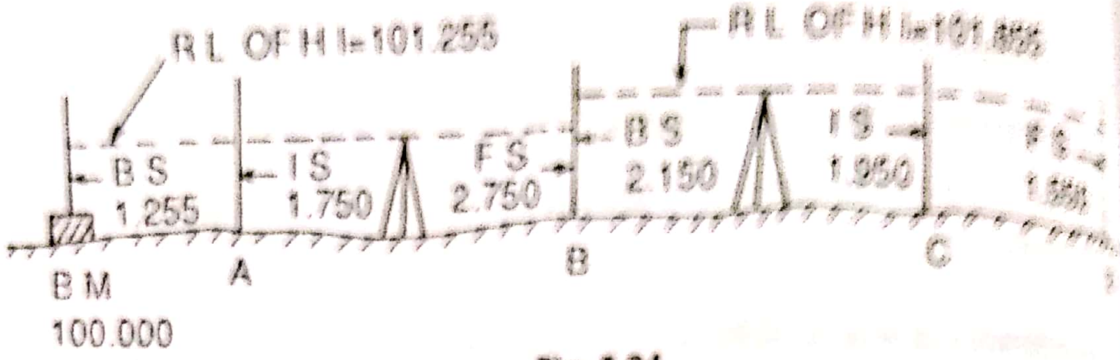


Fig. 5.24

RL of D = 101.855 – 1.550 = 100.305 and so on.

Arithmetical check: Σ BS – Σ FS = Last RL – 1st RL.

The difference between the sum of backsights and that of foresights must be equal to the difference between the last RL and the first RL. This check verifies the calculation of the RL of the HI and that of the change point. There is no check on the RLs of the intermediate points.

2. The rise-and-fall system In this system, the difference of level between two consecutive points is determined by comparing each forward staff reading with the staff reading at the immediately preceding point.

If the forward staff reading is smaller than the immediately preceding staff reading, a rise is said to have occurred. The rise is added to the RL of the preceding point to get the RL of the forward point.

If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall. The fall is subtracted from the RL of preceding point to get the RL of the forward point.

Consider Fig. 5.25.

Point A (with respect to BM) = 0.75 – 1.25 = – 0.50 (fall)
Point B (with respect to A) = 1.25 – 2.75 = – 1.50 (fall)
Point C (with respect to B) = 2.75 – 1.50 = + 1.25 (rise)
Point D (with respect to C) = 1.50 – 1.75 = – 0.25 (fall)

RL of BM = 100.00
RL of A = 100.00 – 0.50 = 99.50
RL of B = 99.50 – 1.50 = 98.00
RL of C = 98.00 + 1.25 = 99.25
RL of D = 99.25 – 0.25 = 99.00

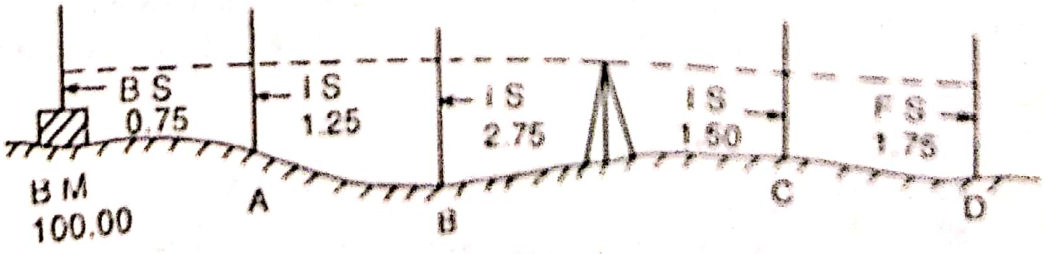


Fig. 5.25

Arithmetical check: ΣBS – ΣFS = Σrise – Σfall = last RL – 1st RL

In this method, the difference between the sum of BSs and that of FSs, the difference between the sum of rises and that of falls and the difference between the last RL, and the first RL must be equal.

Note: The arithmetical check is meant only for the accuracy of calculation to be verified. It does not verify the accuracy of field work. There is a complete check on the RLs of intermediate points in the rise-and-fall system.

Comparison of the two systems

Collimation System	Rise-and-Fall System
1. It is rapid as it involves few calculation.	It is laborious, involving several calculations.
2. There is no check on the RL of intermediate points.	There is a check on the RL of intermediate points.
3. Errors in intermediate RLs cannot be detected.	Errors in intermediate RLs can be detected as all the points are correlated.
4. There are two checks on the accuracy of RL calculation.	There are three checks on the accuracy of RL calculation.
5. This system is suitable for longitudinal levelling where there are a number of intermediate sights.	This system is suitable for fly levelling where there are no intermediate sights.

Considering the above points, the rise-and-fall system is always preferred as there is no possibility of error in the calculation of RLs in the intermediate points.

5.12 POINTS TO BE REMEMBERED WHILE ENTERING THE LEVEL BOOK

1. The first reading of any set up is entered in the BS column, the last reading in the FS column and the other readings in the IS column.
2. A page always starts with a BS reading and finishes with an FS reading.
3. If a page finishes with an IS reading, the reading is entered in the IS and FS columns on that page and brought forward to the next page by entering it in the BS and IS columns.
4. The FS and BS of any change point are entered in the same horizontal line.
5. The RL of the line of collimation is entered in the same horizontal line in which the corresponding BS was entered.
6. Important note, bench-marks and change points should be clearly described in the remark column.

Example The following consecutive readings were taken with a dumpy level along a chain line at a common interval of 15 m. The first reading was at a chainage of 165 m where the RL is 98.085. The instrument was shifted after the fourth and ninth readings.

3.150, 2.245, 1.125, 0.860, 3.125, 2.760, 1.835, 1.470, 1.965, 1.225, 2.390, and 3.035 m.

Mark rules on a page of your notebook in the form of a level book page and enter on it the above readings and find the RL of all the points by:

1. The collimation system, and
2. The rise-and-fall system.

Apply the usual checks.

1. By the collimation system:

Station point	Chainage	BS	IS	FS	RL of collimation line (HI)	RL	Remark
1	165	3.150			101.235	98.085	
2	180		2.245			98.990	
3	195		1.125			100.110	
4	210	3.125		0.860	103.500	100.375	changed point
5	225		2.760			100.740	
6	240		1.835			101.665	
7	255		1.470			102.030	
8	270	1.225		1.965	102.760	101.535	Change point
9	285		2.390			100.370	
10	300			3.035		99.725	
Total =		7.500		5.860			

Arithmetical check:

$$\Sigma BS - \Sigma FS = 7.500 - 5.860 = +1.640$$

$$\text{Last RL} - \text{1st RL} = 99.725 - 99.085 = +1.640$$

2. By the rise-and-fall system:

Station point	Chainage	BS	IS	FS	Rise (+)	Fall (−)	RL	Remark
1	165	3.150					98.085	
2	180		2.245		0.905		98.990	
3	195		1.125		1.120		100.110	
4	210	3.125		0.860	0.265		100.375	changed point
5	225		2.760		0.365		100.740	
6	240		1.835		0.925		101.665	
7	255		1.470		0.365		102.030	
8	270	1.225		1.965		0.495	101.535	changed point
9	285		2.390			1.165	100.370	
10	300			3.035		0.645	99.725	
Total =		7.500		5.860	3.945	2.305		

Arithmetical check: Σ BS − Σ FS = 7.500 − 5.860 = + 1.640
Σ Rise − Σ fall = 3.945 − 2.305 = + 1.640
Last RL − 1st RL = 99.725 − 98.085 = + 1.640

5.13 PROBLEMS ON REDUCTION OF LEVELS

Problem 1 The following consecutive readings were taken with a levelling instrument at intervals of 20 m.

2.375, 1.730, 0.615, 3.450, 2.835, 2.070, 1.835, 0.985, 0.435, 1.630, 2.255 and 3.630 m.

The instrument was shifted after the fourth and eighth readings. The last reading was taken on a BM of RL 110.200 m. Find the RLs of all the points.

Solution

Station point	Chainage	BS	IS	FS	Rise (+)	Fall (−)	RL	Remark
1	0	2.375					112.620	
2	20		1.730		0.645		113.265	
3	40		0.615		1.115		114.380	
4	60	2.835		3.450		2.835	111.545	Change point
5	80		2.070		0.765		112.310	
6	100		1.835		0.235		112.545	
7	120	0.435		0.985	0.850		113.395	Change point
8	140		1.630			1.195	112.200	
9	160		2.255			0.625	111.575	
10	180			3.630		1.375	110.200	On BM
Total =		5.645		8.065	3.610	6.030		

Procedure:

1. First calculate the rise and fall. Then find:

$$\Sigma \text{ BS} - \Sigma \text{ FS} = 5.645 - 8.065 = -2.420$$
$$\Sigma \text{ Rise} - \Sigma \text{ fall} = 3.610 - 6.030 = -2.420$$

2. Then, Last RL − 1st RL = − 2.420

or 1st RL = 110.200 + 2.420 = 112.620

Substitute this value for the RL of the first point and calculate the other RLs in the usual way.

...taken with a dumpy level

Correct reading on A = 1.6300 – 0.0015 = 1.6285 m

Correct reading on B = 1.5600 – 0.0165 = 1.5435 m

SHORT QUESTION WITH ANSWERS FOR VIVA

Q. 1 What is a datum surface?

Ans. A datum surface is an arbitrarily assumed level surface from which the vertical distances of various objects are measured.

Q. 2 What does the term GTS mean?

Ans. GTS means "Great Trigonometrical Survey".

Q. 3 What are bench-marks?

Ans. A reference point whose RL is fixed with respect to the datum surface is known as a bench-mark.

Q. 4 What is the datum adopted for GTS bench-marks?

Ans. The mean sea level at Karachi is adopted as the datum for GTS bench-marks. It is considered as 'zero'.

Q. 5 What are the types of BM that you know of?

Ans. Four types—(a) GTS BM, (b) permanent BM (c) the temporary BM, and (d) the arbitrary BM.

Q. 6 For any engineering work, how will you get the RL of the starting point?

Ans. The starting point is connected to the GTS or permanent BM by fly levelling. Then the RL of the starting point is calculated by the usual method.

Q. 7 What is the difference between a level surface and a horizontal surface?

Ans. A surface parallel to the mean spheroidal surface of the earth is known as a level surface. But a horizontal surface is tangential to the level surface at any point. The surface of a still lake is considered to be level.
The surface perpendicular to the direction of gravity (indicated by the plumb line) is considered to be horizontal.

Q. 8 What is the difference between the line of collimation and axis of the telescope?

Ans. The line of collimation is the line joining the point of intersection of the cross-hairs to the optical centre of the object glass.
The axis of the telescope is the line joining the optical centre of the object glass to that of the eye-piece.

Q. 9 What is the relation between the line of collimation and the axis of a telescope?

Ans. Both these lines should coincide.

Q. 10. In a particular set up of the level, suppose four readings are taken. How should they be entered in the level book?

Ans. The first reading should be entered in the BS column, the last reading in the FS column, and the other two readings in the IS column.

Q. 11 What is a change point?

Ans. Such a point indicates shifting of the instrument. At this point, a foresight reading is taken from one setting and a backsight reading from the next setting.

Q. 12 The staff readings on A and B are 1.735 and 0.965 respectively. Which point is higher?

Ans. Point B is higher.

Q. 13 What is the procedure of levelling by foot screws?

Ans. The telescope is first placed parallel to any pair of foot screws and the bubble is brought to the centre by turning the foot screws equally either inward or outward. Then the telescope is turned through 90° and the bubble is brought to the centre by turning the third foot screw. This process is repeated several times.

7.4 COMPUTATION OF AREA FROM PLOTTED PLAN

The area may be calculated in the two following ways.

Case I—Considering the entire area The entire area is divided into regions of a convenient shape, and calculated as follows:

(a) By dividing the area into triangles The triangles are so drawn as to equalise the irregular boundary line.

Then the bases and altitudes of the triangles are determined according to the scale to which the plan was drawn. After this, the areas of these triangles are calculated (area = 1/2 × base × altitude). The areas are then added to obtain the total area (Fig. 7.6).

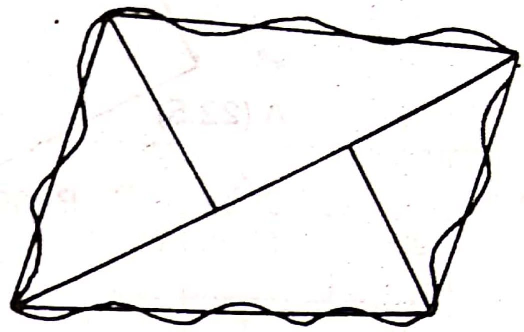


Fig. 7.6

(b) By dividing the area into squares In this method, squares of equal size are ruled out on a piece of tracing paper. Each square represents a unit area, which could be 1 cm^2 or 1 m^2. The tracing paper is placed over the plan and the number of full squares are counted. The total area is then calculated by multiplying the number of squares by the unit area of each square (Fig. 7.7).

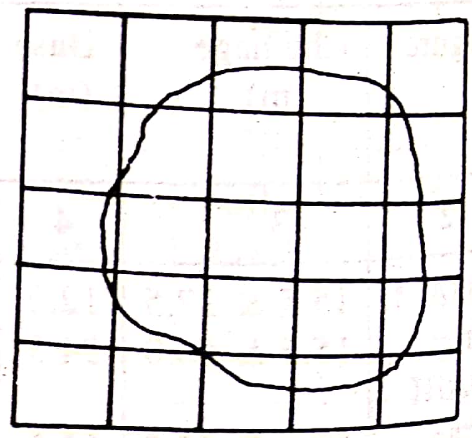


Fig. 7.7

(c) By drawing parallel lines and converting them to rectangles In this method, a series of equidistant parallel lines are drawn on a tracing paper (Fig. 7.8). The constant distance represents a metre or centimetre. The tracing paper is placed

over the plan in such a way that the area is enclosed between the two parallel lines at the top and bottom. Thus the area is divided into a number of strips. The curved ends of the strips are replaced by perpendicular lines (by give and take principle) and a number of rectangles are formed. The sum of the lengths of the rectangles is then calculated.

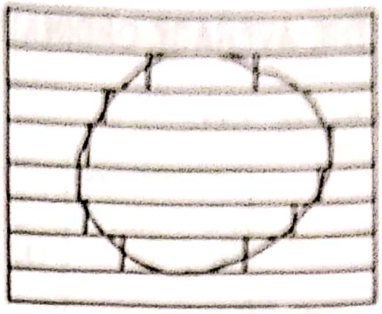


Fig. 7.8

Then,

Required area = Σ length of rectangles × constant distance

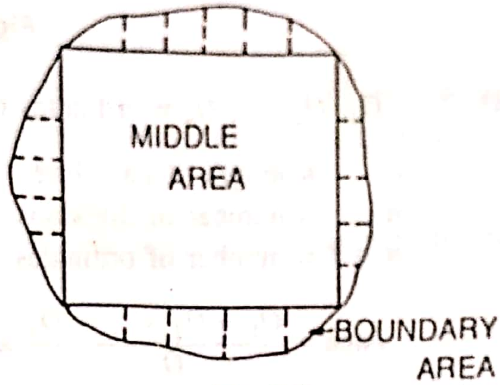


Fig. 7.9

Case II In this method, a large square or rectangle is formed within the area in the plan. Then ordinates are drawn at regular intervals from the side of the square to the curved boundary. The middle area is calculated in the usual way. The boundary area is calculated according to one of the following rules:

1. The mid-ordinate rule
2. The average ordinate rule
3. The trapezoidal rule
4. Simpson's rule

The various rules are explained in the following sections.

7.5 THE MID-ORDINATE RULE

Consider Fig. 7.10

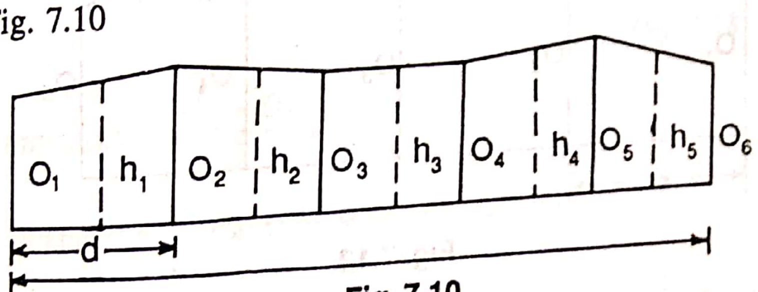


Fig. 7.10

Let $O_1, O_2, O_3, \ldots, O_n$ = ordinates at equal intervals

l = length of base line

d = common distance between ordinates

$h_1, h_2, \ldots h_n$ = mid-ordinates

$$\text{Area of plot} = h_1 \times d + h_2 \times d + \ldots + h_n \times d \qquad (7.1)$$

$$= d(h_1 + h_2 + \ldots + h_n)$$

i.e. Area = common distance × sum of mid-ordinates

7.7 THE TRAPEZOIDAL RULE

While applying the trapezoidal rule, boundaries between the ends of ordinates are assumed to be straight. Thus the areas enclosed between the base line and the irregular boundary line are considered as trapezoids.

Consider Fig. 7.12.

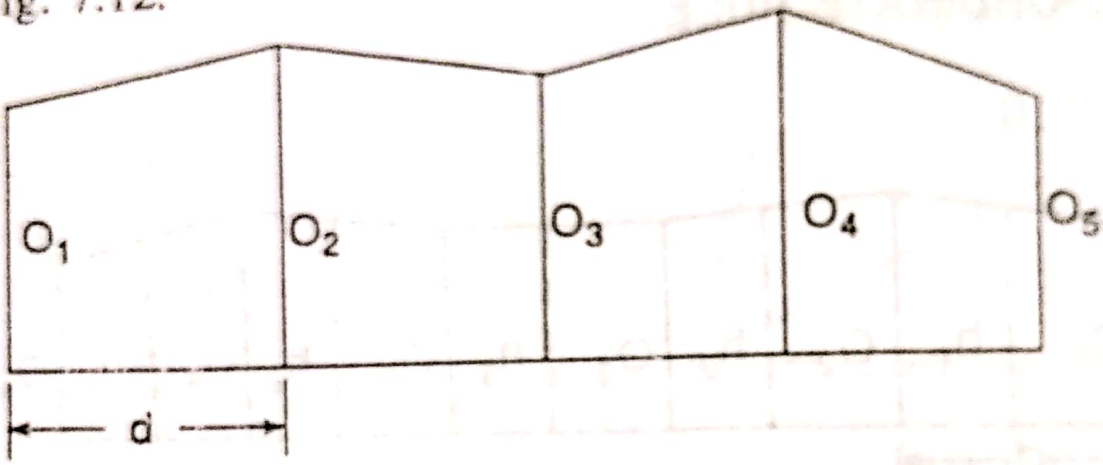


Fig. 7.12

Let $O_1, O_2, \ldots, O_n$ = ordinates at equal intervals

d = common distance

$$\text{1st area} = \frac{O_1 + O_2}{2} \times d$$

$$\text{2nd area} = \frac{O_2 + O_3}{2} \times d$$

$$\text{3rd area} = \frac{O_3 + O_4}{2} \times d$$

....

$$\text{Last area} = \frac{O_{n-1} + O_n}{2} \times d$$

$$\text{Total area} = \frac{d}{2}\{O_1 + 2O_1 + 2O_2 + \ldots + 2O_{n-1} + O_n\} \quad (7.3)$$

$$= \frac{\text{common distance}}{2}\{(\text{1st ordinate} + \text{last ordinate} + 2\ (\text{sum of other ordinate})\}$$

Thus, the trapezoidal rule may be stated as follows:

To the sum of the first and the last ordinate, twice the sum of intermediate ordinates is added. This total sum is multiplied by the common distance. Half of this product is the required area.

Limitation There is no limitation for this rule. This rule can be applied for any number of ordinates.

7.8 SIMPSON'S RULE

In this rule, the boundaries between the ends of ordinates are assumed to form an arc of a parabola. Hence Simpson's rule is sometimes called the parabolic rule.

Refer to Fig. 7.13.

Let

O_1, O_2, O_3 = three consecutive ordinates

d = common distance between the ordinates

Area AFeDC = area of trapezium AFDC + area of segment FeDEF

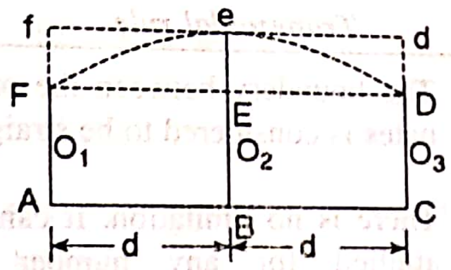


Fig. 7.13

Here,

$$\text{Area of trapezium} = \frac{O_1 + O_3}{2} \times 2d$$

$$\text{Area of segment} = \frac{2}{3} \times \text{area of parallelogram FfdD}$$

$$= \frac{2}{3} \times \text{Ee} \times 2d = \frac{2}{3} \times \left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$$

So, the area between the first two divisions,

$$\Delta_1 = \frac{O_1 + O_3}{2} \times 2d + \frac{2}{3}\left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$$

$$= \frac{d}{3}(O_1 + 4O_2 + O_3)$$

Similarly, the area between next two divisions,

$$\Delta_2 = \frac{d}{3}(O_3 + 4O_4 + O_5) \text{ and so on.}$$

$$\therefore \quad \text{Total area} = \frac{d}{3}(O_1 + 4O_2 + 2O_3 + 4O_4 + \ldots + O_n)$$

$$= \frac{d}{3}\{O_1 + O_n + 4(O_2 + O_4 + \ldots) + 2(O_3 + O_5 + \ldots)\}$$

$$= \frac{\text{common distance}}{3}\{\text{1st ordinate + last ordinate}) + 4\text{ (sum of even ordinates)} + 2\text{ (sum of remaining odd ordinates)}\}$$

Thus, the rule may be stated as follows.

To the sum of the first and the last ordinate, four times the sum of even ordinates and twice the sum of the remaining odd ordinates are added. This total sum is multiplied by the common distance. One-third of this product is the required area.

Limitation This rule is applicable only when the number divisions is even, i.e. the number of ordinates is odd.

The trapezoidal rule and Simpson's rule may be compared in the following manner:

Trapezoidal rule	*Simpson's rule*
1. The boundary between the ordinates is considered to be straight.	1. The boundary between the ordinates is considered to be an arc of a parabola.
2. There is no limitation. It can be applied for any number of ordinates.	2. To apply this rule, the number of ordinates must be odd. That is, the number of divisions must be even.
3. It gives an approximate result	3. It gives a more accurate result.

Note Sometimes one, or both, of the end ordinates may be zero. However, they must be taken into account while applying these rules.

7.9 WORKED-OUT PROBLEMS

Problem 1 The following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m:

0, 2.50, 3.50, 5.00, 4.60, 3.20, 0 m

compute the area between the chain line, the irregular boundary line and the end offsets by:

(a) The mid-ordinate rule

(b) The average-ordinate rule
(c) The trapezoidal rule
(d) Simpson's rule

Solution

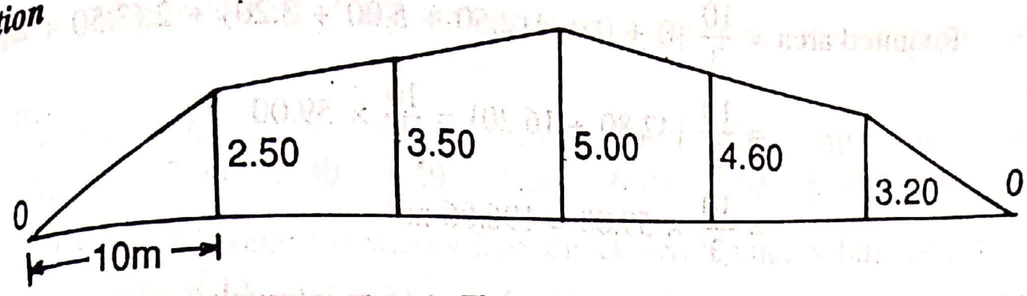


Fig. P.7.1

(a) *By mid-ordinate rule*: The mid-ordinates are

$$h_1 = \frac{0 + 2.50}{2} = 1.25 \text{ m}$$

$$h_2 = \frac{2.50 + 3.50}{2} = 3.00 \text{ m}$$

$$h_3 = \frac{3.50 + 5.00}{2} = 4.25 \text{ m}$$

$$h_4 = \frac{5.00 + 4.60}{2} = 4.80 \text{ m}$$

$$h_5 = \frac{4.60 + 3.20}{2} = 3.90 \text{ m}$$

$$h_6 = \frac{3.20 + 0}{2} = 1.60 \text{ m}$$

$$\text{Required area} = 10\,(1.25 + 3.00 + 4.25 + 4.80 + 3.90 + 1.60)$$
$$= 10 \times 18.80 = 188 \text{ m}^2$$

(b) *By average-ordinate rule*:

Here $d = 10$ m and $n = 6$ (no. of divs)

Base length = 10 × 6 = 60 m
Number of ordinates = 7

$$\text{Required area} = 60 \times \left\{\frac{0 + 2.50 + 3.50 + 5.00 + 4.60 + 3.20 + 0}{7}\right\}$$

$$= 60 \times \frac{18.80}{7} = 161.14 \text{ m}^2$$

(c) *By trapezoidal rule*:

Here $d = 10$

$$\text{Required area} = \frac{10}{2}\{0 + 0 + 2(2.50 + 3.50 + 5.00 + 4.60 + 3.20)\}$$

$$= 5 \times 37.60 = 188 \text{ m}^2$$

Scanned with CamScanner

(d) *By Simpson's rule:*

$d = 10$

$$\text{Required area} = \frac{10}{3}\{0 + 0 + 4(2.50 + 5.00 + 3.20) + 2(3.50 + 4.6\ldots$$

$$= \frac{10}{3}\{42.80 + 16.20\} = \frac{10}{3} \times 59.00$$

$$= \frac{10}{3} \times 59.00 = 196.66 \text{ m}^2$$

Problem 2 The following offsets were taken at 15 m intervals from a survey line to an irregular boundary line:

3.50, 4.30, 6.75, 5.25, 7.50, 8.80, 7.90, 6.40, 4.40, 3.25 m

Calculate the area enclosed between the survey line, the irregular boundary line, and the first and last offsets, by:

(a) The trapezoidal rule

(b) Simpson's rule

Solution (Fig. P-7.2)

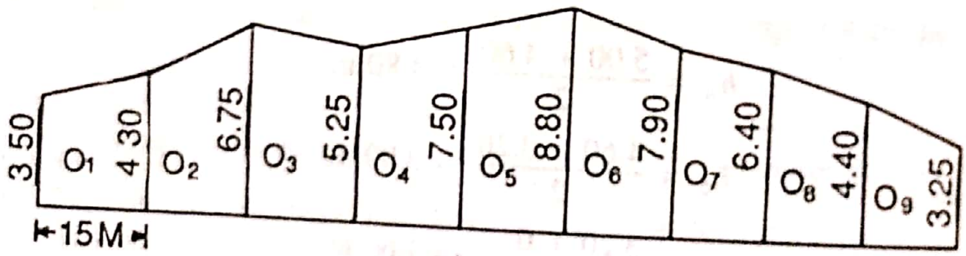


Fig. P-7.2

(a) *By trapezoidal rule:*

$$\text{Required area} = \frac{15}{2}\{3.50 + 3.25 + 2(4.30 + 6.75 + 5.25 + 7.50$$
$$+ 8.80 + 7.90 + 6.40 + 4.40)\}$$
$$= \frac{15}{2}\{6.75 + 102.60\} = 820.125 \text{ m}^2$$

(b) *Simpson's rule:* If this rule is to be applied, the number of ordinates must be odd. But here the number of ordinate is even (ten).

So, Simpson's rule is applied from O_1 to O_9 and the area between O_9 and O_{10} is found out by the trapezoidal rule.

$$A_1 = \frac{15}{3}\{3.50 + 4.40 + 4(4.30 + 5.25 + 8.80 + 6.40)$$
$$+ 2(6.75 + 7.50 + 7.90)\}$$
$$= \frac{15}{3}\{7.90 + 99.00 + 44.30\} = 756.00 \text{ m}^2$$

$$A_2 = \frac{15}{2}\{4.40 + 3.25\} = 57.38 \text{ m}^2$$

$$\text{Total area} = A_1 + A_2 = 756.00 + 57.38 = 813.38 \text{ m}^2$$

... line to a curved boundary

SHORT QUESTIONS WITH ANSWERS FOR VIVA

Q. 1 State the trapezoidal rule. What are the considerations and limitations of this rule?

Ans. "To the sum of the first and the last ordinate, twice the sum of the intermediate ordinates is added. This total sum is multiplied by the common distance. Half of this product is the required area". This is the trapezoidal rule.

The boundaries between the ends of ordinates are assumed to be straight lines.

There is no limitation in this rule. It can be applied at any number of ordinates.

Q. 2 State Simpson's rule. What are the considerations and limitations of this rule.

Ans. To the sum of the first and the last ordinate, four times the sum of even ordinates and twice the sum of odd ordinates are added. This total sum is multiplied by the common distance. One-third of this product is the required area." This is Simpson's rule.

The boundary between the ordinates is assumed to form an arc of a parabola.

To apply this rule, the number of ordinates must be odd.

Q. 3 What is a planimeter?

Ans. It is an instrument for measuring the area of a field from the map.

Q. 4 What is a zero circle?

Ans. When a circle is described by the tracing point without a change in reading in the measuring wheel, then that circle is known as the zero circle.

Q. 5 Give the simplest method for finding the area of a zero circle from the manufacturer's table.

Ans. Area of zero circle = $M \times C$

where, M = Multiplier
C = Constant

The values of both M and C are available in the table.

Q. 6 What is the need of finding the area of the zero circle?

Ans. When the anchor point is inside the figure, the computed area does not cover the whole area. It is less by the area of the zero circle. In that case, the area of the zero circle is added to the computed area to obtain the actual area.

SHORT QUESTIONS WITH ANSWERS FOR VIVA

Q. 1 What is a transit theodolite?

Ans. A transit theodolite is one in which the telescope can be revolved completely about the horizontal axis in a vertical plane.

Q. 2 What is a 12 cm theodolite?

Ans. A theodolite whose base circle (horizontal graduated circle) has a diameter of 12 cm is known as a 12 cm theodolite.

Q. 3 What are the functions of a theodolite?

Ans. The function of a theodolite are to measure the following quantities: (a) the horizontal angle, (b) the vertical angle, (c) the deflection angle, (d) the magnetic bearing, and (e) the horizontal distance.

Q. 4 Describe the location and function of the plate bubble and the altitude bubble?

Ans. The plate bubble is fixed over the horizontal graduated circle. It is levelled at the time of measuring the horizontal angle. The altitude bubble is fixed on top of the vertical vernier scale, and is levelled at the time of measuring the vertical angle.

Q. 5 What is the function of the shifting head?

Ans. Quick perfect centring may be done by moving the shifting head slowly.

Q. 6 State the procedure involved in bringing the bubble to the centre?

Ans. The bubble is first made parallel to any pair of foot screws. By turning the foot screws equally inwards or outwards the bubble is brought to the centre. Then the bubble is turned through 90°, and brought to the centre by means of the third foot screw. This process is repeated several times until the bubble is exactly in the centre for both directions of the bubble tube.

Q. 7 What are the functions of the clamp screw, tangent screw and clip screw?

Ans. Clamp screws are provided for fixing or releasing the main scale or vernier scale, and tangent screws for fine adjustment while bisecting objects. The clip screw is provided for levelling the altitude bubble.

Q. 8 What do the terms 'face left' and 'face right' mean?

Ans. When the vertical circle is on the left of the observer, the observation is said to be face left. When it is on the right of the observer, the observation is said to be face right.

Q. 9 What do the terms 'telescope normal' and 'telescope inverted' mean?

Ans. The face left position is known as telescope normal, and the face right position as telescope inverted.

Q. 10 What is an azimuth?

Ans. The true bearing of a line is also called its azimuth.

Q. 11 What is a trunnion axis?

Ans. The horizontal axis is also known as the trunnion axis.

Q. 12 What is transiting?

Ans. The process of turning the telescope in a vertical plane through 180° is known as transiting.

Q. 13 What does 'swinging the telescope' mean?

Ans. The process of turning the telescope in a horizontal plane is known as swinging. If the telescope is turned clockwise, there is said to be a right swing, and if it is turned anticlockwise, a left swing.

Q. 14 What is the least count of a theodolite?

Ans. The difference between the value of the smallest division of the main scale and that of the smallest division of the vernier scale known as the least count of the theodolite. It is the least value that can be measured by theodolite.

Q. 15 How can a theodolite be used as a level?

Ans. The altitude bubble is first perfectly levelled. Then the zero of the vertical circle (which is fixed to the telescope) is set at the zero of the vernier scale, and the telescope is clamped. Under this condition, the theodolite can be used as a level.

Q. 16 What is a deflection angle?

Ans. When a line (or alignment) changes its direction, the forward line makes an angle with the extension of the preceding line. This angle is known as the deflection angle.

Q. 17 Why are face left and face right observations taken?

Ans. These observations are taken to eliminate the error when the line of collimation is not perpendicular to the horizontal axis.

Q. 18 Why are two vernier readings taken?

Ans. Both vernier readings are taken to eliminate the error due to eccentricity of the inner and outer axes.