4. (a) Locate the centroid of a semicircular section using method of integration.
   (b) Locate the centroid of the plane shown in Fig. 5 with respect to 'O'.

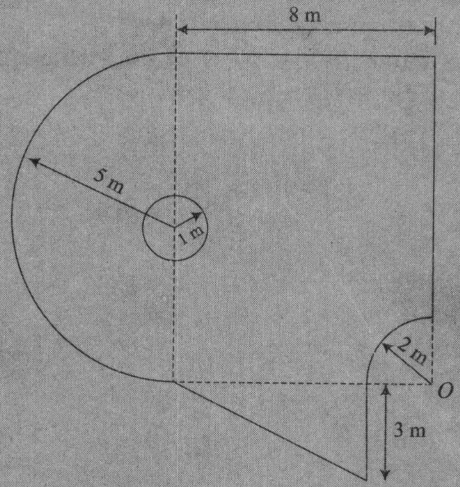


Fig. 5

   (c) The centroid of a rectangle is to be shifted from O to O_1 (Refer Fig. 6). This is accomplished by removing the hatched portion which is symmetrical about XX axis. Determine the area of the hatched portion.

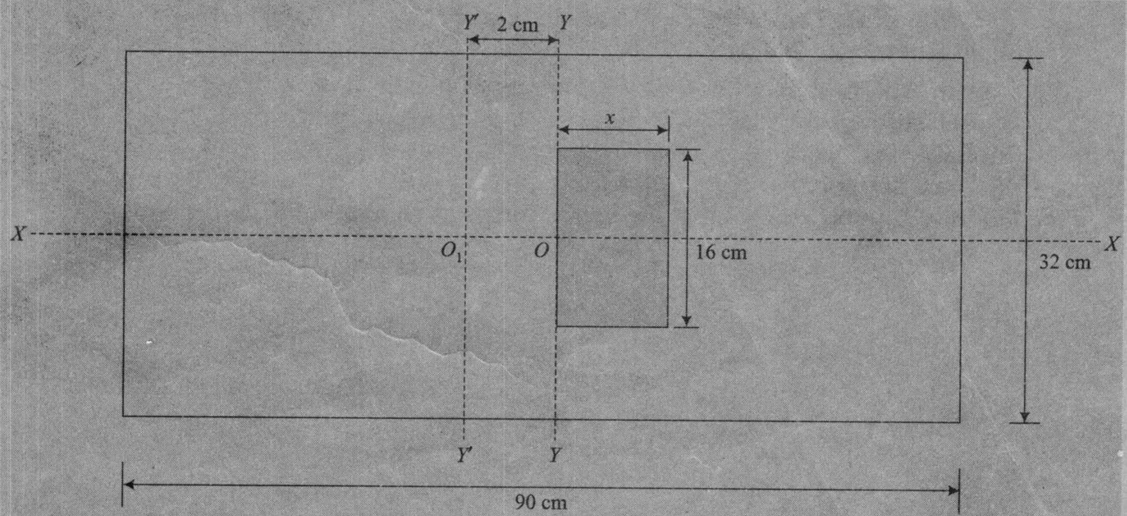


Fig. 6

Part – B

5. (a) State and prove Lami's theorem.
   (b) State the equilibrium condition for:
      (i) A system of coplanar concurrent forces
      (ii) A system of coplanar non-concurrent forces
   (c) Determine the tensions in different parts of the string shown in Fig. 7. Also find the values of W_1 and W_2 if the portion BC is horizontal.

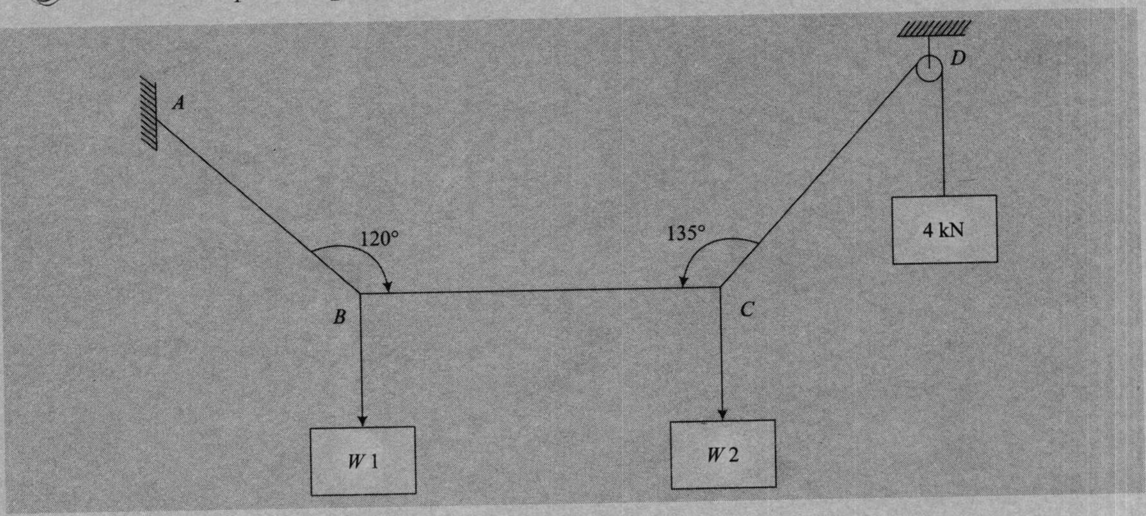


Fig. 7

6. (a) Write short notes on the following:
      (i) Determinate beams
      (ii) Indeterminate beams
   (b) Explain with neat sketches the following types of supports:
      (i) Roller support
      (ii) Hinged support
      (iii) Fixed support
   (c) Find the support reactions of the beam loaded as shown in Fig. 8

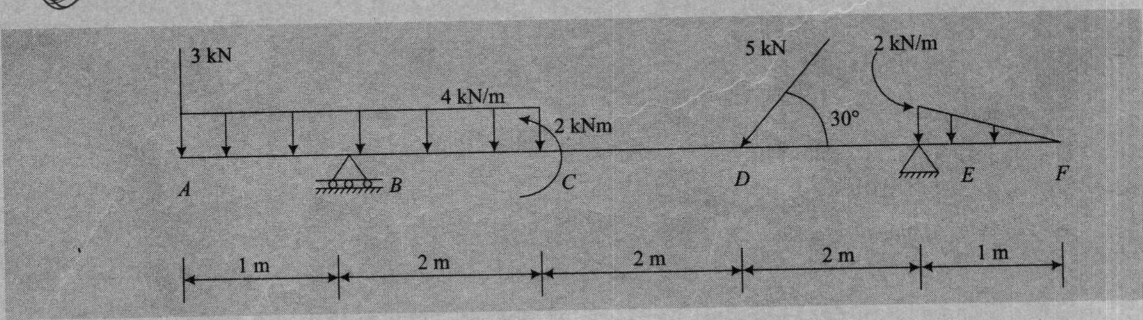


Fig. 8

7. (a) Define the following:
   (i) Angle of friction
   (ii) Angle of repose
   (iii) Cone of friction

(b) A body of weight 200 N is acted upon by a force of 40 kN as shown in Fig. 9. If the coefficient of friction between the inclined plane and the body is 0.3., check wheather the body moves up the plane or down the plane or remains stationary.

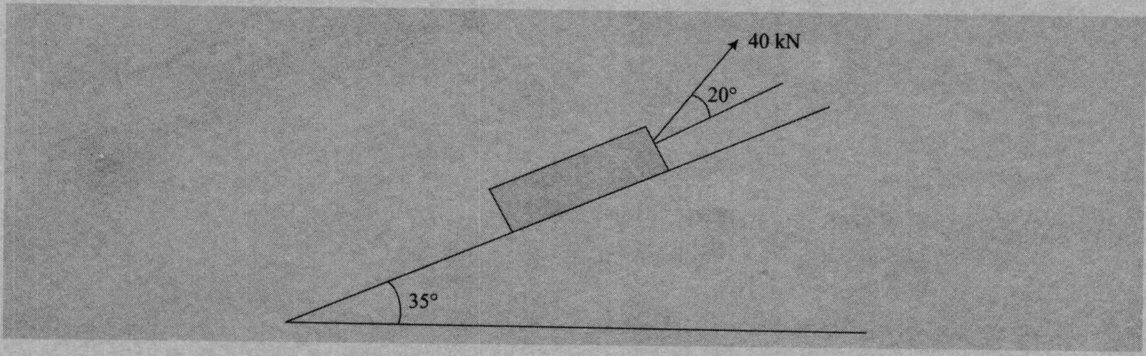


Fig. 9

(c) Find the force P on the wedge in the arrangement of block and wedge shown in Fig. 10 to cause the impending motion. Take $\mu = 0.3$ at all surfaces of contact.

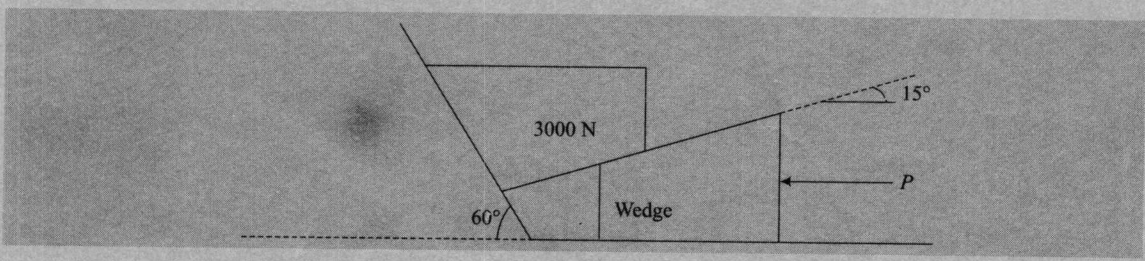


Fig. 10

8. (a) Write a note on second moment of area.

(b) Obtain an expression for the moment of inertia of a rectangular section about its horizontal centroidal axis from first principle.

(c) Compute the moment of inertia of the area shown in Fig. 11 about the axis $A - B$. All dimensions are in mm.

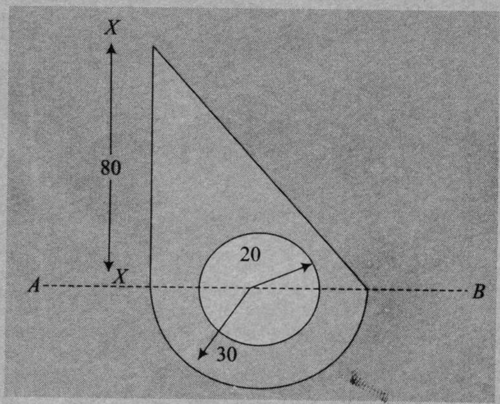


Fig. 11

Model Question Paper-II (Revised Syllabus)

Note: Answer FIVE full questions choosing at least TWO from each Part

Part- A

1. (a) Briefly explain the scope of following fields of civil engineering:
   (i) Surveying
   (ii) Water Resources Engineering
   (b) With a neat sketch, explain the following components of the road:
   (i) Pavement
   (ii) Camber
   (iii) Shoulder
   (iv) Formation
   (c) With a neat sketch, explain the following:
   (i) Skew bridge
   (ii) Gravity dam.
2. (a) What is a force? What are its characteristics?
   (b) Write a note on the principle of transmissibility of forces and its limitations.
   (c) What is a couple? List its characteristics.
   (d) Reduce the force acting at *A* into a system of force and couple at point '*O*' (Refer Fig. 1)

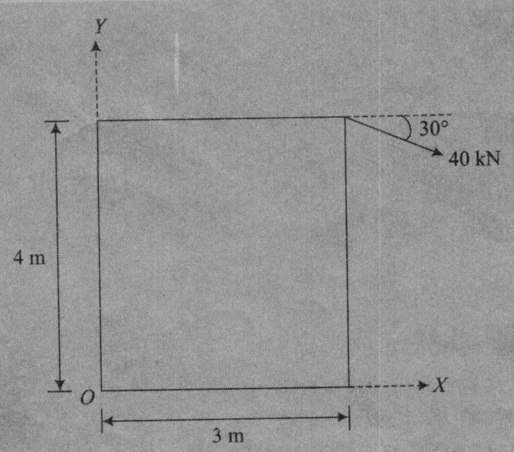


Fig. 1

3. (a) State and prove Varignon's theorem of moments.
   (b) Define the terms:
   (i) Composition of a force system.
   (ii) Resolution of force

(c) Find the magnitude, direction and distance of the resultant from the point *A* for the system of forces shown in Fig. 2.

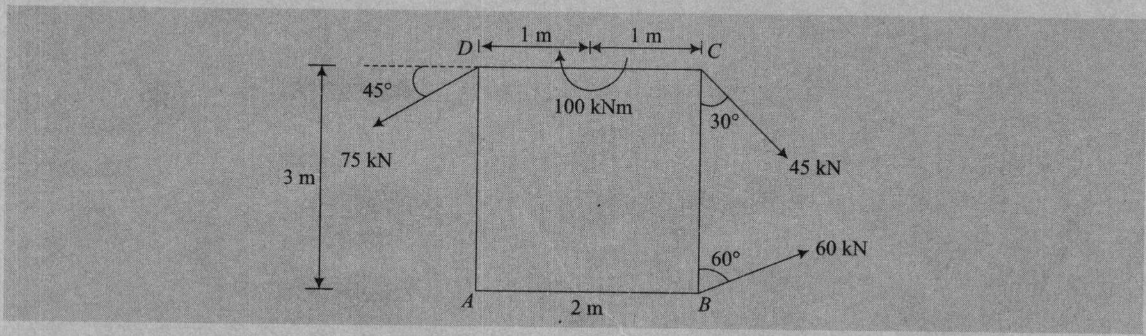


Fig. 2

4. (a) Locate the centriod of a triangle by the method of integration.
   (b) Determine the position of the centroid of the area shown in Fig. 3.
   (*All dimensions are in mm*)

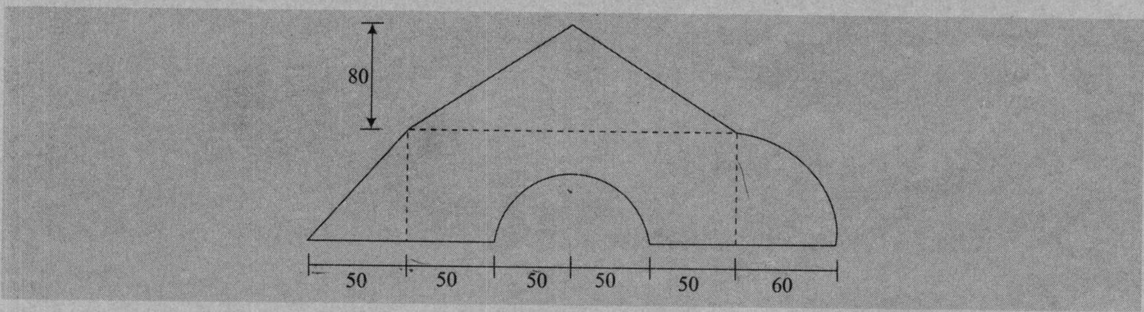


Fig. 3

Part- B

5. (a) Explain the following:
   (i) Free body diagram.
   (ii) Equilibrium conditions
   (iii) Lami's theorem
   (iv) Equilibrant
   (b) Determine the reactions at the surface of contact and tension in the string *AB* shown in Fig. 4.
   $R_1 = R_2 = R_3 = 200$ mm
6. (a) With neat sketches, explain various types of supports.

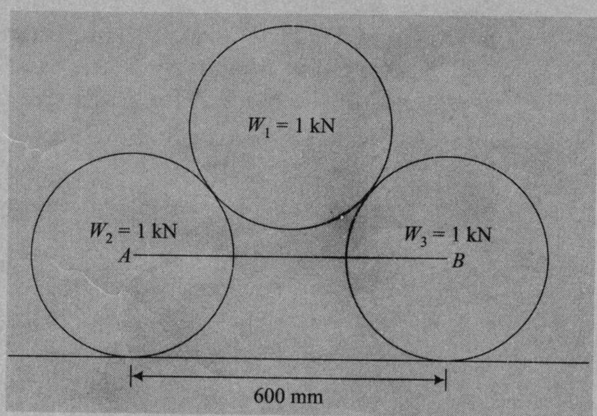


Fig. 4

(b) Write the free body diagrams of identical spheres A and B shown in Fig. 5.

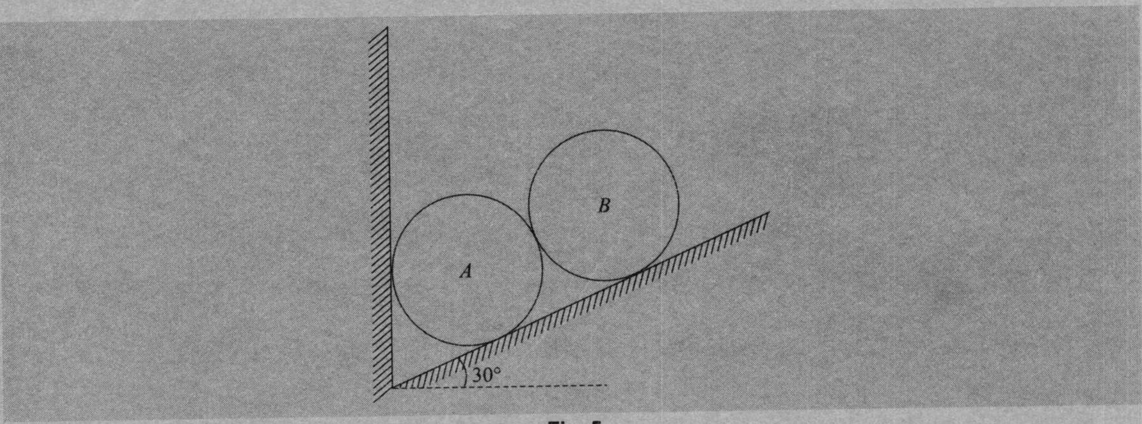


Fig. 5

(c) Determine the reactions at the supports A and B for a beam loaded as shown in Fig. 6.

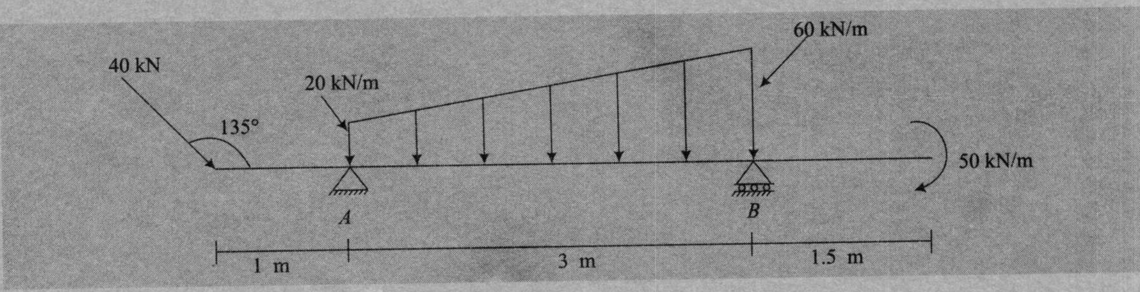


Fig. 6

7. (a) State the laws of static friction.
   (b) Show that angle of friction is equal to angle of repose.
   (c) Two blocks *A* and *B* connected by a horizontal link are supported on two rough planes as shown in Fig. 7. The coefficient of friction of the block *A* and the horizontal plane is 0.40. The angle of friction for block *B* on the inclined plane is 20°. What is the smallest weight W_A of the block *A* for which the equilibrium of system can exist?

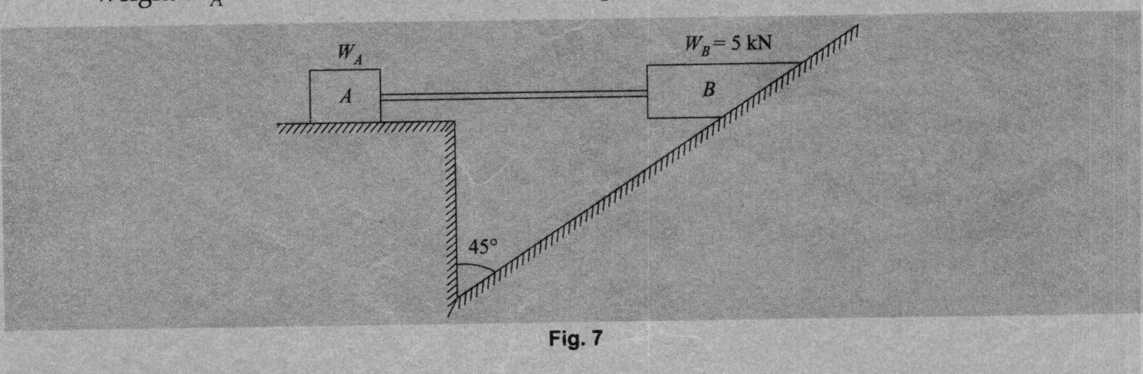
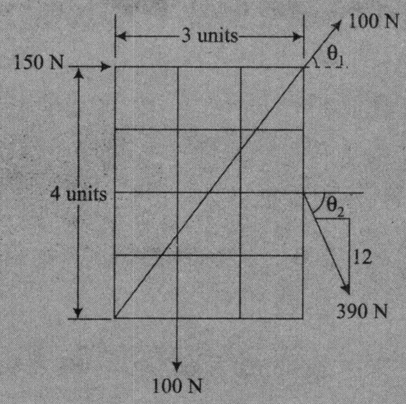


Fig. 7



Angle made by 100 N force with x-axis be θ_1. Then $\tan\theta_1 = \frac{4}{3}$ $\quad \therefore\ \theta_1 = 53.13°$

Angle made by resultant with x-axis be θ_2, then $\tan\theta_2 = \frac{12}{5}$ $\quad \therefore\ \theta_2 = 67.38°$.

$\sum$ forces in x direction = 0 (gives)

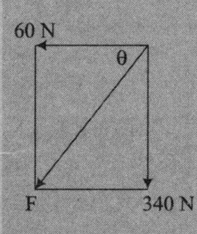
$$390 \cos 67.38 = 150 + 100 \cos 53.13 + F \cos\theta$$

$$\therefore \quad F \cos\theta = -60 \quad \ldots(1)$$

$$\sum F_y = 0 \text{ gives}$$

$$-390 \sin 67.38 = 100 \sin 53.13 - 100 + F \sin 60$$

$$\therefore \quad F \sin 60° = -340 \quad \ldots(2)$$



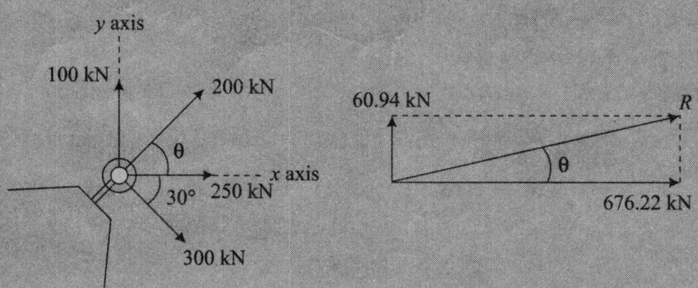
The component of force F are as shown in the Figure.

$$\therefore \quad F = \sqrt{60^2 + 340^2} = 345.25$$ **(Ans.)**

and $$\theta = \tan^{-1}\frac{340}{60}$$

$$= 79.99° \text{ as shown in figure}$$ **(Ans.)**

(b)



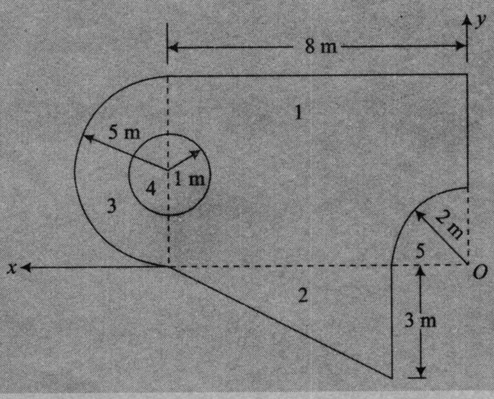
Let 200 kN make an angle θ_1 with X-axis.

Then, $\tan\theta_1 = \frac{2}{3}$ $\therefore$ $\theta_1 = 33.69°$

$$\sum F_x = 200\cos 33.69° + 250 + 300\cos 30°$$
$$= 676.22 \text{ kN}$$
$$\sum F_y = 100 + 200\sin 33.69 - 300\sin 30$$
$$= 60.94 \text{ kN}$$
$$R = \sqrt{676.22^2 + 60.94^2} = 678.96 \text{ kN}$$
$$\theta = \tan^{-1}\frac{60.94}{676.22} = 5.15° \text{ as shown in figure.}$$

4. (a) Ref Art 7.6

(b)



The composite figure is divided into five simple figures.

(i) A rectangle of size 8 m × 10 m

(ii) A triangle of size 6 m × 3 m

(iii) A semicircle of radius 5 m in which the following areas are to be subtracted

(iv) A circle of radius 1 m

(v) A quadrant of radius 2 m.

Taking x and y-axes as shown in figure

$$A_1 = 8 \times 10 = 80 \text{ m}^2$$
$$x_1 = 4 \text{ m} \quad y_1 = 5 \text{ m}$$
$$A_2 = \frac{1}{2} \times 6 \times 3 = 9 \text{ m}^2$$

8. (a) Write short notes on
   (i) Polar moment of inertia.
   (ii) Radius of gyration
   (b) State and prove parallel axis theorem.
   (c) Compute the second moment of the built-up area shown in Fig. 8 about its horizontal centroidal axis and find the corresponding radius of gyration.
   (*All dimensions are in mm*)

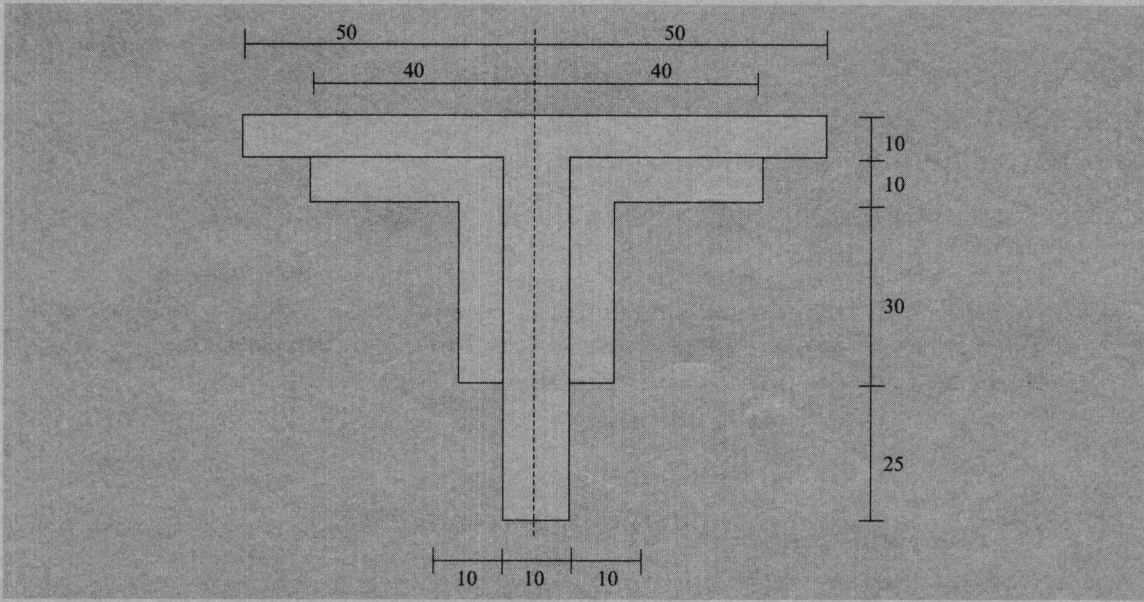
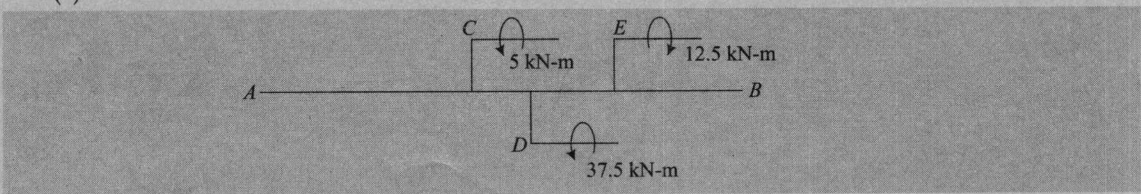


Fig. 8

Answers to Model Question Paper I

1. (a) Ref. Art 1.3
   (b) Ref. Art 1.1 (v)
   (c) Ref. Art 2.1
   (d) Ref. Art 3.22 a,b.
2. (a) Ref. Art 4.1
   (b) Ref. Art 4.7.1 and 4.7.2
   (c)



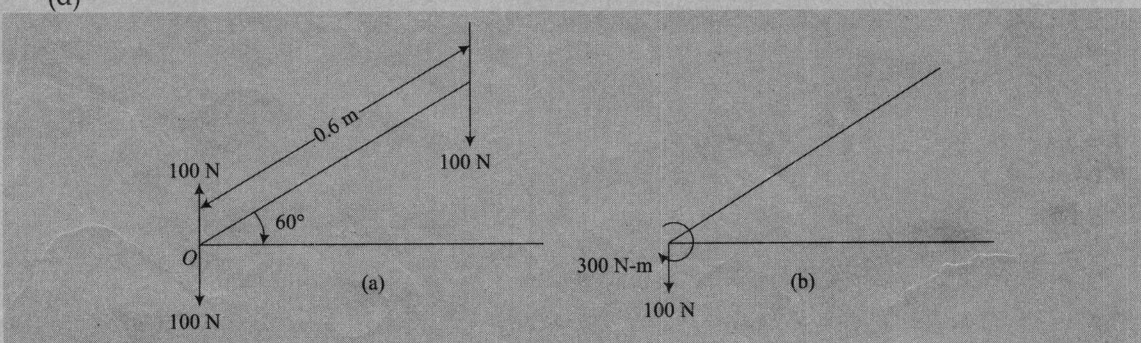
Forces on arm C give a couple moment of $10 \times 0.5 = 5$ kN-m anticlockwise

Forces on arm D give a couple moment of $50 \times 0.75 = 37.5$ kN-m anticlockwise and forces on arm E give a couple moment of $25 \times 0.5 = 12.5$ kN-m clockwise.

Hence net moment at A (or any other point)

$$M_A = -5 - 37.5 + 12.5$$
$$= -30 \text{ kN-m}$$
$$= 30 \text{ kN-m anticlockwise}$$

(d)



Applying equal and opposite 100 N force at A as shown in the figure and then looking at 100 N upward force at A and 100 N given force, the equivalent force system will be

(i) 100 N downward load at A

(ii) $100 \times 0.6 \cos 60 = 30$ N-m anticlockwise moment as shown in Fig. (b)

3. (a) Let missing force be F, making angle θ with x-axis.

$$x_2 = 2 + \frac{6}{3} = 4 \text{ m} \quad y_2 = -\frac{1}{3} \times 3 = -1 \text{ m}$$

$$A_3 = \frac{1}{2} \times \pi \times 5^2 = 39.27 \text{ m}^2$$

$$x_3 = 8 + \frac{4 \times 5}{3\pi} = 10.\,122 \text{ m} \quad y_3 = 5 \text{ m}$$

$$A_4 = -\pi \times 1^2 = -3.142 \text{ m}^2$$

$$x_4 = 8 \text{ m} \quad y_4 = 5 \text{ m}$$

$$A_5 = -\frac{1}{4} \times \pi \times 2^2 = -3.142 \text{ m}^2$$

$$x_5 = \frac{4 \times 2}{3\pi} = 0.849 \text{ m} \quad y_5 = \frac{4 \times 2}{3\pi} = 0.849 \text{ m}$$

$\therefore$ Total area $\quad A = 80 + 9.0 + 39.27 - 3.142 - 3.142$

$$= 121.99 \text{ m}^2$$

$$A\bar{x} = A_1 x_1 + A_2 x_2 + A_3 x_3 + A_4 x_4 + A_5 x_5$$

$$121.99\bar{x} = 80 \times 4 + 9 \times 4 + 39.27 \times 10.122 - 3.142 \times 8 - 3.142 \times 0.849$$

$\therefore \quad \bar{x} = 5.949$ m **Ans.**

Similarly,

$$A\bar{y} = \sum A_i y_i$$

$$121.99\bar{y} = 80 \times 5 + 9 \times (-1) + 39.27 \times 5 - 3.142 \times 5 - 3.142 \times 0.849$$

$\therefore \quad \bar{y} = 4.664$ m **Ans.**

(c) After removing shaded portion

$$A = 32 \times 90 - 16x = 2880 - 16x$$

Taking moment of areas about O, we have

$$A\bar{x} = \sum A_i x_i \quad \text{since } \bar{x} = -2 \text{ cm.}$$

$$(2880 - 16x)(-2) = 90 \times 32 \times 0 - 16x\,(0.5x)$$

$$5760 - 32x = -8x^2$$

$\therefore \quad x^2 - 4x + 720 = 0$

$\therefore \quad x = \dfrac{4 \pm \sqrt{4^2 + 4 \times 710}}{2}$

$= 24.907$ cm. [After ignoring unrealistic value]

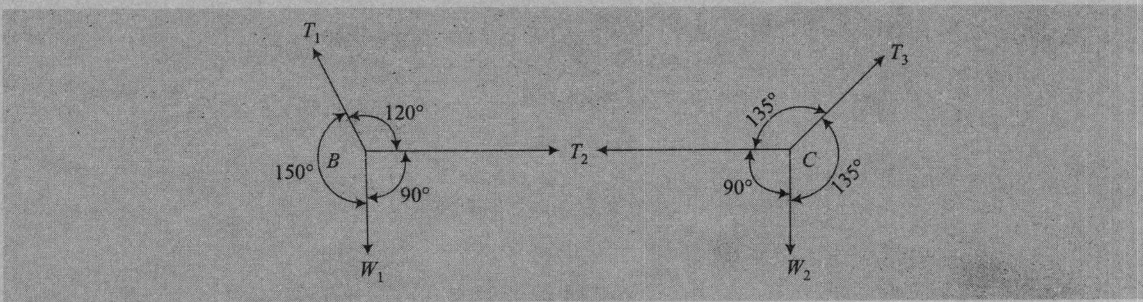
[centimetre unit should not have been used in SI]

5. (a) Ref Art 8.4
   (b) (i) Ref eqn. 8.2
   (ii) Ref eqn. 9.3

(c) Let T_1, T_2 and T_3 be tensile forces in the segments *AB*, *BC* and *CD*. Assuming pulley at *D* is frictionless, then tension in segment *CD*

$$T_3 = 4 \text{ kN.}$$

Free body diagrams for the system of forces at *C* and *B* are as shown in figures below.



Applying Lami's theorem to the system of forces at *C*, we get

$$\frac{W_2}{\sin 135} = \frac{T_2}{\sin 135} = \frac{T_3}{\sin 90}$$

$$= \frac{4}{1}$$

$$W_2 = \mathbf{2.282 \text{ kN}} \quad \textbf{Ans.}$$

$\therefore$ $$T_2 = \mathbf{2.828 \text{ kN}} \quad \textbf{Ans.}$$

Applying Lami's theorem to the system of forces at *B*, we get

$$\frac{W_1}{\sin 120} = \frac{T_1}{\sin 90} = \frac{T_2}{\sin 150}$$

$$= \frac{2.828}{5.4150}$$

$$= 5.656$$

$\therefore$ $$W_1 = \mathbf{4.898 \text{ kN}} \quad \textbf{Ans.}$$

and $$T_1 = \mathbf{5.656 \text{ kN}} \quad \textbf{Ans.}$$

6. (a) Ref. Art 9.4 final two paragraphs.
   (b) Ref. Art 9.3
   (c) Reaction at support *B* is vertical and that at *E* can be in any direction. Hence free body diagram of the beam is as shown below:

$$\sum M_A = 0 \text{ gives}$$

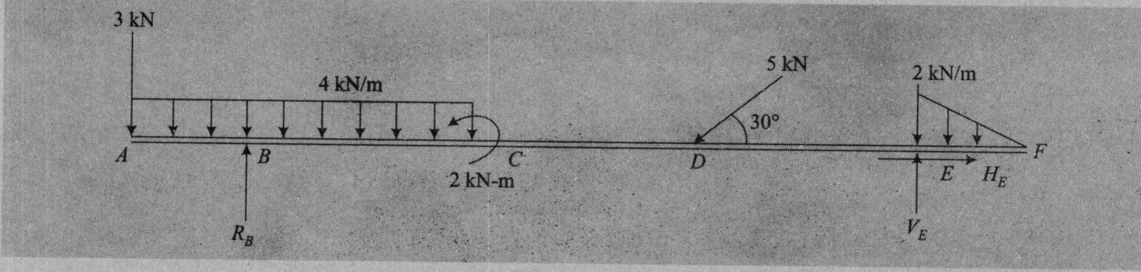


Fig. 7

$$R_B \times 6 - 3 \times 7 - 4 \times 3(7 - 1.5) - 2 - 5 \sin 30° \times 2 + \frac{1}{2} \times 2 \times 1 \times \frac{1}{3} = 0$$

$\therefore$ $$R_B = \frac{21 + 66 + 2 + 5 - 0.333}{6} = \frac{93.667}{6}$$

Thus, $\mathbf{R_B = 15.611\ kN}$ **Ans.**

$\sum V = 0$ gives

$$R_B + V_E - 3 - 4 \times 3 - 5 \sin 30 - \frac{1}{2} \times 2 \times 1 = 0$$

$$V_E = 18.50 - R_B = 18.50 - 15.611$$

i.e., $\mathbf{V_E = 2.889\ kN}$ **Ans.**

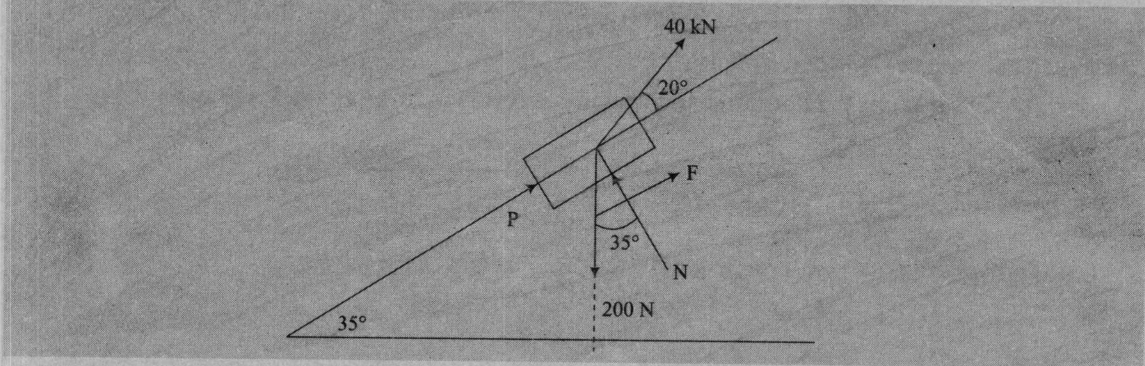
$\sum H = 0 \rightarrow$

$$H_E - 5 \cos 30° = 0$$

$\mathbf{H_E = 4.330\ kN}$ **Ans.**

7. (a) Ref Art 10.3 (need not prove eqn. 10.3)

(b) Assuming possible motion is downward, let P be the force required to prevent the motion (see Figure).



$\sum$Forces normal to plane = 0 gives

$$N - 200 \cos 35° + 40 \sin 20° = 0$$

$$\therefore \quad N = 150.15 \text{ kN}$$

$$\therefore \quad F = \mu N = 0.3 \times 150.15 = 45.045 \text{ kN}$$

$\sum$Forces parallel to plane = 0 gives

$$P + F + 40 \sin 20° - 200 \sin 35° = 0$$

$$P + 45.045 + 40 \sin 20° - 200 \sin 35° = 0$$

$$\therefore \quad P = 55.99 \text{ kN}$$

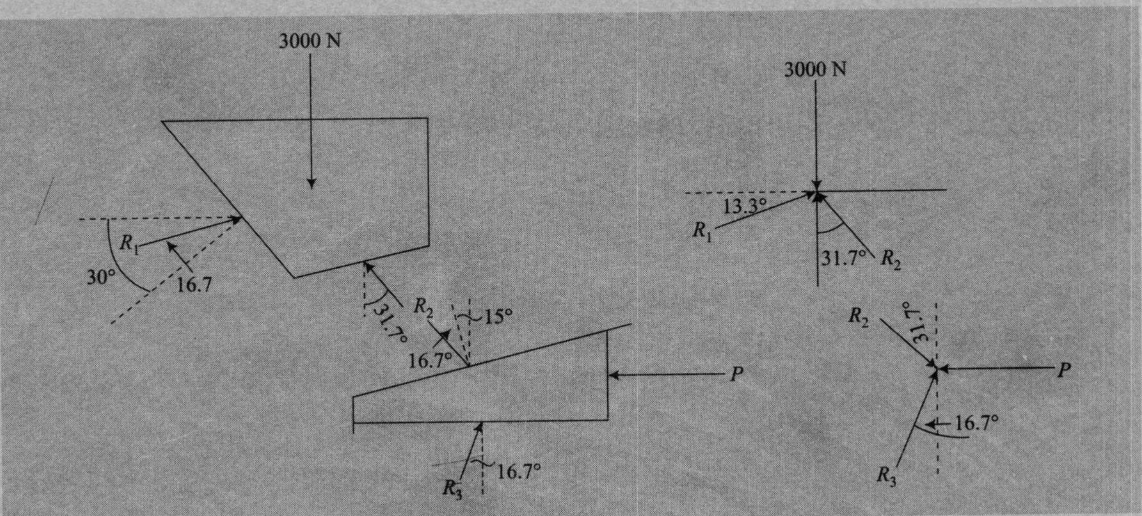
Since P is $+ve$, it is the true situation.

Hence **motion is downward** with a force of 55.99 kN. **Ans.**

(c) $\mu = 0.3$ Hence if ϕ is angle of friction

$$\tan \phi = 0.3 \text{ or } \phi = 16.7°$$

Free body diagram for block and the wedge are as shown in the figure.



Applying Lami's theorem to the system of forces acting on block we get

$$\frac{R_1}{\sin(90 - 13.7)} = \frac{R_2}{\sin(90 + 13.3)} = \frac{3000}{\sin(90 - 13.3 + 31.7)}$$

i.e.,
$$R_2 = 3000 \frac{\sin 103.3°}{\sin 108.4°} = 3076.84 \text{ N.}$$

Now, applying Lami's theorem to system of forces acting on wedge, we get

$$\frac{R_3}{\sin(90+31.7)} = \frac{P}{\sin(180-31.7-16.7)} = \frac{R_2}{\sin(90+16.7)}$$

i.e.,
$$P = 3076.84 \frac{\sin 131.6}{\sin 106.7}$$

$\therefore$
$$P = 2402.17 \text{ N} \quad \textbf{Ans.}$$

8. (a) Art 11.1
   (b) Art 11.5 (1)
   (c) The compound figure given is equal to a triangle of base width 60 m and height 80 mm plus a semicircle of radius 30 mm and minus a circle of radius 20 mm. Moment of inertia is required about axis *AB*.

$\therefore$
$$I = \frac{1}{12} \times 60 \times 80^3 + \frac{1}{2} \times \frac{\pi}{4}\, 30^4 - \frac{\pi}{4} \times 20^4$$
$$= 2560000 + 318086.2 - 125663.7$$
$$I = 2752422.5 \text{ mm}^4 \quad \textbf{Ans.}$$

Answers to Model Question Paper II

1. (a) Art 1.1 (i) and (vii)
   (b) Art 2.2 (i) and (ii)
   (c) Art 3.1.2, and 3.2.3 (a).
2. (a) Art 4.2 - Newton's first law and second law, and Art 4.4.
   (b) Art 4.7
   (c) Art 4.9
   (d)

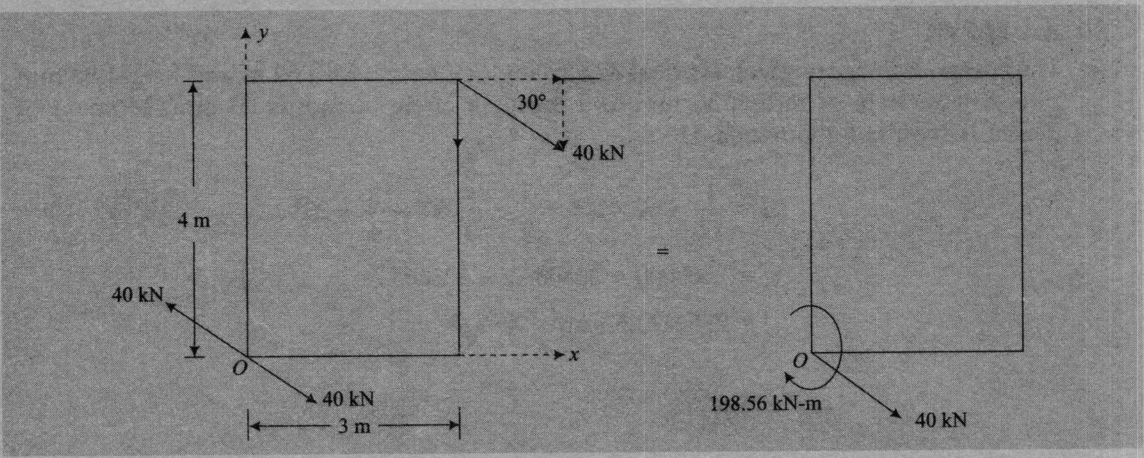
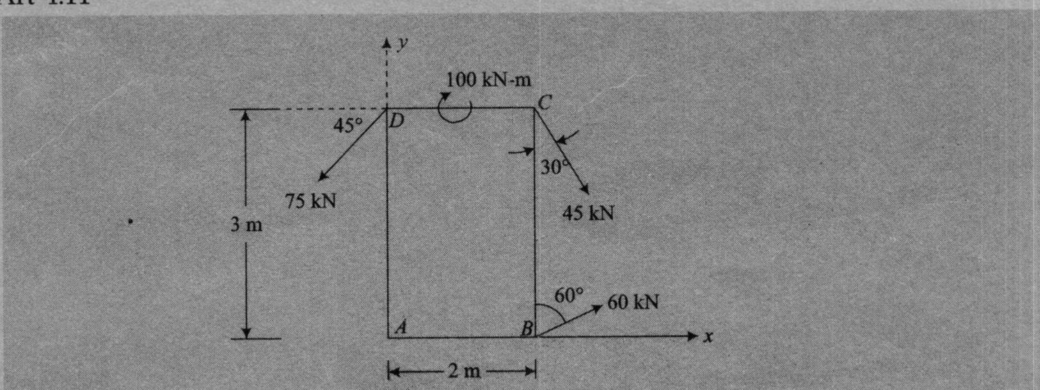


Fig. 10

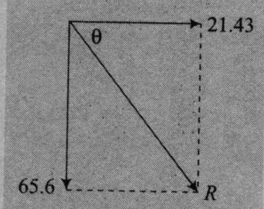
Applying two equal and opposite 40 kN forces at O parallel to given force, we can look at the system as a 40 kN force at O parallel to given 40 kN force (at 30° to x-axis) and a couple moment at O. The couple moment is found as that due to x and y component of 40 kN forces. Thus

$$M = 40 \cos 30° \times 4 + 40 \sin 30° \times 3 = 198.56 \text{ kN-m, clockwise.}$$

3. (a) Art 6.1
   (b) Art 4.11
   (c)



Selecting x and y directions as shown in figure,

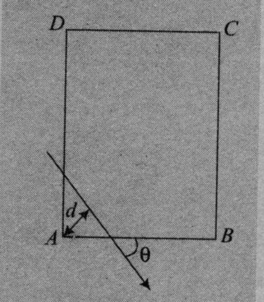


$$\sum F_x = 60 \sin 60° + 45 \sin 30° - 75 \cos 45° = 21.43 \text{ kN}$$

$$\sum F_y = 60 \cos 60° - 45 \cos 30° - 75 \sin 45° = 62 \text{ kN}$$

$$R = \sqrt{21.43^3 + 62^2} = 65.60 \text{ kN} \quad \textbf{Ans.}$$

$$\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{62}{21.43} = 2.893$$



$\therefore$ $\theta = 70.93°$ as shown in the figure **Ans.**

Taking clockwise moment as positive,

$$M_A = -60 \cos 60 \times 2 + 0 + 45 \sin 30 \times 3 + 45 \cos 30 \times 2 + 100$$
$$- 75 \cos 45 \times 3 + 0 = 26.34 \text{ m}$$

If d is the distance of resultant from A, then

$$Rd = 26.34$$

$$\therefore \quad d = \frac{26.34}{R} = \frac{26.34}{65.60} = 0.402 \text{ m as shown in figure}$$

4. (a) Art 7.6 – centroid of a triangle
   (b)

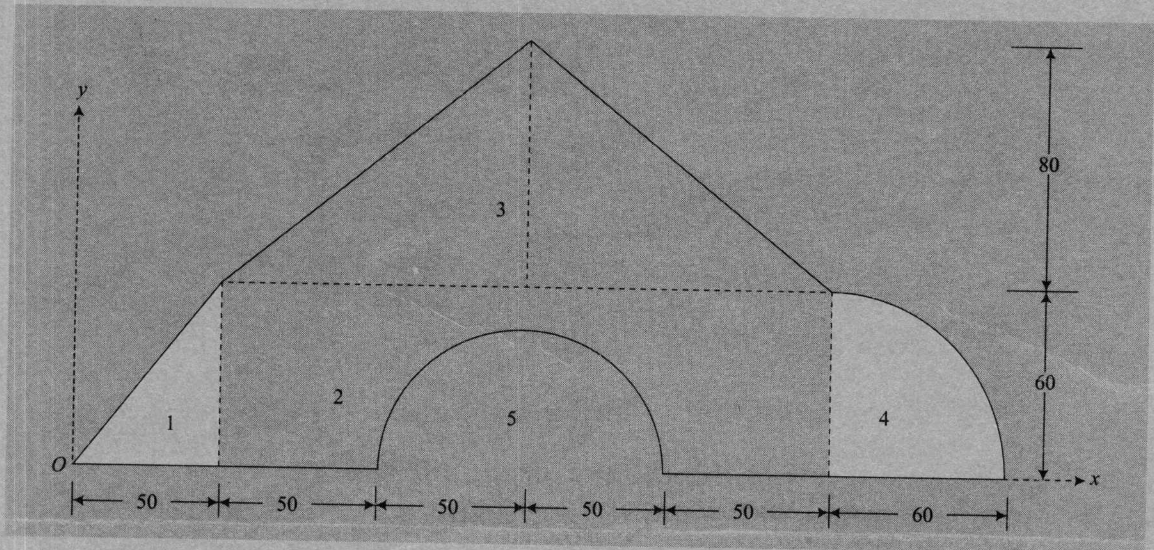


Fig. 12

Given composite area is divided into five simple figures as shown in the figure. Coordinates of their centroids are noted down below after selecting x and y axes as shown in the figure.

$$T - R_1 \cos\theta = 0$$

$\therefore$ $$T = 0.756 \cos 41.4° = 0.567 \text{ kN} \quad \textbf{Ans.}$$

$$\sum V = 0 \rightarrow$$

$$R_3 - 1 - R_1 \sin\theta = 0$$

$$R_3 = 1 + 0.756 \sin 41.4° = 1.5 \text{ kN Ans.}$$

Due to symmetry, $R_3 = R_4 = 1.5$ kN **Ans.**

6. (a) Art 9.3

(b) Free body diagram of identical spheres A and B are as shown in figures below:

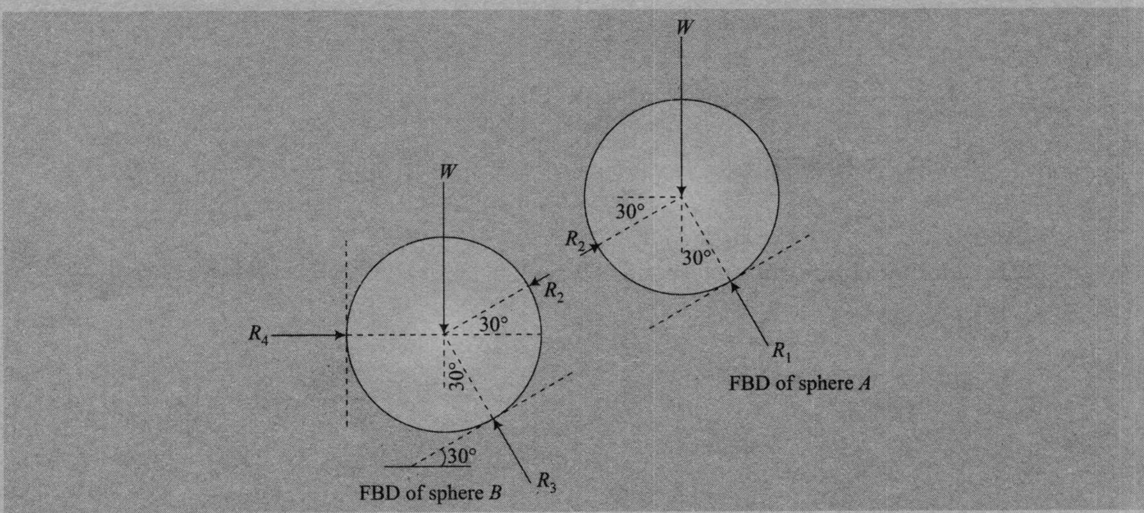


Fig. 15

(c)

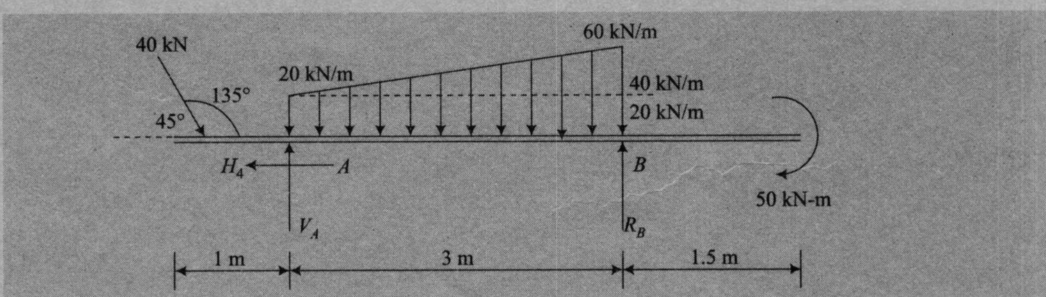


Fig. 16

Let the reactions developed at A be V_A and H_A ad that developed at B be R_B as shown in the figure. Dividing trapezoidal load into a load of intensity 20 kN/m and a triangular load with maximum intensity of 40 kN/m at B,

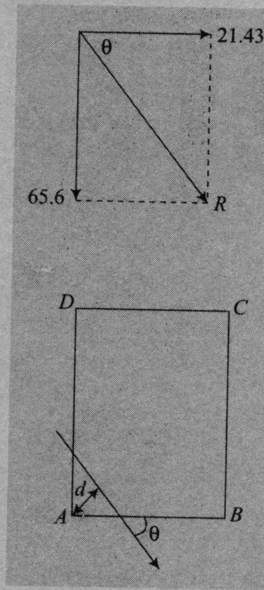
$$\sum M_A = 0 \rightarrow$$

Selecting x and y directions as shown in figure,

$$\sum F_x = 60 \sin 60° + 45 \sin 30° - 75 \cos 45° = 21.43 \text{ kN}$$

$$\sum F_y = 60 \cos 60° - 45 \cos 30° - 75 \sin 45° = 62 \text{ kN}$$

$$R = \sqrt{21.43^3 + 62^2} = 65.60 \text{ kN} \quad \textbf{Ans.}$$



$$\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{62}{21.43} = 2.893$$

$\therefore$ $\theta = 70.93°$ as shown in the figure **Ans.**

Taking clockwise moment as positive,

$M_A = -60 \cos 60 \times 2 + 0 + 45 \sin 30 \times 3 + 45 \cos 30 \times 2 + 100$
$- 75 \cos 45 \times 3 + 0 = 26.34$ m

If d is the distance of resultant from A, then

$$Rd = 26.34$$

$$\therefore \quad d = \frac{26.34}{R} = \frac{26.34}{65.60} = 0.402 \text{ m as shown in figure}$$

4. (a) Art 7.6 – centroid of a triangle
   (b)

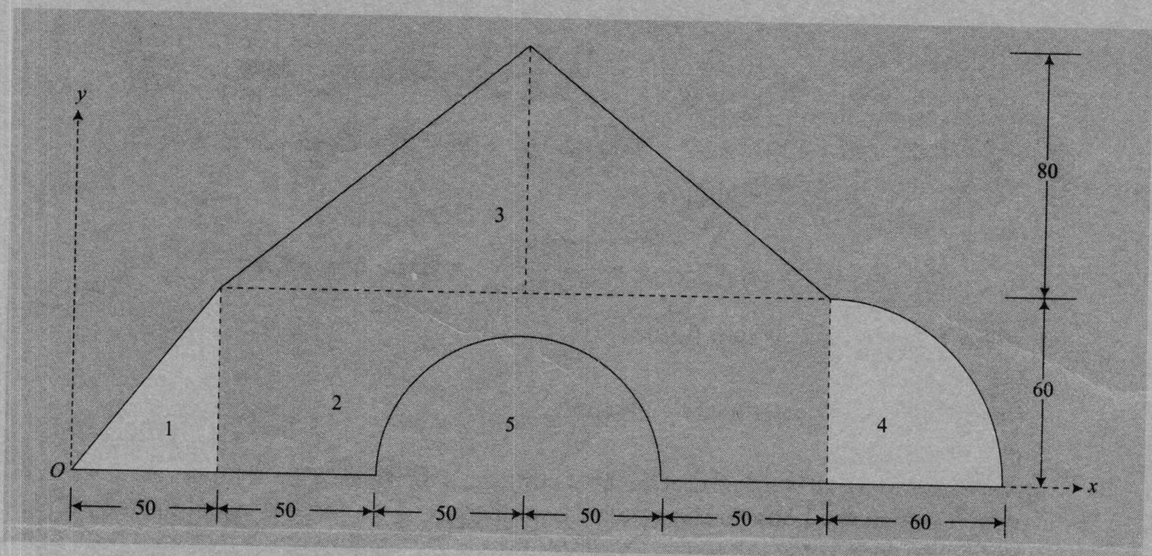


Fig. 12

Given composite area is divided into five simple figures as shown in the figure. Coordinates of their centroids are noted down below after selecting x and y axes as shown in the figure.

(1) $A_1 = \frac{1}{2} \times 50 \times 60 = 1500 \text{ mm}^2$; $x_1 = \frac{2}{3} \times 50 = 33.33$ mm; $y_1 = \frac{60}{3} = 20$ mm

(2) $A_2 = 200 \times 60 = 12000 \text{ mm}^2$; $x_2 = 150$ mm; $y_2 = \frac{60}{2} = 30$ mm.

(3) $A_3 = \frac{1}{2} \times 200 \times 80 = 8000 \text{ mm}^2$; $x_3 = 150$ mm; $y_3 = 60 + \frac{80}{3} = 86.67$ mm

(4) $A_4 = \frac{1}{4} \times \pi \times 60^2 = 2827.43 \text{ mm}^2$; $x_4 = 250 + \frac{4 \times 60}{3\pi} = 275.46$ mm

$$y_4 = \frac{4 \times 60}{3\pi} = 25.46 \text{ mm.}$$

(5) $A_5 = -\frac{1}{2} \times \pi \times 50^2 = -3926.99 \text{ mm}^2$; $x_5 = 150$ mm

$$y_5 = \frac{4 \times 50}{3\pi} = 21.22 \text{ mm.}$$

$\therefore$ Total area $A = \sum A_i$

$= 1500 + 12000 + 8000 + 2827.43 - 3926.99$

$= 20400.44 \text{ mm}^2$

$\sum A_i x_i = 1500 \times 33.33 + 12000 \times 150 + 8000 \times 150 + 2827.43 \times 275.46 - 3926.99 \times 150$

$= 3239795.3$

$$\therefore \quad \bar{x} = \frac{\sum A_i y_i}{A} = \frac{3239795.3}{20400.44} = 158.8 \text{ mm} \quad \textbf{Ans.}$$

$\sum A_i y_i = 1500 \times 20 + 12000 \times 30 + 8000 \times 86.67 + 2827.43 \times 25.46 - 3926.99 \times 21.22$

$= 107198.9$

$$\therefore \quad \bar{y} = \frac{\sum A_i y_i}{A} = \frac{107198.9}{20400.44} = 52.55 \text{ mm} \quad \textbf{Ans.}$$

5. (a). (i)Art 8.2 with one or two figures

(ii) Art 8.3

(iii) Art 8.4 (proof need not be given)

(iv) Equilibriant

An equilibriant of a system of forces acting on a body may be defined as 'the force which brings the body to the state of equilibrium'. This force is equal in magnitude but opposite in direction to the resultant. Hence the equilibriant can be found by first finding the resultant and then marking the direction opposite to the resultant.

(b) Let C be the centre of top sphere. Now,

$$AC = BC = r_1 + r_2 = 200 + 200 = 400 \text{ mm}$$

$$AB = 600 \text{ mm (given)}$$

∴ Inclination of AC and BC to horizontal θ is given by

$$\cos\theta = \frac{AB/2}{AC} = \frac{600 \times 0.5}{400}$$

$$\therefore \qquad \theta = 41.40°$$

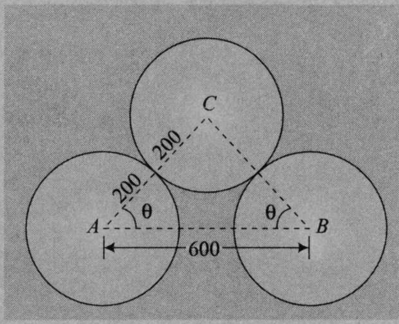


Fig. 13

Reaction at contact surfaces are at right angles to contact surfaces. Hence reactions R_1 and R_2 are along AC and BC respectively as shown in the figure. Considering equilibrium of sphere 1. we get

$$\sum H = 0 \rightarrow$$

$$R_1 \cos\theta = R_2 \cos\theta$$

$$\therefore \qquad R_1 = R_2$$

$$\sum V = 0 \rightarrow$$

$$R_1 \sin\theta + R_2 \sin\theta - 1 = 0$$

$$\therefore \qquad 2R_1 \sin 41.4° = 1$$

$$R_1 = R_2 = 0.756 \text{ kN.}$$

Considering equilibrium of sphere (2) we get

$$\sum H = 0 \rightarrow$$

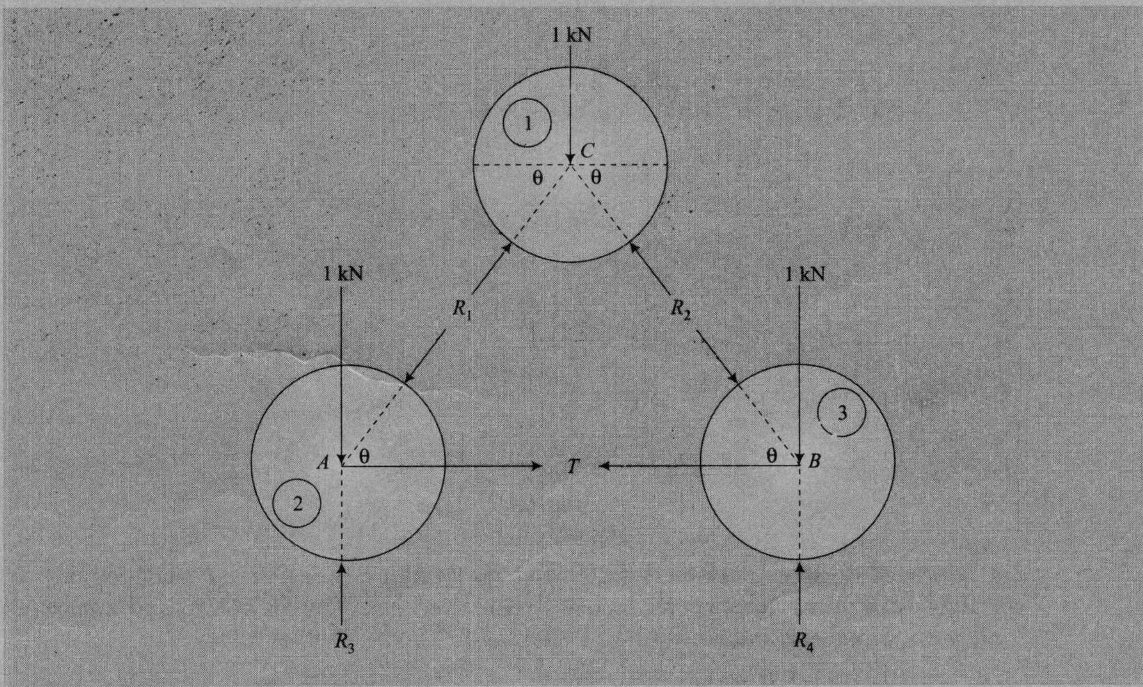


Fig. 14

$T - R_1 \cos\theta = 0$

$\therefore \quad T = 0.756 \cos 41.4° = 0.567$ kN **Ans.**

$$\sum V = 0 \rightarrow$$

$R_3 - 1 - R_1 \sin\theta = 0$

$R_3 = 1 + 0.756 \sin 41.4° = 1.5$ kN Ans.

Due to symmetry, $R_3 = R_4 = 1.5$ kN **Ans.**

6. (a) Art 9.3

(b) Free body diagram of identical spheres A and B are as shown in figures below:

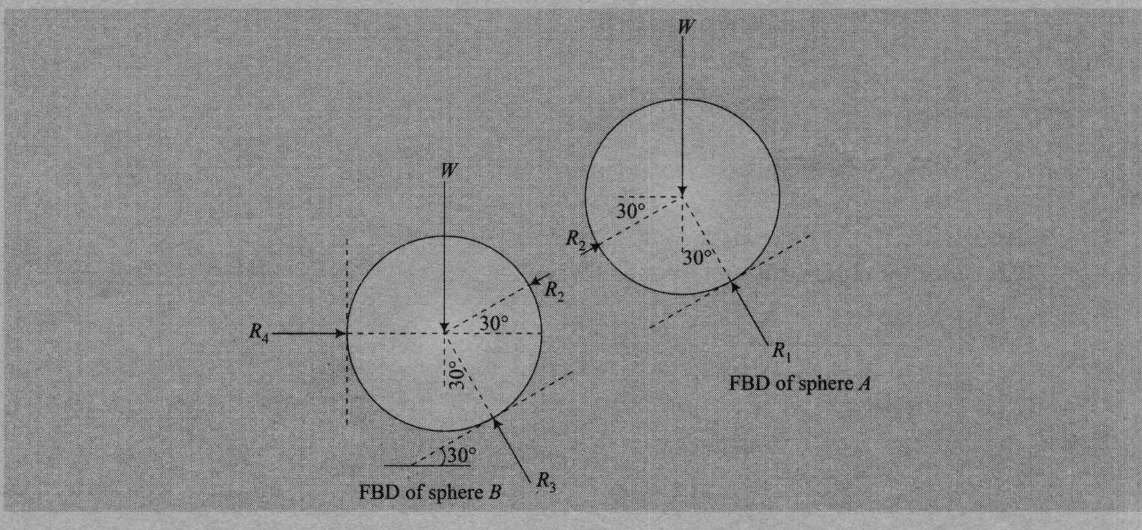


Fig. 15

(c)

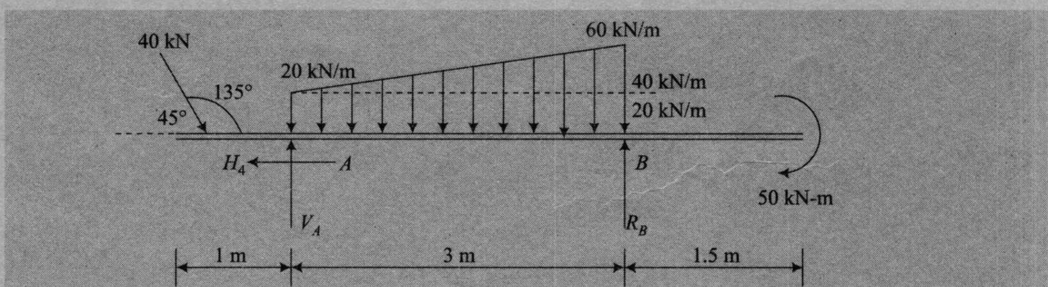


Fig. 16

Let the reactions developed at A be V_A and H_A ad that developed at B be R_B as shown in the figure. Dividing trapezoidal load into a load of intensity 20 kN/m and a triangular load with maximum intensity of 40 kN/m at B,

$$\sum M_A = 0 \rightarrow$$

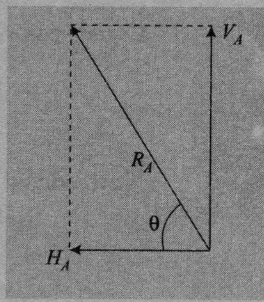
$$-40 \sin 45 \times 1 + 20 \times 3 \times \frac{3}{2} + \frac{1}{2} \times 3 \times 40 \times \frac{2}{3} \times 3 - R_B \times 3 + 50$$

$\therefore \quad R_B = 77.24$ kN **Ans.**

$$\sum H = 0 \rightarrow$$

$$40 \cos 45 - H_A = 0$$

$\therefore \quad H_A = 28.28$ kN



$$\sum V = 0 \rightarrow$$

$$-40 \sin 45 + V_A + R_B - 20 \times 3 - \frac{1}{2} \times 40 \times 3 = 0$$

$\therefore \quad V_A = 148.28 - R_B = 148.28 - 77.24$

$\therefore \quad V_A = 71.04$ kN

V_A and H_A may be clubbed to get single force

$$R_A = \sqrt{H_A^2 + V_A^2} = \sqrt{28.28^2 + 71.04^2}$$

$\therefore \quad R_A = 76.46$ kN. **Ans.**

$$\theta = \tan^{-1} \frac{71.04}{28.28}$$

$= 68.29°$ as shown in figure. **Ans.**

7. (a) Art 10.2
   (b) Art 10.3 (after 2 paragraphs on angle of friction)
   (c) Free body diagrams for block A and block B are as shown in the figures above. Consider block B.

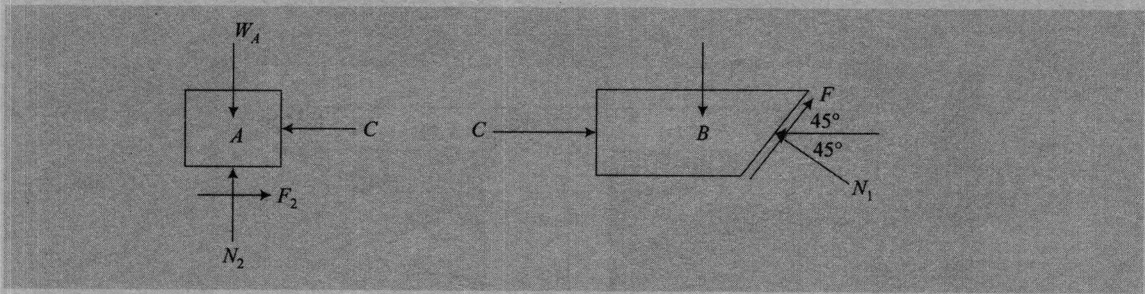


Fig. 17

$\mu = \tan 20°$, given

$\therefore \quad F_1 = N_1 \tan 20°$

$$\sum F_V = 0 \rightarrow$$

$$N_1 \sin 45 + F_1 \sin 45 - 5 = 0$$

$$0.707\, N_1 + N_1 \tan 20 \sin 45 = 5$$

$$N_1 = \frac{5}{0.707 + \tan 20 \times \sin 45} = 5.184 \text{ kN.}$$

$\therefore \quad F_1 = 5.184 \tan 20° = 1.887$ kN

$$\sum F_H = 0 \rightarrow$$

$$C + F_1 \cos 45° - N_1 \cos 45° = 0$$

$$C = (N_1 - F_1) \cos 45°$$
$$= (5.184 - 1.887) \cos 45$$
$$= 2.331 \text{ kN}$$

Now consider the equilibrium of block A.

$$\sum F_H = 0 \rightarrow$$

$$F_2 - C = 0 \text{ or } F_2 = C = 2.331 \text{ kN.}$$

From law of friction, $F_2 = \mu N_2 = 0.4 \text{ N}_2$

$$\therefore \quad N_2 = \frac{F_2}{0.4} = \frac{2.331}{0.4} = 5.828 \text{ kN.}$$

$$\sum F_v = 0 \rightarrow$$

$$N_2 - W_A = 0$$

$\therefore \quad W_A = N_2 = 5.828$ kN. **Ans.**

8. (a) (i) Art 11.2
   (ii) Art 11.3
   (b) Art 11.4 parallel axis theorem.
   (c)

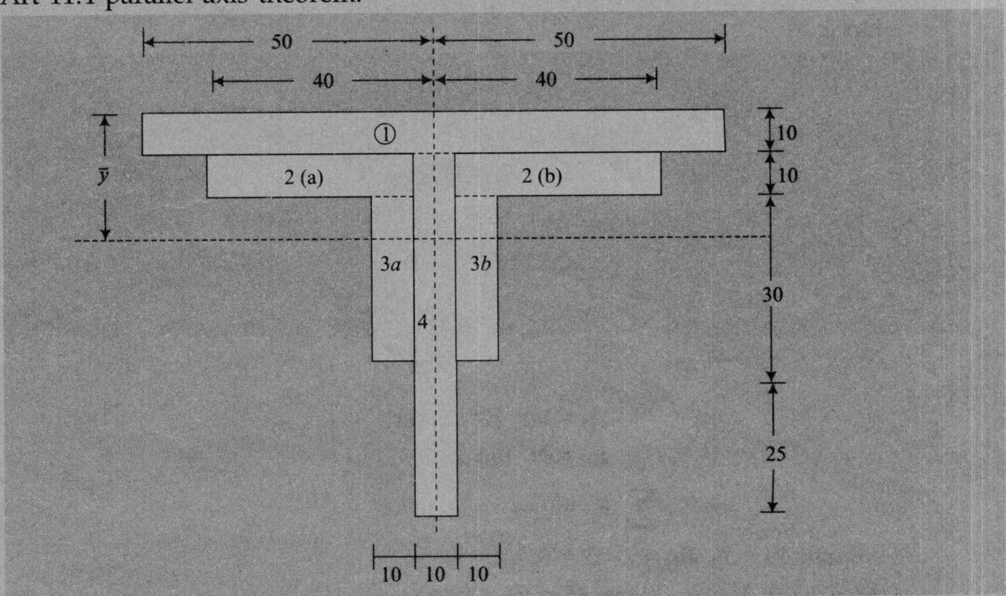


Fig. 18

The composite figure is divided into rectangles as shown in figure. 2(a) and 2(b) are identical for the calculation of moment of inertia about x-x axis and similarly 3(a) and 3(b) are also identical. Hence by doubling contributions of 2(a) and 3(a), contribution of 2(b) and 3(b) are also taken care.

$$A = 100 \times 10 + 35 \times 10 \times 2 + 30 \times 10 \times 2 + 10 \times 65$$
$$= 2950 \text{ mm}^2$$

Taking topmost fiber as reference axis.

$$y_1 = 5 \text{ mm}, \; y_2 = 15 \text{ mm}, \; y_3 = 35 \text{ mm}, \; y_4 = 10 + \frac{40 + 25}{2}$$
$$= 42.5 \text{ mm}$$

$$\sum A_i y_i = 100 \times 10 \times 5 + 35 \times 10 \times 2 \times 15 + 30 \times 10 \times 2 \times 35 + 10 \times 65 \times 42.5$$
$$= 64125 \text{ mm}^2$$

$$\therefore \qquad \bar{y} = \frac{\sum A_i y_i}{A} = \frac{64125}{2950} = 21.74 \text{ mm.}$$

$$I_{xx} = \frac{1}{12} \times 100 \times 10^3 + 100 \times 10 \times (21.74 - 5)^2$$
$$+ 2\left[\frac{1}{12} \times 35 \times 10^3 + 35 \times 10\,(21.74 - 15)^2\right]$$
$$+ 2\left[\frac{1}{2} \times 30 \times 10^3 + 30 \times 10\,(35 - 21.74)^2\right]$$
$$+ \frac{1}{12} \times 10 \times 65^3 + 10 \times 65\,(42.5 - 21.74)^2$$
$$I_{xx} = 945679.8 \text{ mm}^4 \quad \textbf{Ans.}$$

Radius of gyration

$$r_{xx} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{945679.8}{2950}}$$

Hence $\qquad r_{xx} = 17.9$ mm **Ans.**

Model Question Paper-III—New Scheme

I/II Semester B.E. degree Examination, Dec. 06/ Jan. 07
Common to All Branches

Elements of Civil Engineering and Engineering Mechanics

Time: 3 hrs. [Max. Marks: 100]

Note: Answer any FIVE full questions.

1. a. List the various civil engineering amenities covered under infrastructural development.
   b. What are the different bases under which the dams are classified?
   c. Write short notes on:
      (i) Shoulders
      (ii) Kerbs
2. a. State the Newton's three laws of motion.
   b. State and explain principle of transmissibility of forces.
   c. A force of 200 N is acting on a block as shown in Fig. 2(c), find the components of forces along the horizontal and vertical axes.
   d. Find the moment of force $F = 600$ N about 'a' as shown in Fig. 2(d).

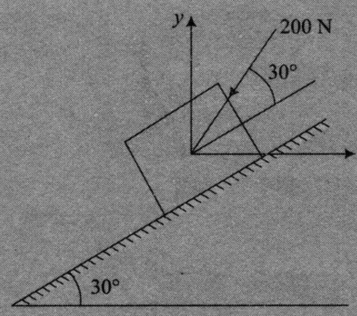


Fig. 2c

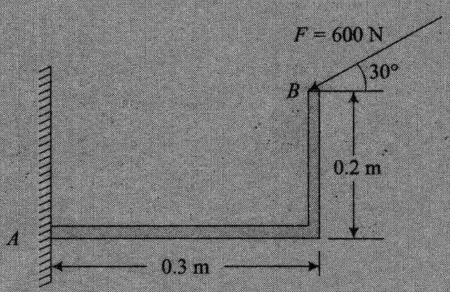


Fig. 2d

3. a. State and explain parallelogram law of forces.
   b. Determine the resultant force acting on the structure at point 'O' both in magnitude and direction. Refer Fig. 3(b)

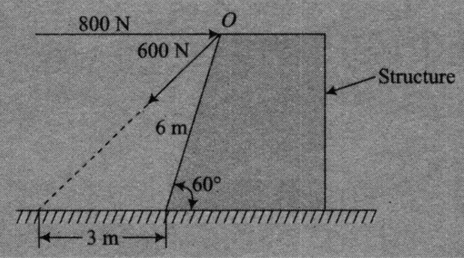


Fig. 3b

c. Determine the magnitude, direction of the resultant force for the force system shown in fig. 3(c). Locate the resultant force with respect to point 'D'.

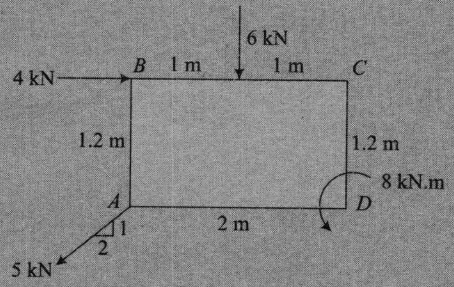


Fig. 3c

4. a. Define centroid and centroidal axis.
   b. Derive an expression for the co-ordinates for the position of centroid of rectangle.
   c. Determine the position of centroid with respect to 'O'

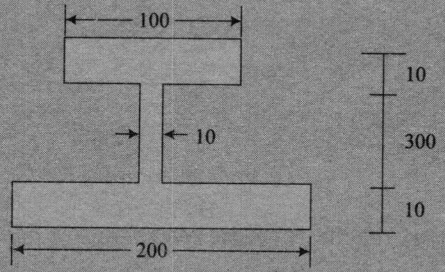


Fig. 4c All dimensions are in mm

5. a. Define:
   (i) Free body diagram
   (ii) Action and reaction at a point of contact of bodies in equilibrium.
   b. Compute the tensions in the strings *AB*, *BC* and *CD* shown in Fig. 5(b).

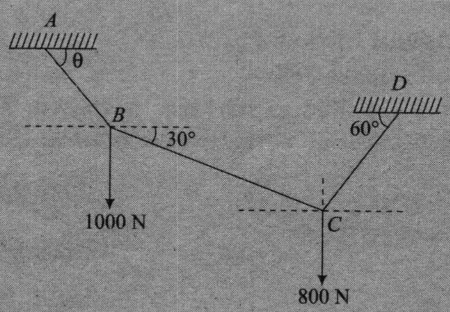


Fig. 5b

c. Two spheres each of radius 100 mm and weight 5 kN is in a rectangular box as shown in Fig. 5(c). Calculate the reactions at all the points of contact.

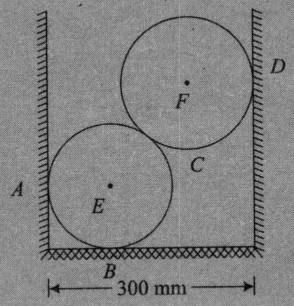


Fig. 5c

6 a. Determine the distance x such that the reactions R_A an R_B are equal, for the beam shown in Fig. 6 (a).

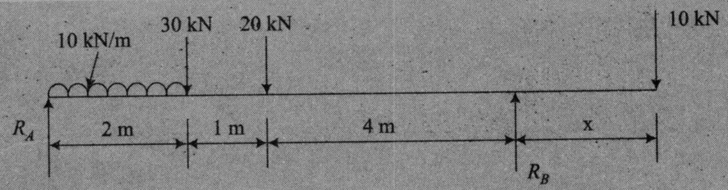


Fig. 6a

b. Determine the support reactions of the overhanging beam shown in Fig. 6(b).

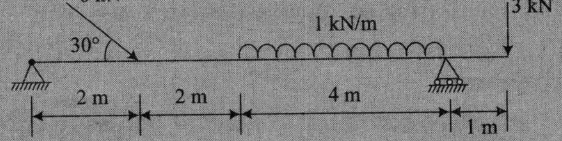


Fig. 6b

7. a. Distinguish between
   (i) Dry friction and fluid friction
   (ii) Static friction and kinetic friction.

b. Determine the force P required to start the movement of the wedge as shown in Fig. 7 (b). The angle of friction for all surfaces of contact is 15°.

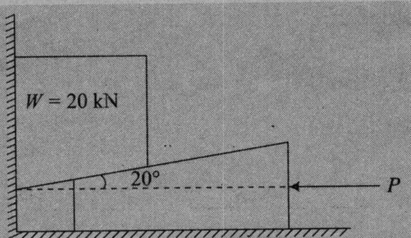


Fig. 7b

8. a. Determine the moment of inertia of a circle about its diametral axis by the method of integration.

   b. Determine the moment of inertia and radii of gyration of the area shown in Fig. 8(b) about the base *AB* and the centroidal axis parallel to *AB*.

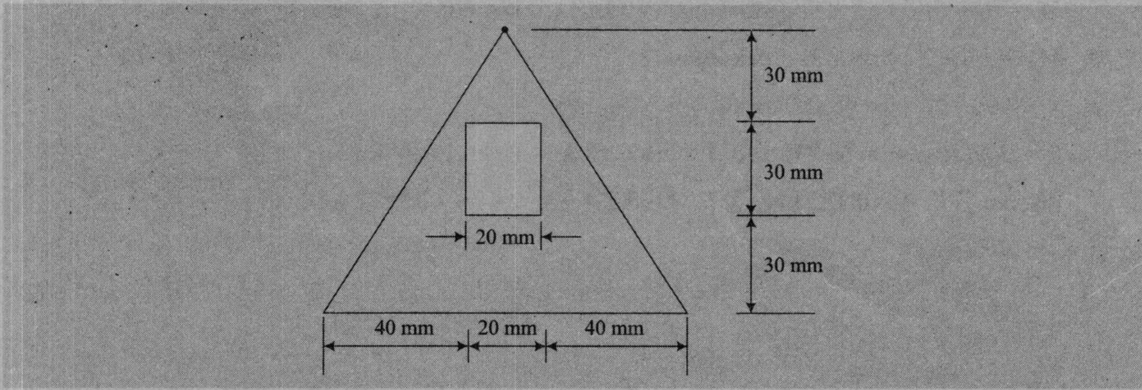
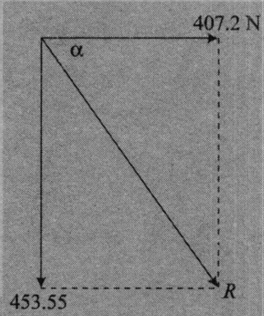


Fig. 8b

Model Question Paper III—Answers to Numerical Problems

2. c. $F_x = -100$ N, $F_y = -173.2$ N

[Hint: 200 N force makes 60° with x-axis]

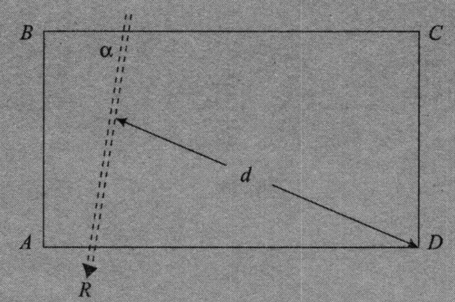


2. d. $M_A = 13.923$ N-m anti clockwise.

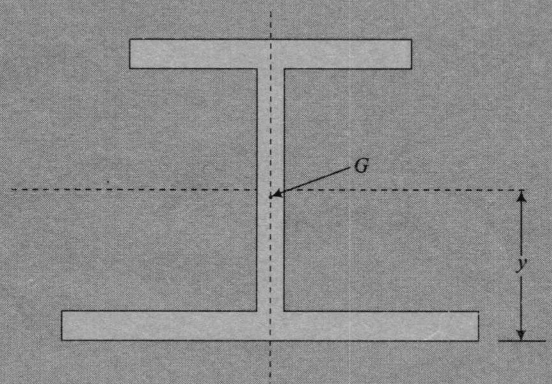
3. b. $R = 609.5$ N, $\propto = 48.08°$ as shown in figure

3. c. $R = 8.25$ kN, $\propto = 86.73°$ and $d = 1.657$ m as shown in figure.

[Hints: $\Sigma F_x = -0.472$ kN, $\Sigma F_y = -8.236$ kN, $M_D = -13.672$ kN]



4. c. On symmetric axis at $\overline{y} = 134.2$ mm from bottommost fibre as shown in figure.



5. b. $T_{CD} = 692.8$ N, $T_{BC} = 400$ N, $T_{AB} = \dfrac{346.4}{\sin(90 + \theta)}$

c. $R_A = 2.887$ kN, $R_B = 10$ kN

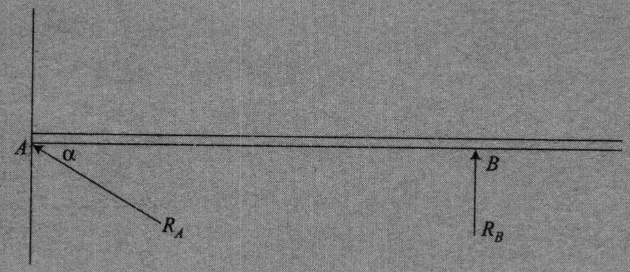
$R_C = 5.774$ kN, $R_D = 2.887$ kN

6. a. $x = 7$ m.

[Hints: $R = R_A = R_B = 40$ kN; $R_B \times 7 = 10 \times 2 \times 1 + 30 \times 2 + 20 \times 3 + 10\,(7 + x)$]

b. $R_B = 7.125$ kN, $V_A = 2.871$ kN, $H_A = 5.196$ kN.

$R_A = 5.938$ kN, $\alpha = 28.96°$ as shown in Figure



7. b. $P = 23.835$ kN

[Hints $\dfrac{R_2}{\sin 75} = \dfrac{20}{\sin 140}$, $\therefore R_2 = 30.054$ kN]

$\dfrac{P}{\sin 130°} = \dfrac{30.054}{\sin 105}$ $\therefore P = 23.835$ kN

8. b. $I_{AB} = 4815000$ mm^4 $r_{AB} = 35.1$ mm

$I_{GG} = 1824230$ mm^4 $r_{GG} = 21.62$ mm.

[Hints $\bar{y} = 27.69$ mm; $I_{GG} = I_{AB} - A\bar{y}^2$]