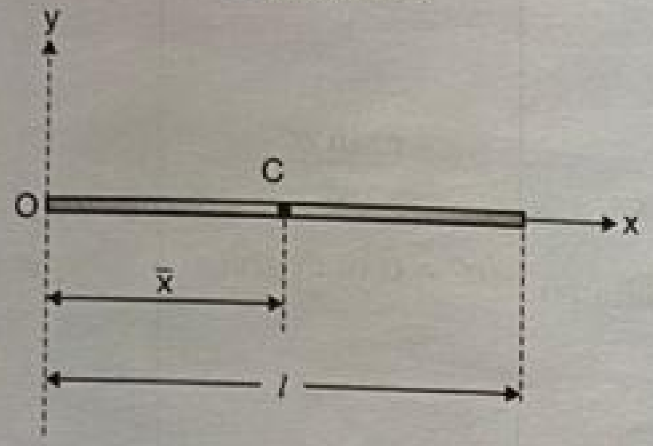
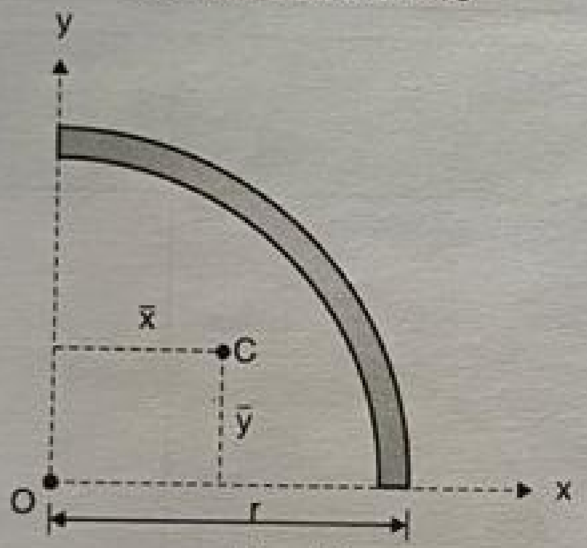
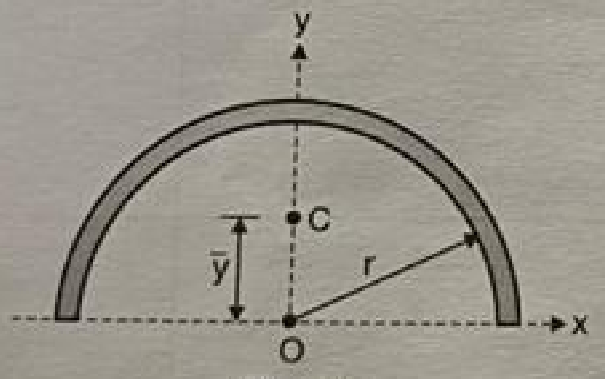
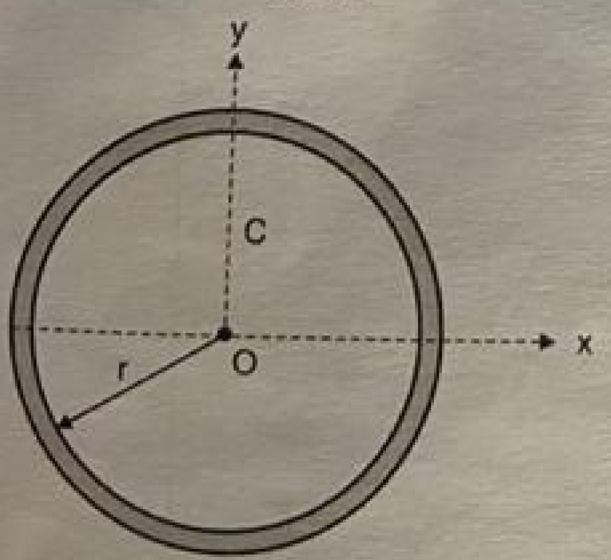
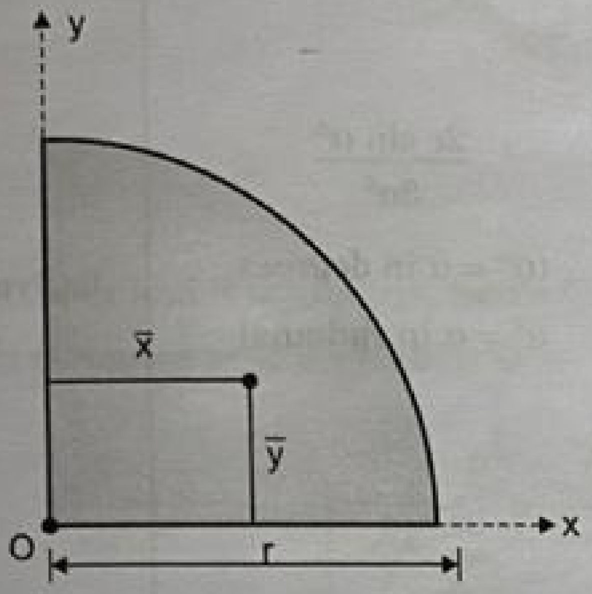
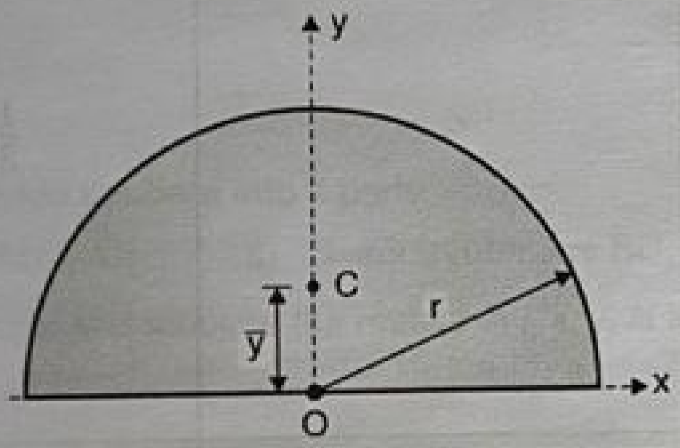
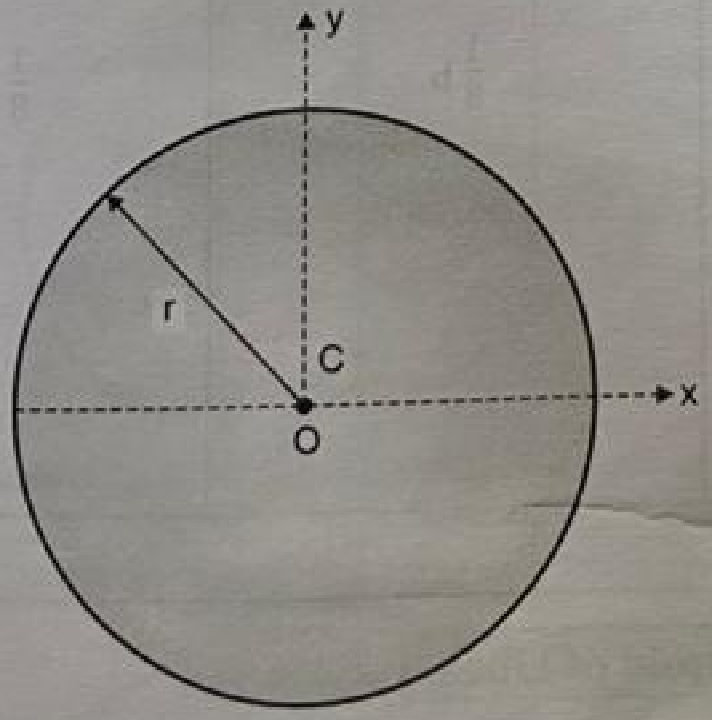
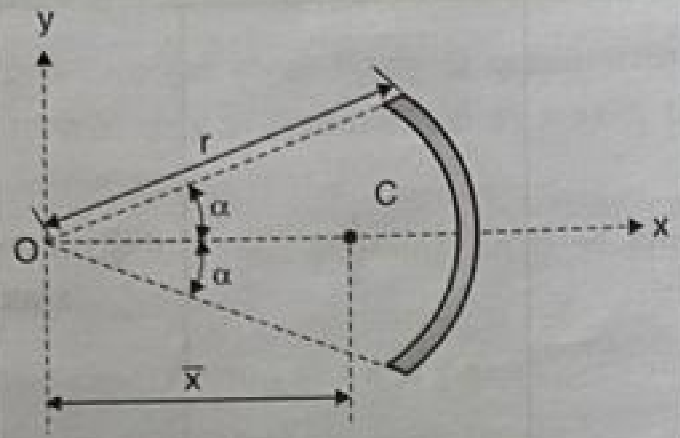
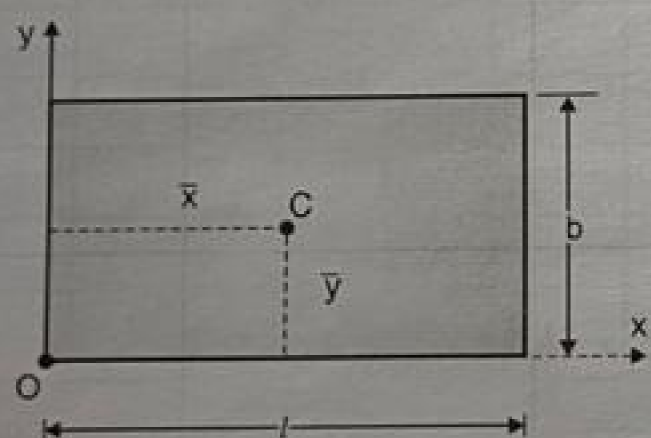
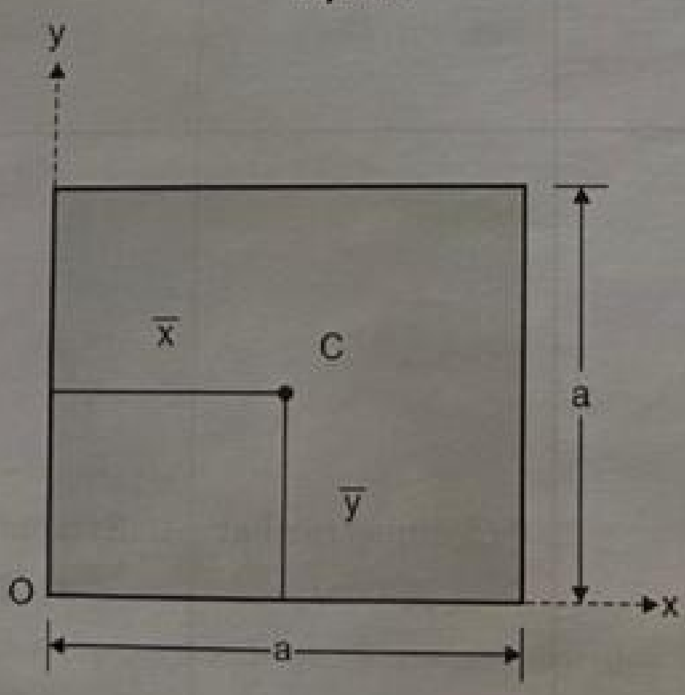
5.6 Centroid of Common Geometrical Shapes of Lines :

Sr. No.	Shape	Length (l)	$\bar{x}$	$\bar{y}$
1	**Straight line**  **Fig. (a)**	l	$\frac{l}{2}$	0 (Symmetrical at x-axis)
2	**Quarter Circular Arc**  **Fig. (b)**	$\frac{\pi r}{2}$	$\frac{2r}{\pi}$	$\frac{2r}{\pi}$
3	**Semi circular arc**  **Fig. (c)**	πr	0 (Symmetrical at y-axis)	$\frac{2r}{\pi}$
4	**Circle**  **Fig. (d)**	$2\pi r$	0 (Symmetrical at y-axis)	0 (Symmetrical at x-axis)

Sr. No.	Shape	Area (A)	$\overline{x}$	$\overline{y}$
3	**Quarter circle**  **Fig. (c)**	$\frac{\pi r^2}{4}$	$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$
4	**Semi-circle**  **Fig. (d)**	$\frac{\pi r^2}{2}$	0 (Symmetrical at y-axis)	$\frac{4r}{3\pi}$
5	**Circle**  **Fig. (e)**	πr^2	0 (Symmetrical at y-axis)	0 (Symmetrical at x-axis)

Sr. No.	Shape	Length (l)	$\bar{x}$	$\bar{y}$
5	Arc of a circle  Fig. (e)	$2r\alpha^c$ ($\alpha^c = \alpha$ in radians)	$\dfrac{r \sin \alpha^\circ}{\alpha^c}$ ($\alpha^\circ = \alpha$ in degrees)	0 (Symmetric x-axis)

5.7 Centroids of Common Geometrical Shapes of Areas :

Sr. No.	Shape	Area (A)	$\bar{x}$	$\bar{y}$
1	Rectangle  Fig. (a)	lb	$\dfrac{l}{2}$	$\dfrac{b}{2}$
2	Square  Fig. (b)	a^2	$\dfrac{a}{2}$	$\dfrac{a}{2}$

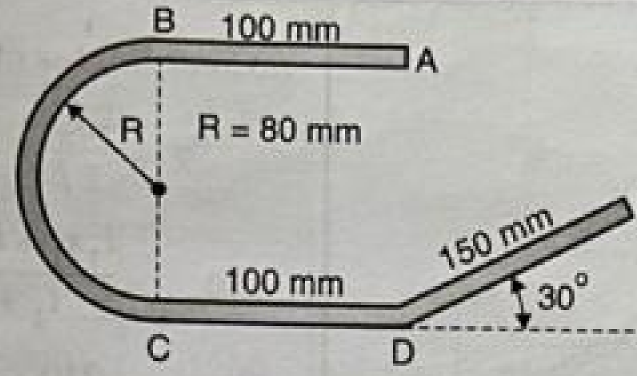


Fig. P. 5.8.1(a)

Soln. :

Wire is 1-D body and it is uniform, hence C.G. coincides with centroid of line.

Step 1 : Select reference axes w.r.t. point 'C'.

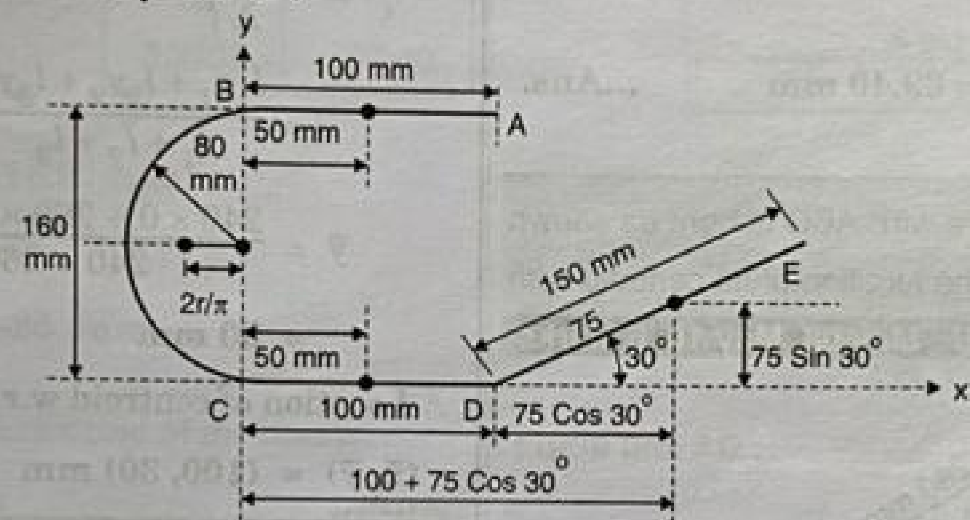


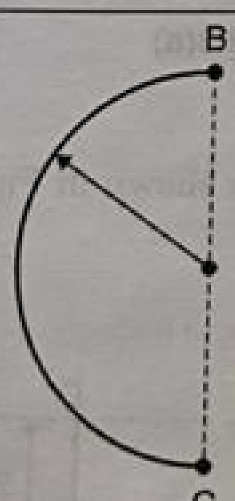
Fig. P. 5.8.1(b)

Step 2 : Divide the bent into 4 parts :

(1) Line AB (2) Semicircular arc BC (3) Line CD (4) Line DE

Step 3 : Obtain and tabulate the results of l, x, y, lx and ly.

Table P. 5.8.1

Line	l (mm)	x (mm)	y (mm)	l . x (mm^2)	l . y (mm^2)
	100	50	160	5000	16000
	πr $= \pi \times 80$ $= 251.33$	$-\left(\frac{2r}{\pi}\right) = -\left(\frac{2 \times 80}{\pi}\right) = -50.93$	80	−12800.13	20106.40
	100	50	0	5000	0
	150	$100 + 75 \cos 30° = 164.95$	$75 \sin 30° = 37.50$	24742.5	5625
	601.33			**21942.37**	**41731.4**

Step 4 : Take Summation of l, lx and ly.

$$\Sigma l = 601.33 \text{ mm}$$

$$\Sigma lx = 21942.37 \text{ mm}^2$$

$$\Sigma ly = 41731.4 \text{ mm}^2$$

Step 5 : Co-ordinates of centre of gravity w.r.t. point 'C' are;

$$\bar{x} = \frac{\Sigma l \cdot x}{\Sigma l} = \frac{21942.37}{601.33} = \mathbf{36.49 \text{ mm}} \quad \text{...Ans.}$$

$$\bar{y} = \frac{\Sigma l \cdot y}{\Sigma l} = \frac{41731.4}{601.33} = \mathbf{69.40 \text{ mm}} \quad \text{...Ans.}$$

Ex. 5.8.2 : A thin homogeneous wire ABC is bent as shown in Fig. P. 5.8.2(a). Determine the location of its centroid with respect to A. **SPPU : May 08, May 16, 6 Marks**

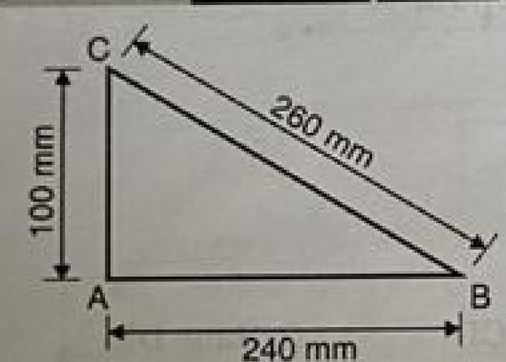


Fig. P. 5.8.2(a)

Soln. :

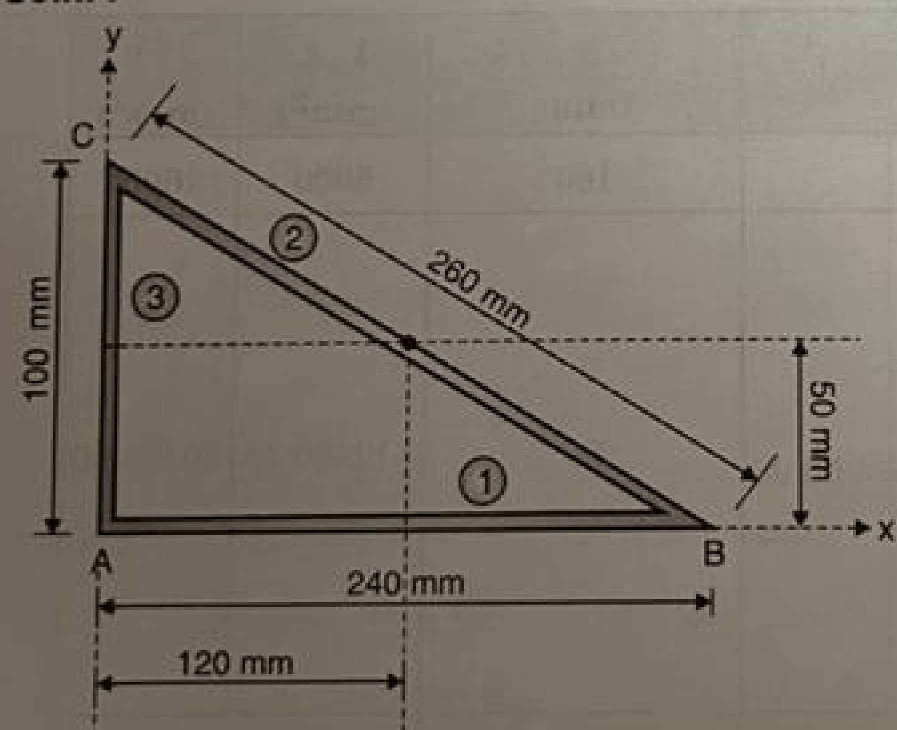


Fig. P. 5.8.2(b)

Dividing the bent into three parts, AB, BC and CA as (1), (2) and (3) respectively.

$l_1 = 240$ mm, $\quad x_1 = 120$ mm, $\quad y_1 = 0$

$l_2 = 260$ mm, $\quad x_2 = 120$ mm, $\quad y_2 = 50$ mm

$l_3 = 100$ mm, $\quad x_3 = 0$, $\quad y_3 = 50$ mm

$\therefore$ Co-ordinates of centroid are given by,

$$\bar{x} = \frac{\Sigma l_x}{\Sigma l} = \frac{l_1 x_1 + l_2 x_2 + l_3 x_3}{l_1 + l_2 + l_3} = \frac{240 \times 120 + 260 \times 120 + 100 \times 0}{240 + 260 + 100} = \mathbf{100 \text{ mm}}$$

$$\bar{y} = \frac{\Sigma l_y}{\Sigma l} = \frac{l_1 y_1 + l_2 y_2 + l_3 y_3}{l_1 + l_2 + l_3}$$

$$\bar{y} = \frac{240 \times 0 + 260 \times 50 + 100 \times 50}{240 + 260 + 100} = \mathbf{30 \text{ mm}}$$

$\therefore$ Location of centroid w.r.t. point A is

$$(\bar{x}, \bar{y}) = \mathbf{(100, 30) \text{ mm}}$$

Ex. 5.8.3 : A thin rod is bend into a shape OABC in Fig. P. 5.8.3(a). Determine the centroid of t with respect to origin O. **SPPU : May**

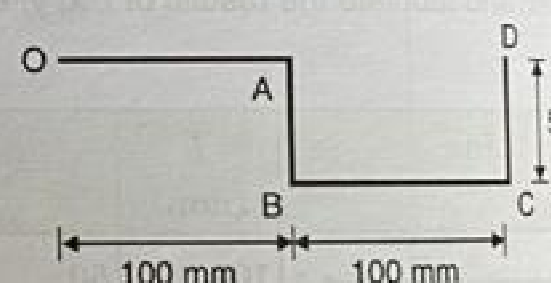


Fig. P. 5.8.3(a)

Soln. :

Selecting x and y axes as shown in F w.r.t. 'O'.

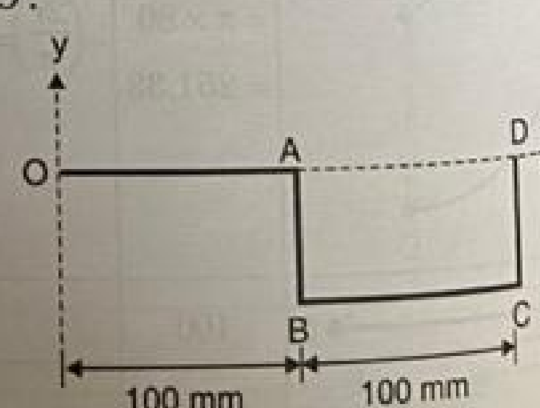


Fig. P. 5.8.3(b)

The length of line segments and the x-axis and y-axis are shown in the follow

6.8 M.I for Standard Shapes (Areas)

1. Rectangular Area :

(A) About Centroidal x-axis :

- Consider rectangle of width 'b' and depth 'd' as shown in Fig. 6.8.1.

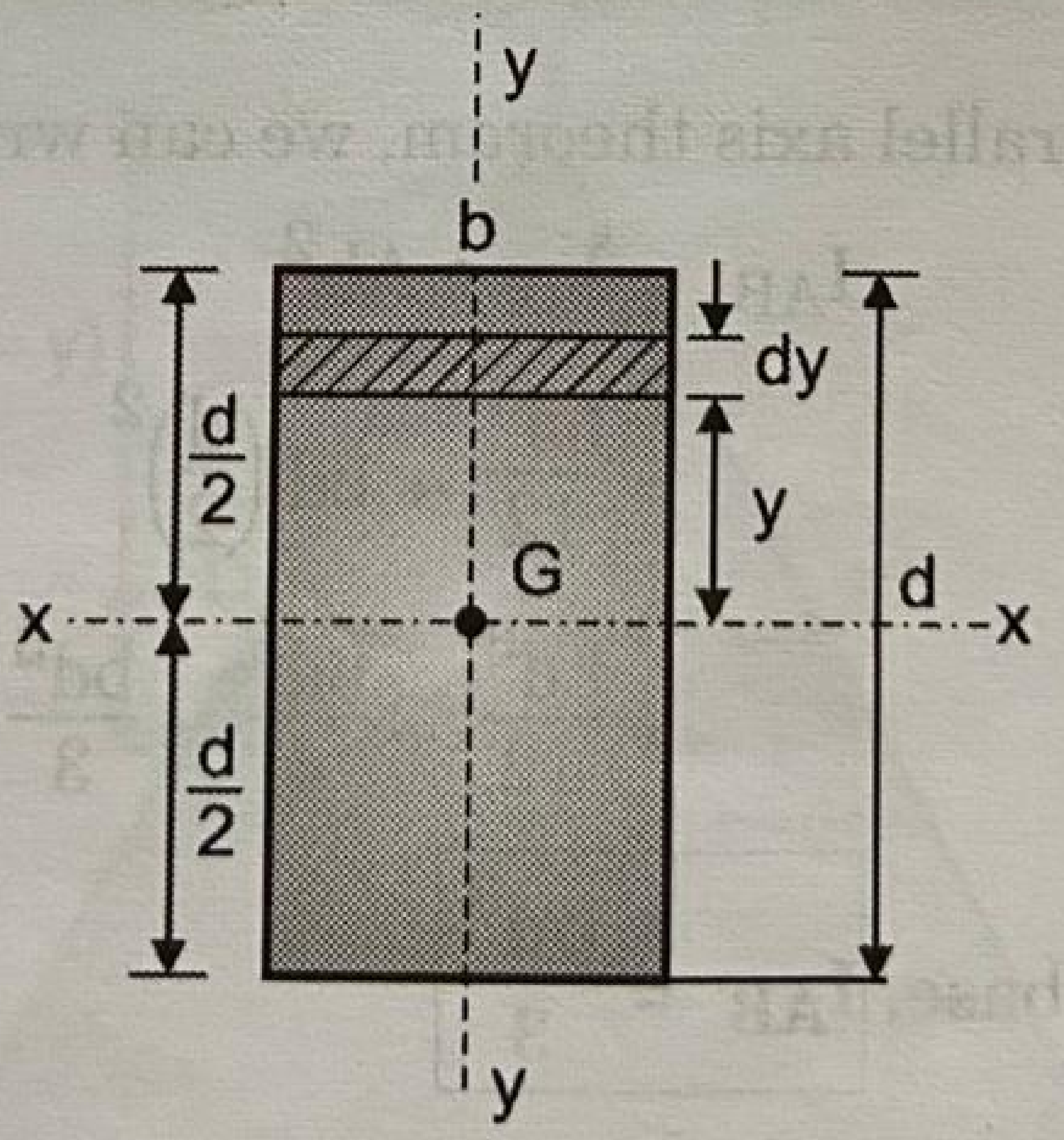


Fig. 6.8.1

- Consider a small strip of width 'b' and thickness dy at a distance 'y' from the centroidal x-axis.

– Area of elemental strip, $dA = b \cdot dy$

Moment of inertia of elemental strip at centroidal x-axis,

$$dI_{xx} = y^2 \cdot dA$$

Total M.I about x-axis,

$$I_{xx} = \int y^2 \cdot dA = b \int_{-d/2}^{+d/2} y^2 \cdot dy$$

$$= b\left[\frac{y^3}{3}\right]_{-d/2}^{+d/2} = \frac{b}{3}\left[\frac{d^3}{8} + \frac{d^3}{8}\right]$$

$$= \frac{b}{24}(2d^3) = \frac{bd^3}{12}$$

$$\therefore \boxed{I_{xx} = \frac{bd^3}{12}}$$

Similarly, $\boxed{I_{yy} = \frac{b^3d}{12}}$

(B) About Base of the Rectangle :

M.I at the base i.e AB can be found by using parallel axis theorem.

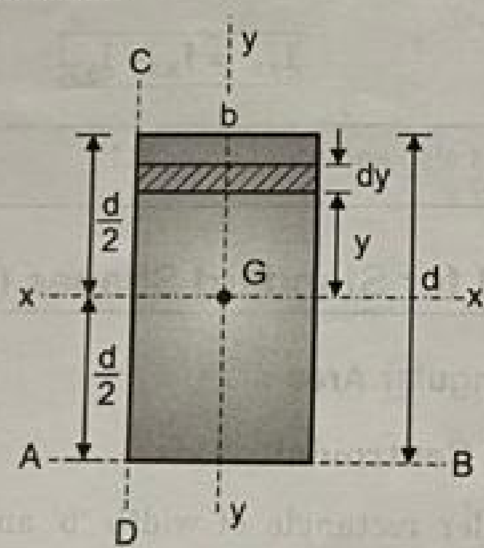


Fig. 6.8.2

From parallel axis theorem, we can write,

$$I_{AB} = I_{xx} + Ah^2$$

$$= \frac{bd^3}{12} + bd\left(\frac{d}{2}\right)^2$$

$$= \frac{bd^3}{12} + \frac{bd^3}{4} = \frac{bd^3}{3}$$

$\therefore$ M.I about base, $\boxed{I_{AB} = \frac{bd^3}{3}}$

Similarly, M.I about vertical edge, CD is

$$\boxed{I_{CD} = \frac{b^3d}{3}}$$

2. Hollow Rectangular area :

$$I_{xx} = \left(\frac{BD^3}{12} - \frac{bd^3}{12}\right)$$

and

$$I_{yy} = \left(\frac{B^3D}{12} - \frac{b^3d}{12}\right)$$

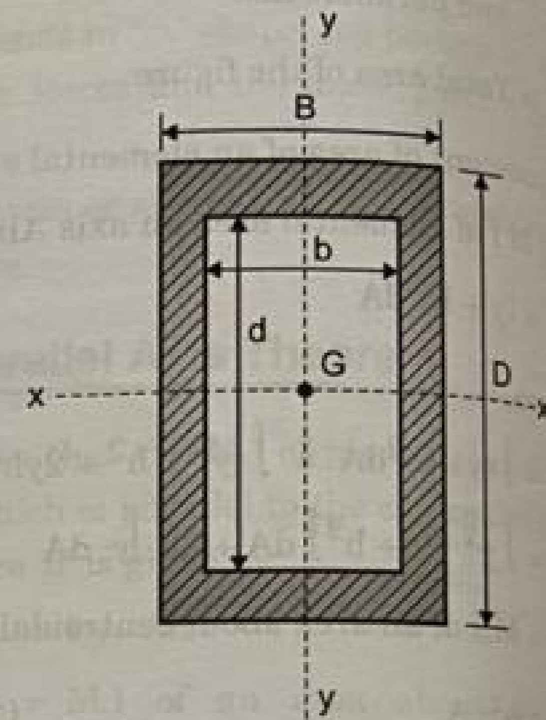


Fig. 6.8.3

3. Square :

Here, $b = d = a$

$$\therefore \boxed{I_{xx} = I_{yy} = \frac{a^4}{12}}$$

4. Circular area :

Consider circular area of radius, R.

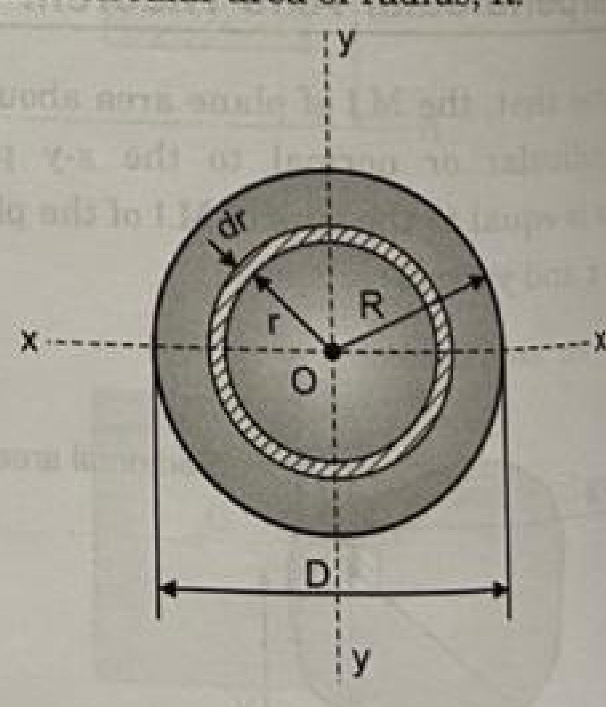


Fig. 6.8.4

Consider an elemental ring of thickness dr distance 'r' from the centre O.i.e. z or polar axis.

Area of elemental ring, $dA = 2\pi r \cdot dr$

M.I of an elemental ring about z-axis is

$$d\,I_{zz} = r^2 \cdot dA$$
$$= r^2 \cdot 2\pi r\,dr$$

M.I of the whole area,

$$I_{zz} = \int_0^R r^2 2\pi r dr = 2\pi \int_0^R r^3 \cdot dr = 2\pi \left[\frac{r^4}{4}\right]_0^R$$

$$= 2\pi \frac{R^4}{4} = \frac{\pi R^4}{2}$$

$$\therefore \quad \boxed{I_{zz} = \frac{\pi R^4}{2}}$$

Using perpendicular axis theorem;

$$I_{zz} = I_{xx} + I_{yy}$$

But $I_{xx} = I_{yy}$ due to symmetry

$$\therefore I_{zz} = 2I_{xx} \text{ or } 2I_{yy}$$

$$\therefore I_{xx} = I_{yy} = \frac{I_{zz}}{2} = \frac{1}{2}\left(\frac{\pi R^4}{2}\right)$$

$$\therefore \boxed{I_{xx} = I_{yy} = \frac{\pi R^4}{4}}$$

$$R = \frac{D}{2} \qquad \text{(D = Diameter)}$$

$$\therefore I_{zz} = \frac{\pi}{2}\left(\frac{D}{2}\right)^4 = \frac{\pi D^4}{32}$$

$$\therefore \quad \boxed{I_{zz} = \frac{\pi D^4}{32}}$$

and $\boxed{I_{xx} = I_{yy} = \frac{\pi D^4}{64}}$

5. Hollow Circular Area :

Due to symmetry,

$$\boxed{I_{xx} = I_{yy} = \frac{\pi}{64}(D^4 - d^4)}$$

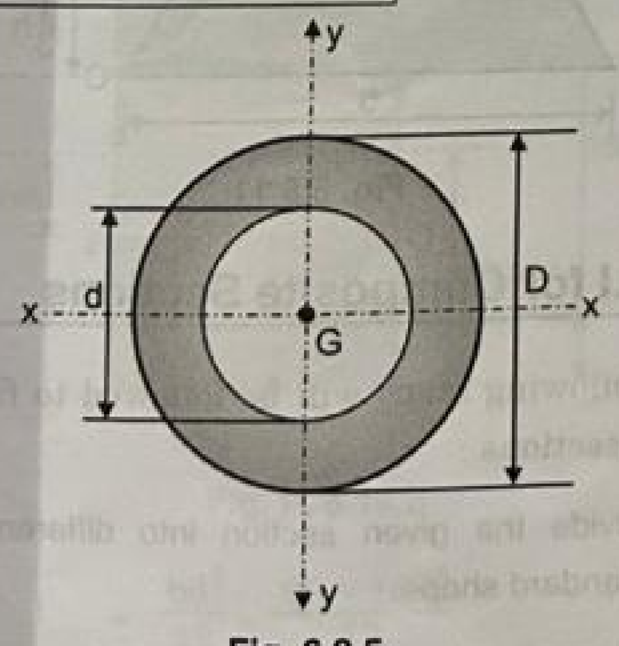


Fig. 6.8.5

6. Semi-circle

$$I_{zz} = \frac{\pi R^4}{4}$$

$$I_{xx} = I_{yy} = I_{base} = \frac{\pi R^4}{8}$$
$$= \frac{\pi D^4}{128}$$

$$I_G = 0.11R^4$$

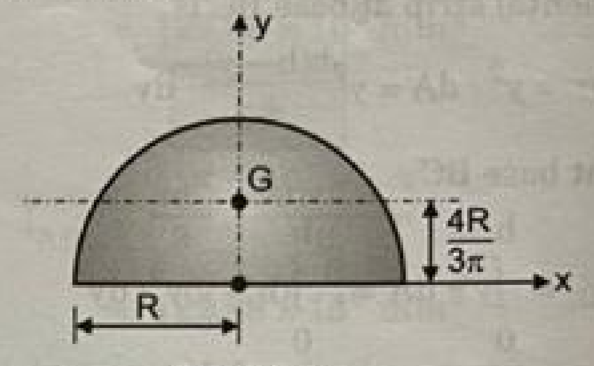


Fig. 6.8.6

7. Quarter circle :

$$I_{xx} = I_{yy} = \frac{\pi R^4}{16} = \frac{\pi D^4}{256}$$

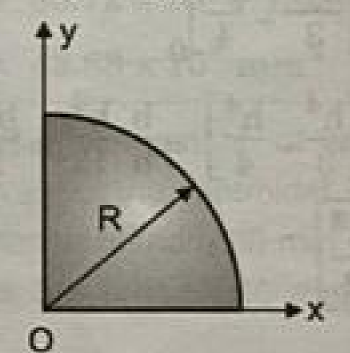


Fig. 6.8.7

8. Triangle

(A) About base 'BC'

Consider a triangular area with base 'b' and height 'h'.

Consider an elemental strip of width x and thickness dy at a distance y from the base BC.

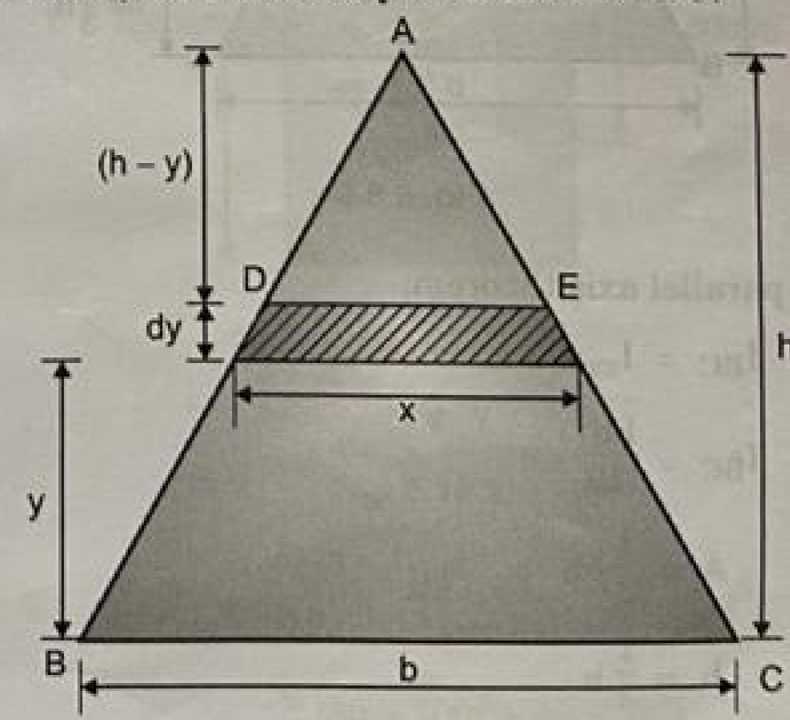


Fig. 6.8.8

From similar Δ^{les} ABC and ADE ;

$$\frac{b}{h} = \frac{x}{h-y}$$

$$\therefore x = \frac{b(h-y)}{h}$$

Area of elemental strip, $dA = x \cdot dy$

$$= \frac{b(h-y)}{h}\, dy$$

M.I of elemental strip at base BC is

$$dI_{BC} = y^2 \cdot dA = y^2 \frac{b(h-y)}{h} \cdot dy$$

Total M.I at base BC,

$$I_{BC} = \int_0^h y^2 \cdot dA = \frac{b}{h}\int_0^h (h-y)y^2 \cdot dy$$

$$= \frac{b}{h}\int_0^h (hy^2 - y^3)dy$$

$$= \frac{b}{h}\left[\frac{hy^3}{3} - \frac{y^4}{4}\right]_0^h$$

$$= \frac{b}{h}\left[\frac{h^4}{3} - \frac{h^4}{4}\right] = \frac{b}{h} \cdot \frac{h^4}{12} = \frac{bh^3}{12}$$

$$\therefore \quad \boxed{I_{BC} = \frac{bh^3}{12}}$$

(B) About Centroidal x-axis :

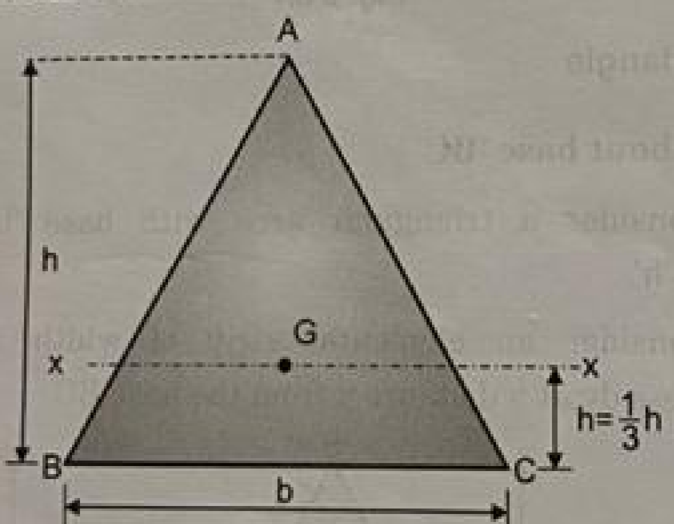


Fig. 6.8.9

Using parallel axis theorem;

$$I_{BC} = I_{xx} + Ah^2$$

$$I_{BC} = \frac{bh^3}{12}$$

$$A = \frac{1}{2} bh$$

$$h = \frac{1}{3} h$$

$$\frac{bh^3}{12} = I_{xx} + \frac{bh}{2} \cdot \left(\frac{h}{3}\right)^2$$

$$I_{xx} = \frac{bh^3}{12} - \frac{bh^3}{18} = \frac{bh^3}{36}$$

$$\therefore \boxed{I_{xx} = \frac{bh^3}{36}}$$

(C) About Vertex 'A'

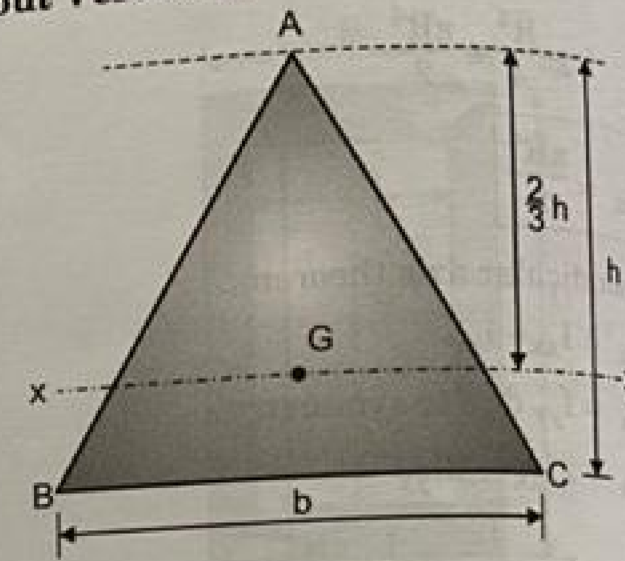


Fig. 6.8.10

Again using parallel axis theorem ;

$$I_A = I_{xx} + Ah^2 = \frac{bh^3}{36} + \frac{bh}{2}\left(\frac{2h}{3}\right)^2$$

$$= \frac{bh^3}{36} + \frac{4bh^3}{18} = \frac{bh^3}{36} + \frac{2bh^3}{9} = \frac{bh^3}{4}$$

$$\therefore \boxed{I_A = \frac{bh^3}{4}}$$

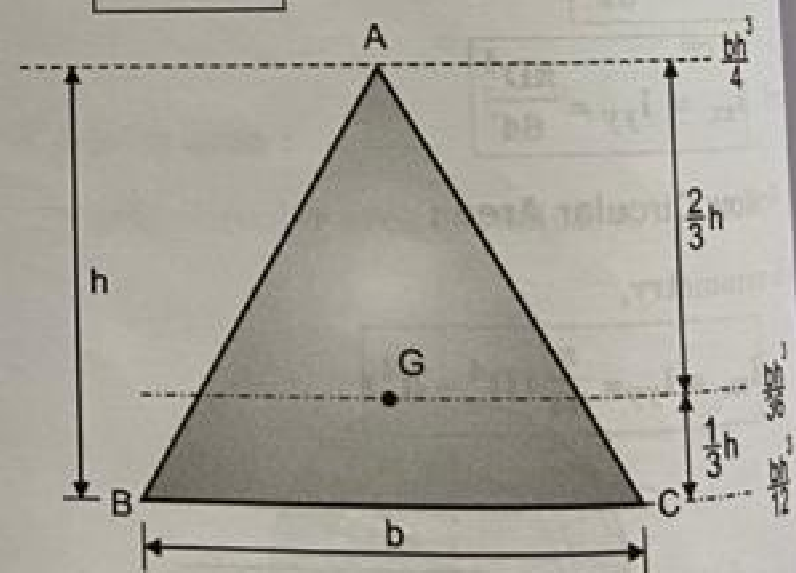


Fig. 6.8.11

6.9 M.I for Composite Sections

The following steps will be followed to find M.I composite sections :

Step 1 : Divide the given section into different parts standard shape.

Step 2 : Determine the centre of gravity of the section.

Step 3 : Find M.I of each part using standard formulae.

Step 4 : Using parallel axis theorem, find the M.I of each part about the centroidal axes of the composite section.

Step 5 : Addition of M.I of each part will give the M.I of whole section.

Step 6 : If hollow section is given, M.I of inner portion is to be subtracted from the M.I of external portion.

6.10 Solved Examples

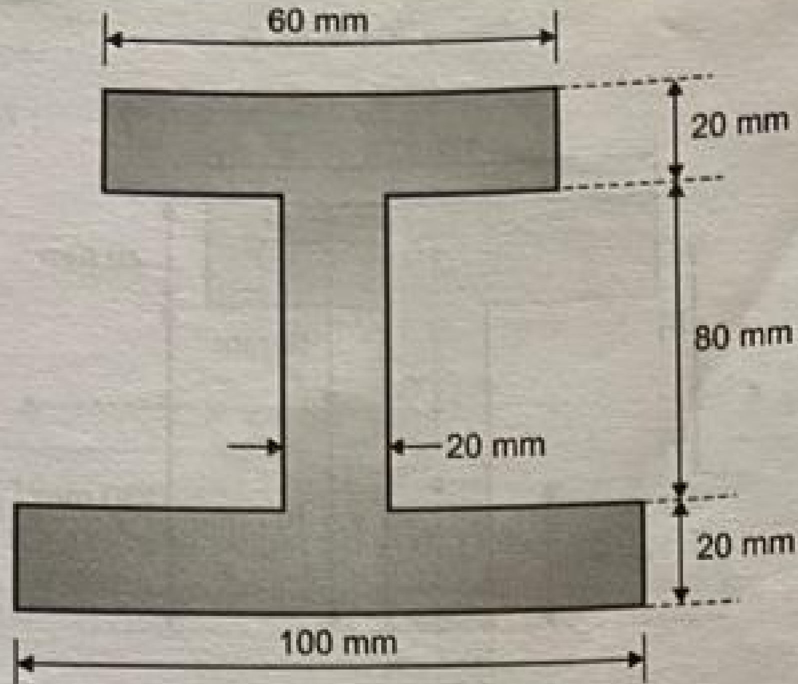


Fig. 6.10.7(a)

Soln. :

Step 1 : Location of centroid of the section :

Section is symmetrical about vertical axis i.e. y-axis.

$\therefore \; \bar{x} = 0$

To find $\bar{y}$, divide the section into 3 rectangles.

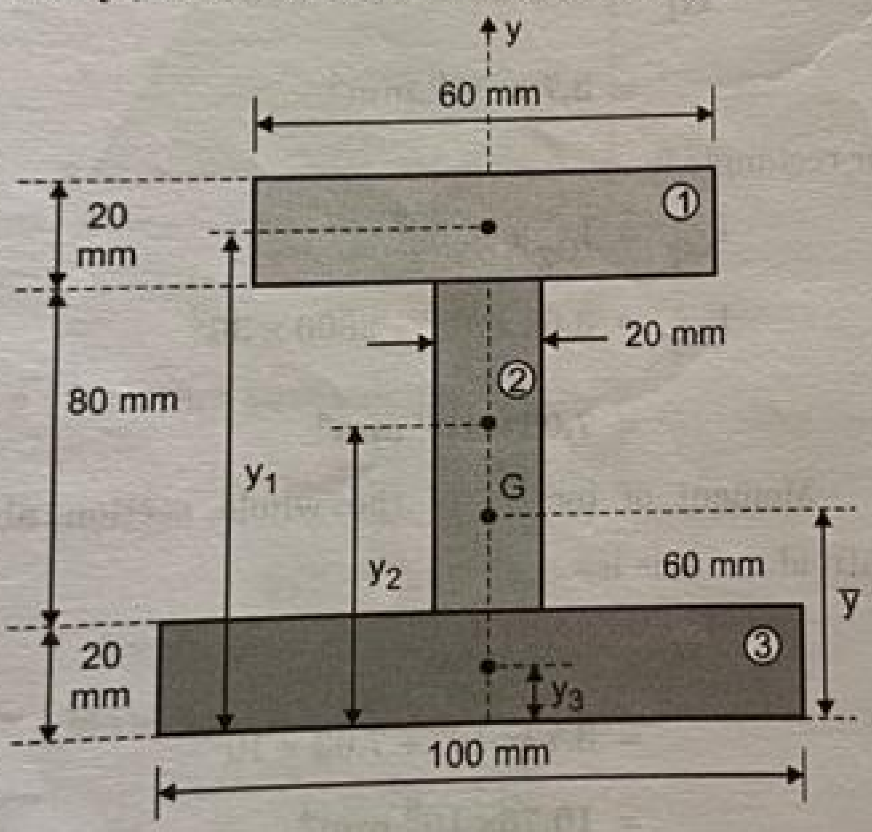


Fig. 6.10.7(b)

$$A_1 = 60 \times 20 = 1200 \text{ mm}^2$$

$$y_1 = 120 - 10 = 110 \text{ mm}$$

$$A_2 = 80 \times 20 = 1600 \text{ mm}^2$$

$$y_2 = 20 + 40 = 60 \text{ mm}$$

$$A_3 = 100 \times 20 = 2000 \text{ mm}^2$$

$$y_3 = 10 \text{ mm}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2 + A_3 y_3}{A_1 + A_2 + A_3}$$

$$\therefore \bar{y} = \frac{1200 \times 110 + 1600 \times 60 + 2000 \times 10}{1200 + 1600 + 2000}$$

$$= \frac{248000}{4800} = \mathbf{51.67 \text{ mm}}$$

Step 2 : M·I about horizontal axis passing through C.G.

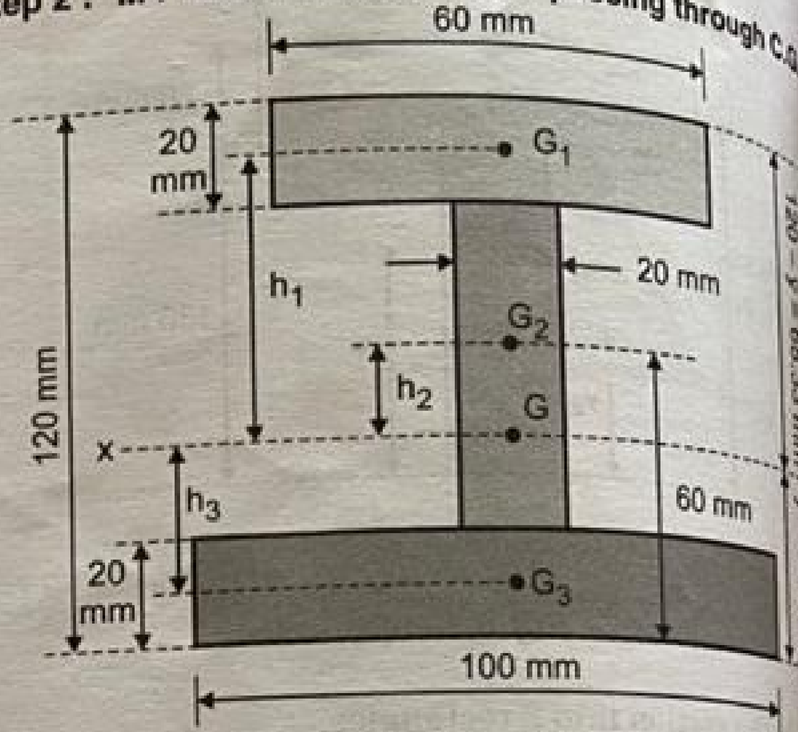


Fig. 6.10.7(c)

$$h_1 = 68.33 - 10 = 58.33 \text{ mm}$$

$$h_2 = 60 - 51.67 = 8.33 \text{ mm}$$

$$h_3 = 51.67 - 10 = 41.67 \text{ mm}$$

Using parallel axis theorem;

$$I_{G_1} = \frac{60 \times 20^3}{12} = 40{,}000 \text{ mm}^4$$

$$I_{xx1} = I_{G_1} + A_1 h_1^2$$

$$= 40{,}000 + 1200 \times 58.33^2$$

$$= 4.123 \times 10^6 \text{ mm}^4.$$

$$I_{G_2} = \frac{20 \times 80^3}{12} = 853333.33 \text{ mm}^4$$

$$I_{xx_2} = I_{G_2} + A_2 h_2^2$$

$$= 853333.33 + 1600 \times 8.33^2$$

$$= 0.964 \times 10^6 \text{mm}^4$$

$$I_{G_3} = \frac{100 \times 20^3}{12} = 66666.67 \text{ mm}^4$$

$$I_{xx_3} = I_{G_3} + A_3 h_3^2 = 66666.67 + 2000 \times 41.67^2$$

$$= 3.54 \times 10^6 \text{ mm}^4$$

M.I of the whole section,

$$I_{xx} = I_{xx1} + I_{xx2} + I_{xx3}$$

$$\therefore I_{xx} = 4.123 \times 10^6 + 0.964 \times 10^6 + 3.54 \times 10^6$$

$$= \mathbf{8.627 \times 10^6 \text{ mm}^4}$$

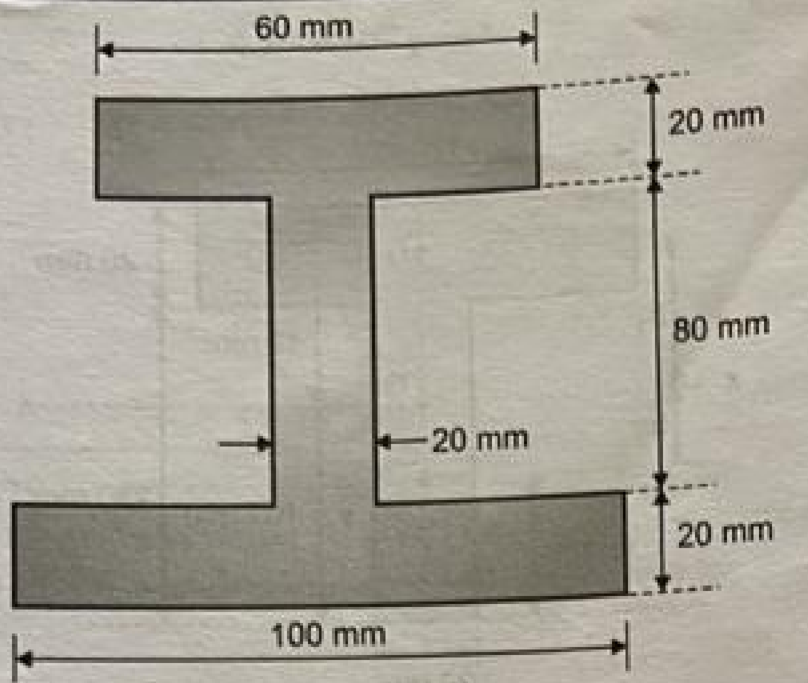


Fig. 6.10.7(a)

Soln. :

Step 1 : Location of centroid of the section :

Section is symmetrical about vertical axis i.e. y-axis.

$\therefore \ \bar{x} = 0$

To find $\bar{y}$, divide the section into 3 rectangles.

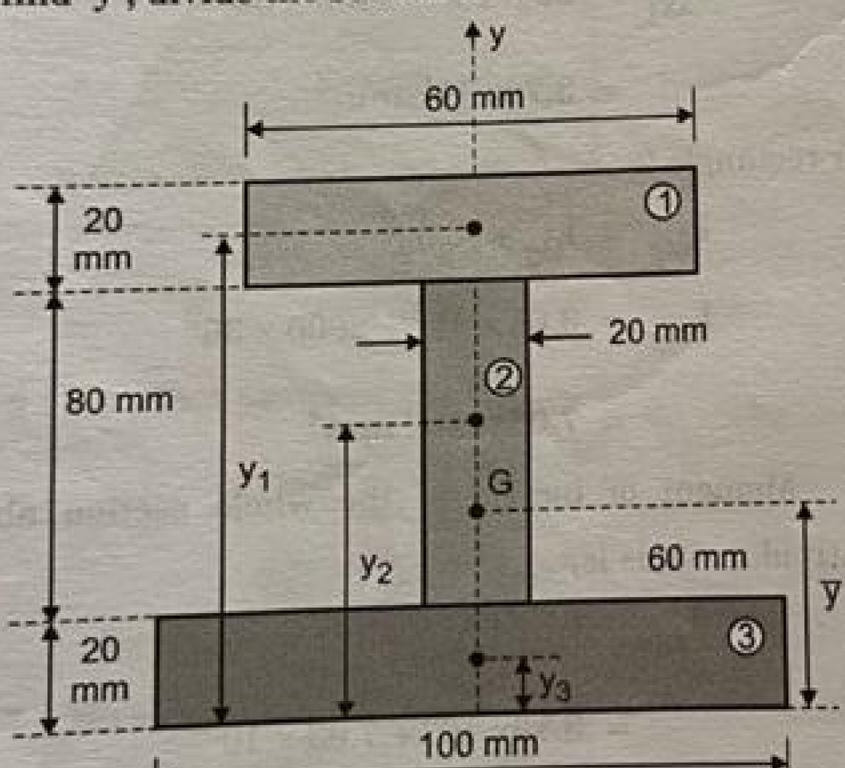


Fig. 6.10.7(b)

$$A_1 = 60 \times 20 = 1200 \text{ mm}^2$$

$$y_1 = 120 - 10 = 110 \text{ mm}$$

$$A_2 = 80 \times 20 = 1600 \text{ mm}^2$$

$$y_2 = 20 + 40 = 60 \text{ mm}$$

$$A_3 = 100 \times 20 = 2000 \text{ mm}^2$$

$$y_3 = 10 \text{ mm}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2 + A_3 y_3}{A_1 + A_2 + A_3}$$

$$\therefore \bar{y} = \frac{1200 \times 110 + 1600 \times 60 + 2000 \times 10}{1200 + 1600 + 2000}$$

$$= \frac{248000}{4800} = \mathbf{51.67 \ mm}$$

Step 2 : M·I about horizontal axis passing through C.G.

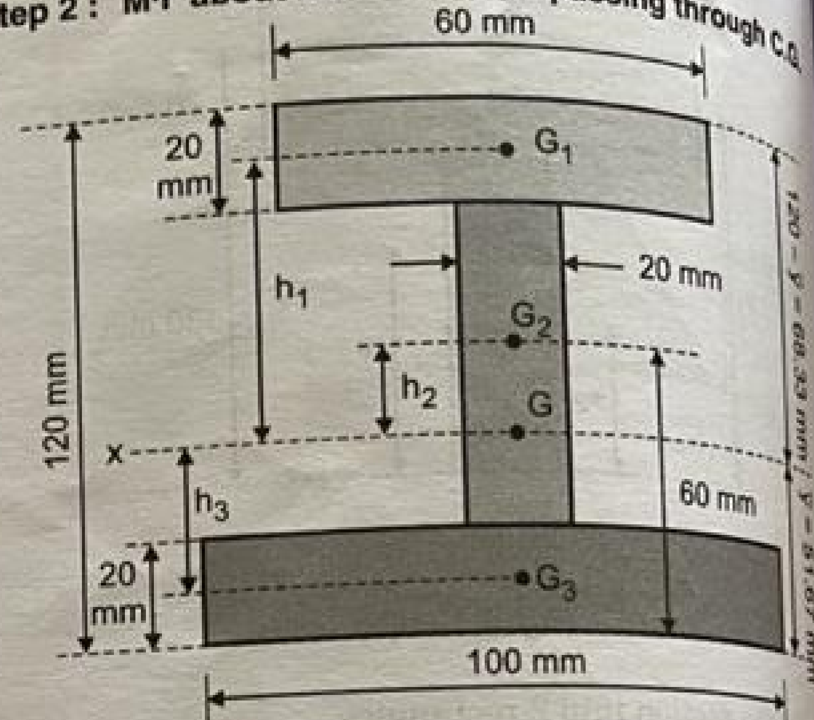


Fig. 6.10.7(c)

$$h_1 = 68.33 - 10 = 58.33 \text{ mm}$$

$$h_2 = 60 - 51.67 = 8.33 \text{ mm}$$

$$h_3 = 51.67 - 10 = 41.67 \text{ mm}$$

Using parallel axis theorem;

$$I_{G_1} = \frac{60 \times 20^3}{12} = 40{,}000 \text{ mm}^4$$

$$I_{xx1} = I_{G_1} + A_1 h_1^2$$

$$= 40{,}000 + 1200 \times 58.33^2$$

$$= 4.123 \times 10^6 \text{ mm}^4.$$

$$I_{G_2} = \frac{20 \times 80^3}{12} = 853333.33 \text{ mm}^4$$

$$I_{xx_2} = I_{G_2} + A_2 h_2^2$$

$$= 853333.33 + 1600 \times 8.33^2$$

$$= 0.964 \times 10^6 \text{mm}^4$$

$$I_{G_3} = \frac{100 \times 20^3}{12} = 66666.67 \text{ mm}^4$$

$$I_{xx_3} = I_{G_3} + A_3 h_3^2 = 66666.67 + 2000 \times 41.67^2$$

$$= 3.54 \times 10^6 \text{ mm}^4$$

M.I of the whole section,

$$I_{xx} = I_{xx_1} + I_{xx_2} + I_{xx_3}$$

$$\therefore I_{xx} = 4.123 \times 10^6 + 0.964 \times 10^6 + 3.54 \times 10^6$$

$$= \mathbf{8.627 \times 10^6 \ mm^4}$$

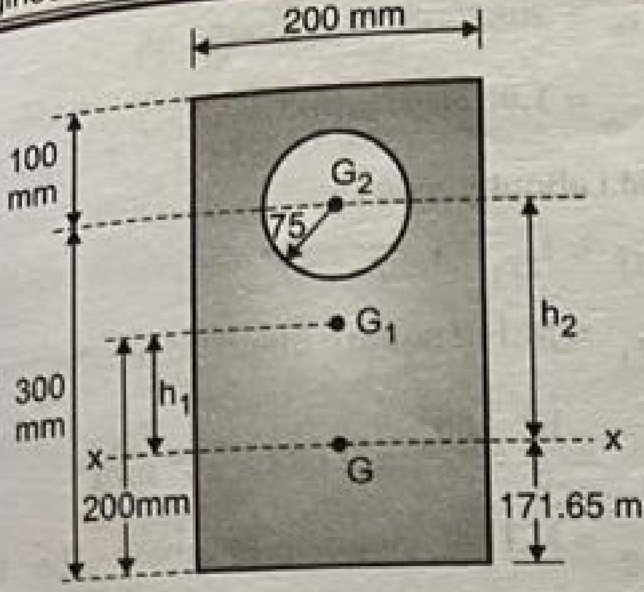


Fig. P. 6.10.9(c)

Using parallel axis theorem ;

$$I_{xx_1} = I_{G_1} + A_1 h_1^2$$

$$= \left(\frac{200 \times 400^3}{12}\right) + 80{,}000 \times 28.35^2$$

$$= \mathbf{1130.96 \times 10^6\ mm^4}$$

$$I_{xx_2} = I_{G_2} + A_2 h_2^2$$

$$= \frac{\pi(150)^4}{64} + 17671.46 \times 128.35^2$$

$$= \mathbf{315.96 \times 10^6\ mm^4}$$

$\therefore$ M.I of the hollow section about centroidal x-axis is,

i.e. $I_{xx} = 1130.96 \times 10^6 - 315.96 \times 10^6$

$= \mathbf{815 \times 10^6\ mm^4}$ ...**Ans.**

Ex. 6.10.10 : A rectangular hole is made in a triangular section as shown in Fig. P. 6.10.10(a). Determine the moment of inertia of the section about x-x axis passing through the centre of gravity and the base BC. Section is symmetrical about y-axis.

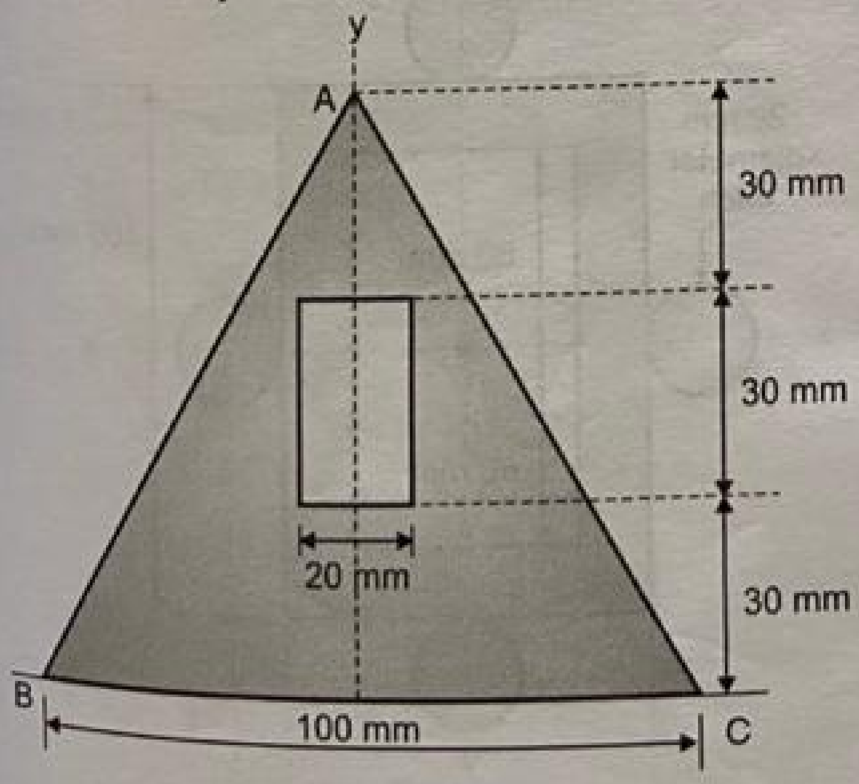


Fig. P. 6.10.10(a)

Soln. :

Step 1 : Location of centre of gravity :

Section can be divided in to two parts.

1. Δ ABC
2. Rectangle (to be removed)

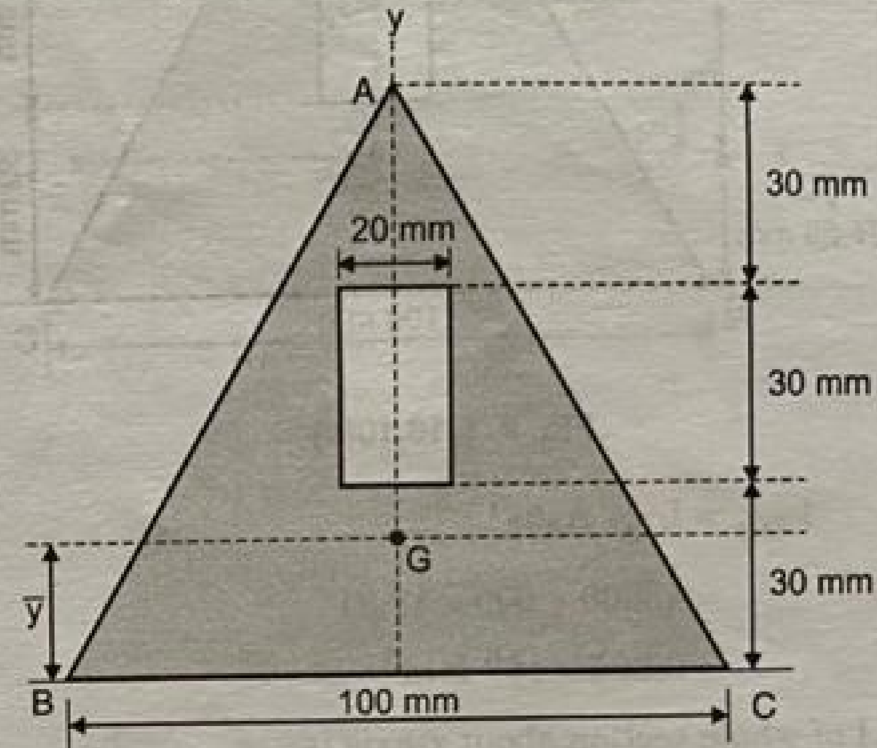


Fig. P. 6.10.10(b)

Section is symmetrical about y-axis.

$$\therefore \bar{x} = 0$$

From base of the triangle,

$$\therefore \bar{y} = \frac{A_1 y_1 - A_2 y_2}{A_1 - A_2}$$

$$A_1 = \frac{1}{2} \times 100 \times 90 = 4500\ mm^2$$

$$y_1 = \frac{1}{3} \times 90 = 30\ mm$$

$$A_2 = 20 \times 30 = 600\ mm^2$$

$$y_2 = 30 + 15 = 45\ mm$$

$$\bar{y} = \frac{4500 \times 30 - 600 \times 45}{4500 - 600} = \mathbf{27.69\ mm}$$

Step 2 : M.I about centroidal x-axis :

$$h_1 = 30 - 27.69 = 2.31\ mm$$

$$h_2 = 45 - 27.69 = 17.31\ mm$$

$$I_{G_1} = \frac{bh^3}{36} = \frac{100 \times 90^3}{36} = 2.025 \times 10^6 mm^4$$

$$I_{xx_1} = I_{G_1} + A_1 h_1^2$$

$$= 2.025 \times 10^6 + 4500 \times 2.31^2$$

$$= \mathbf{2.049 \times 10^6\ mm^4}$$

$$I_{G_1} = \frac{bd^3}{12} = \frac{20 \times 30^3}{12} = 45000\ mm^4$$

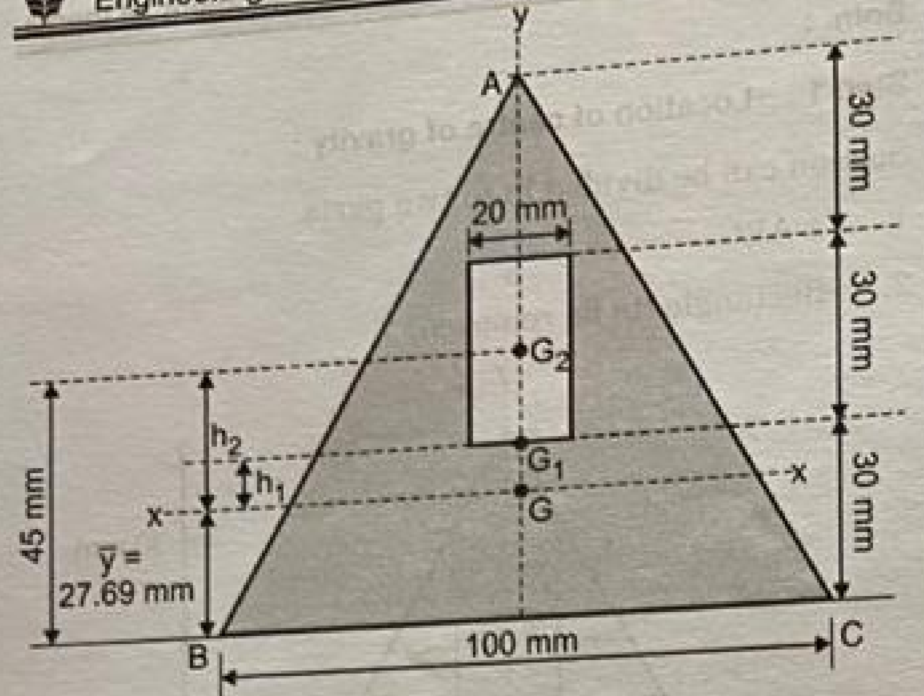


Fig. P. 6.10.10(c)

$$I_{xx2} = I_{G_2} + A_2 h_2^2$$
$$= 45000 + 600 \times 17.31^2$$
$$= \mathbf{0.225 \times 10^6\ mm^4}$$

∴ M.I of whole section about x-axis is

$$I_{xx} = I_{xx_1} - I_{xx_2}$$
$$= 2.049 \times 10^6 - 0.225 \times 10^6$$
$$= \mathbf{1.824 \times 10^6\ mm^4} \quad \text{... Ans.}$$

Ex. 6.10.11 : Determine the M.I of the shaded area shown in Fig. P. 6.10.11(a)about x and y axes.

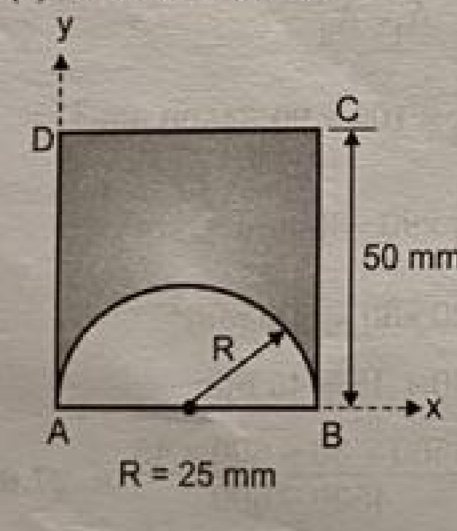


Fig. P. 6.10.11(a)

Soln. :

Step 1 : M.I about x-axis :

$$I_{xx} = I_{xx_1} - I_{xx_2}$$

I_{xx_1} = M.I of square ABCD about base

$$= \frac{b^4}{3} = \frac{50^4}{3} = 2083333.33\ mm^4$$

I_{xx_2} = M.I of semi-circle about base AB

$$= \frac{\pi D^4}{128} = \frac{\pi (50)^4}{128} = 153398.08\ mm^4$$

$$\therefore I_{xx} = 2083333.33 - 153398.08$$
$$= \mathbf{1.93 \times 10^6\ mm^4}$$

Step 2 : M.I about y-axis :

$$I_{yy} = I_{yy_1} - I_{yy_2}$$

I_{yy_1} = M.I of square about edge

$$= \frac{b^4}{3} = \frac{50^4}{3} = 2.083 \times 10^6\ mm^4$$

I_{yy_2} = M.I of Semicircle about the line parallel to its centroidal axis.

$$h_2 = 25\ mm$$

$$A_2 = \frac{\pi (25)^2}{2}$$
$$= 981.75\ mm^2$$

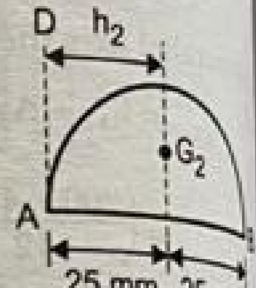


Fig. P. 6.10.11(b)

Using parallel axis theorem ;

$$I_{yy_2} = I_{G_2} + A_2 h_2^2$$
$$= \frac{\pi (50)^4}{128} + 981.75 \times 25^2$$
$$= 153.39 \times 10^3 + 613.592 \times 10^3$$
$$= 766.982 \times 10^3\ mm^4$$
$$\therefore I_{yy} = 2083 \times 10^3 - 766.982 \times 10^3$$
$$= \mathbf{1316.018 \times 10^3 mm^4} \quad \text{...Ans.}$$

Ex. 6.10.12 : Find the M.I of the section shown Fig. P. 6.10.12(a) about centroidal x and y axes.