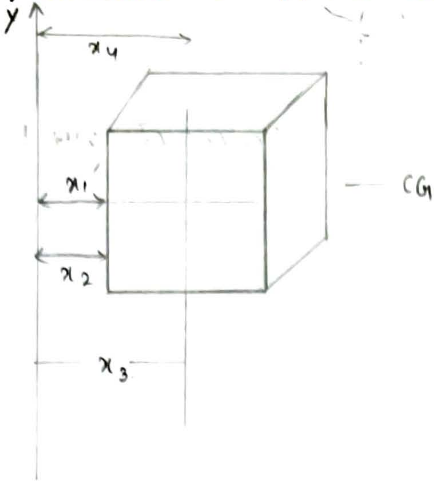
* Centroid :

Centroid of an area lies on the axis of symmetry if it exists.

⇒ Centroid is applied to plane areas or lines (geometry).



$$\gamma V \bar{x} = V_1 \gamma x_1 + V_2 \gamma x_2 + V_3 \gamma x_3 + V_4 \gamma x_4$$

$$V \bar{x} = V_1 x_1 + V_2 x_2 + V_3 x_3 + V_4 x_4$$

$$\Sigma V_i \bar{x} = \Sigma V_i x_i$$

$$V = At$$

$$\therefore \Sigma A_i \bar{x} = \Sigma A_i x_i$$

$$\bar{x} = \frac{\Sigma V_i x_i}{\Sigma V_i} = \frac{\Sigma A_i x_i}{\Sigma A_i} = \frac{\Sigma L_i x_i}{\Sigma L_i}$$

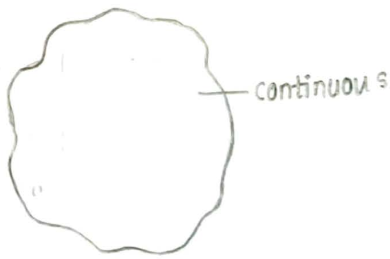
$$C_G = \frac{\text{Summation of all individual forces}}{\text{Summation of volumes/ areas/ lengths}} \times \text{distance}$$

* Areas :

For continuous body,

$$x_c = \frac{\int_A x\,dA}{\int_A dA} = \int_0^1 \int_0^1 x\,dx\,dy$$

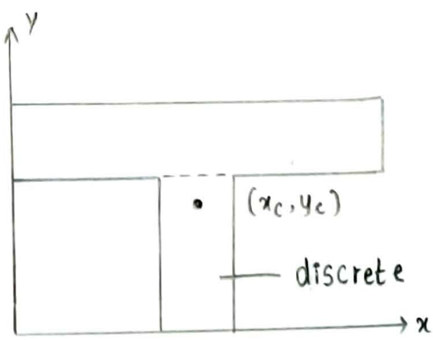
$$y_c = \frac{\int_A y\,dA}{\int_A dA}$$

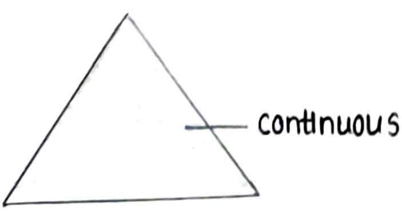


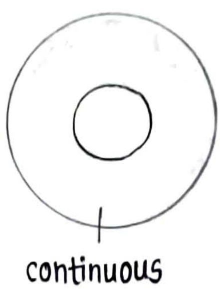
For discrete body,

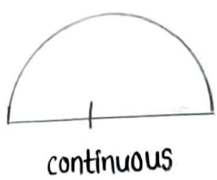
$$x_c = \frac{\Sigma A_i x_i}{\Sigma A_i}$$

$$y_c = \frac{\Sigma A_i y_i}{\Sigma A_i}$$

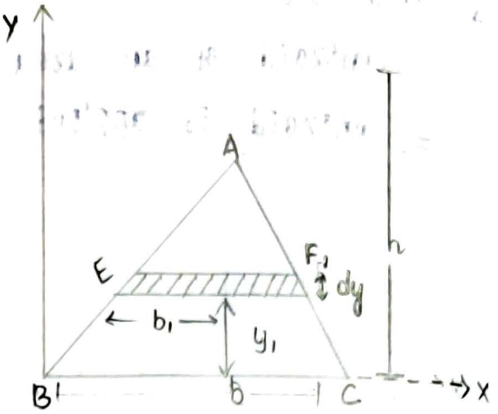








centroid of Δle



$$y_c = \frac{\int_A y\,dA}{\int_A dA}$$

$\Delta ABC \sim \Delta ABF$

$$\frac{b_1}{b} = \frac{h-y}{h}$$

$$b_1 = b\left(1-\frac{y}{h}\right)$$

Area of element $EF = b_1 \times dy = dA$

$$dA = b\left(1-\frac{y}{h}\right)dy$$

$$N = \int y\,b\left(1-\frac{y}{h}\right)dy = b\int_0^h \left(y-\frac{y^2}{h}\right)dy$$

$$= b\left[\frac{y^2}{2} - \frac{y^3}{3h}\right]_0^h$$

$$= b\left[\frac{h^2}{2} - \frac{h^3}{3h}\right] - b(0)$$

$$= b\left[\frac{h^2}{2} - \frac{h^2}{3}\right]$$

$$= \frac{bh^2}{6}$$

$$D = \int_0^h dA$$

$$= b\int_0^h (1 - y/h)\,dy = b\left[y - \frac{y^2}{2h}\right]_0^h$$

$$= b\left[h - \frac{h^2}{2h}\right]$$

$$= \frac{bh}{2},$$

$$y_c = \frac{bh^2/6}{bh/2}$$

$$y_c = h/3.$$

$\therefore$ Centroid $= (x_c, y_c)$

$= (b/2, h/3)$

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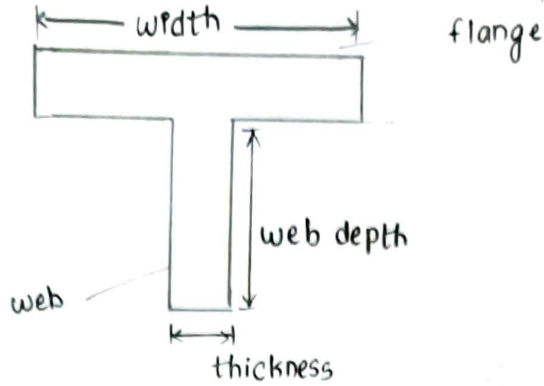
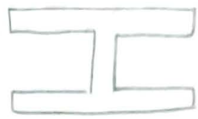
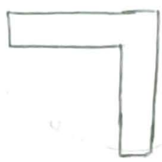


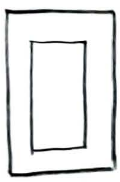
C- section
(steel channel)



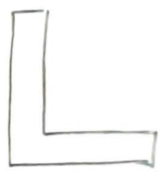
I - section
(steel)

Rectangular solid
(steel)

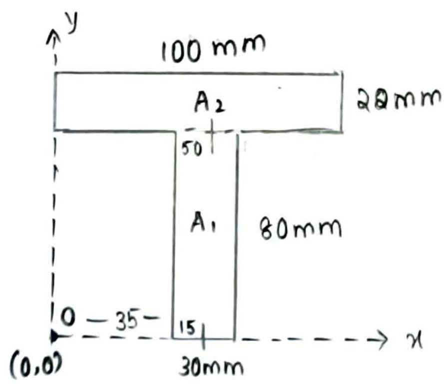




Rectangular hollow.



* Symmetry. : For centroid => area is in same ratio.



$$x_c = \frac{A_1 x_1 + A_2 x_2}{A_1 + A_2}$$

$$= \frac{30 \times 80 \times 50 + 100 \times 20 \times 50}{30 \times 80 + 100 \times 20}$$

$$= \frac{120000 + 100000}{2400 + 2000}$$

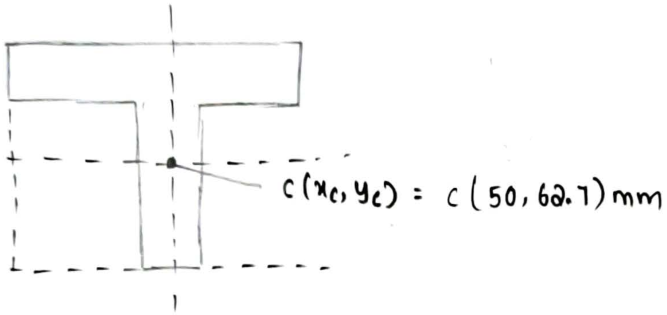
$$= \frac{220000}{4400} = 50 \text{ mm.}$$

$$y_c = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

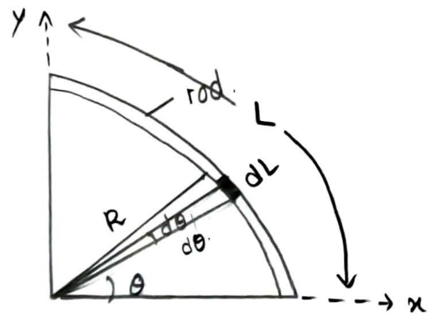
$$= \frac{30 \times 80 \times 40 + 100 \times 20 \times (80+10)}{30 \times 80 + 100 \times 20}$$

$$= \frac{96000 + 180000}{2400 + 2000}$$

$$= 62.7 \text{ mm}$$



* centroid of a line (rod)



$$x_c = \frac{\int_L x\,dL}{\int_L dL}$$

$L = R\theta$

$dl = R\,d\theta$

$x = R\cos\theta$

$$\int x\,dL = \int_0^{\pi/2} R\cos\theta \cdot R\,d\theta$$

$$= R^2 \int_0^{\pi/2} \cos\theta\,d\theta$$

$$= R^2 [\sin\theta]_0^{\pi/2} = R^2(1) = R^2$$

$$\int dL = \int_0^{\pi/2} R\,d\theta$$

$$= R \int_0^{\pi/2} d\theta$$

$$= R\,[\theta]_0^{\pi/2}$$

$$= R\frac{\pi}{2}.$$

$$x_c = \frac{R^2}{R\pi/2}$$

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

$$y_c = \frac{\int y\,dL}{\int dL} \qquad y = R\sin\theta$$

$$\int y\,dL = \int_0^{\pi/2} R\sin\theta \cdot R\,d\theta$$

$$= R^2 \int_0^{\pi/2} \sin\theta\,d\theta$$

$$= -R^2 \left[\cos\theta\right]_0^{\pi/2}$$

$$= -R^2 \left[0 - 1\right] = R^2$$

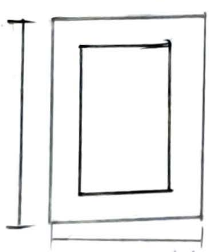
$$\int dL = \int_0^{\pi/2} R\,d\theta$$

$$= \frac{R\pi}{2}.$$

$$y_c = \frac{R^2}{R\pi/2} = \frac{2R}{\pi}$$

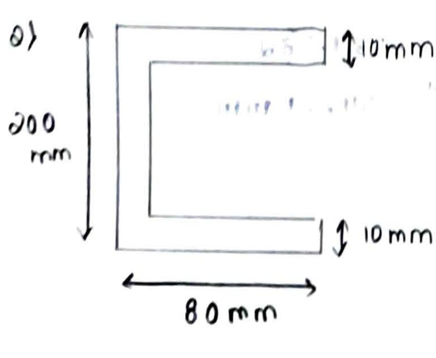
$$\therefore (x_c, y_c) = \left(\frac{2R}{\pi}, \frac{2R}{\pi}\right)$$

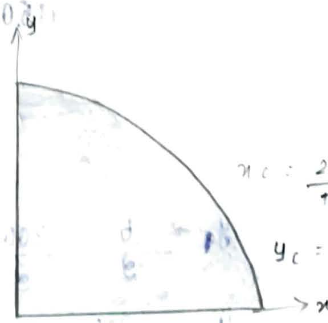
20/10/2019

1) 

thickness = 20 mm

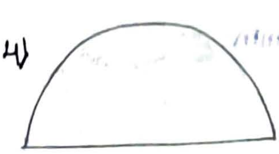
find the centroid. (x_c, y_c)

2) 

3) 

$x_c = \frac{2r}{\pi}$

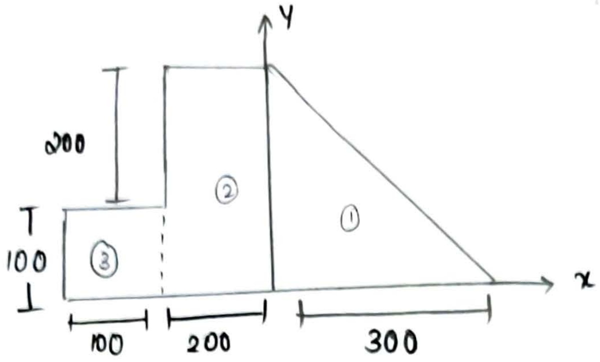
$y_c = \frac{2r}{\pi}$

4) 

$x_c = 0 \quad y_c = \frac{2r}{\pi}$

* Composite area or hybrid area centroid.

1)

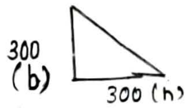


$A_1 = \frac{1}{2} \times 300 \times 300 = 45000\ mm^2$

$A_2 = 200 \times 300 = 60000\ mm^2$

$A_3 = 100 \times 100 = 10000\ mm^2$

$x_1 = \frac{h}{3} = \frac{300}{3} = 100\ mm$



$-x_2 = \frac{b}{2} = \frac{200}{2} = -100\ mm$

$x_3 = 200 + \frac{100}{2} = -250\ mm$

$$x_c = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3}$$

$$= \frac{45000 \times 100 + 60000 \times -100 + 10000 \times -250}{45000 + 60000 + 10000}$$

$$= \frac{4500000 - 6000000 - 2500000}{115000}$$

$$= \frac{4500000 - 8500000}{115000} = \frac{-4000000}{115000}$$

$$= -34.782$$

$$\simeq -34.79\ mm$$

$y_1 = \frac{b}{3} = \frac{300}{3} = 100\ mm$

$y_2 = \frac{300}{2} = 150\ mm$

$y_3 = \frac{100}{2} = 50\ mm$

$$y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$= \frac{45000 \times 100 + 60000 \times 150 + 10000 \times 50}{45000 + 60000 + 10000}$$

$$= \frac{4500000 + 9000000 + 500000}{115000}$$

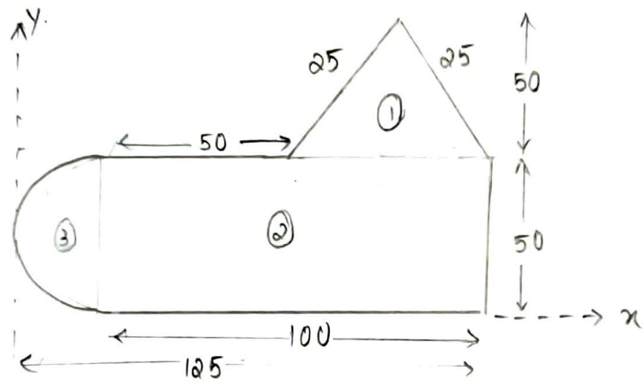
$$= \frac{14000000}{115000}$$

$$= 121.739 \text{ mm}$$

$$\cong 121.7 \text{ mm.}$$

$\therefore \ (x_c, y_c) = (-34.79, 121.7)$ mm

2)



$$A_1 = \frac{1}{2} \times 50 \times 50 = 1250 \text{ mm}^2$$

$$A_2 = 100 \times 50 = 5000 \text{ mm}^2$$

$$A_3 = \frac{1}{2}\pi r^2$$

$$= \frac{1}{2} \times 3.14 \times 25^2 = 981.25 \text{ mm}^2$$

$$x_1 = 25 + \overset{50/2}{50 + 25} = 100 \text{ mm}$$

$$x_2 = \frac{100}{2} + 25 = 75 \text{ mm}$$

$$x_3 = R - \frac{4R}{3\pi} = R\left(1 - \frac{4}{3\pi}\right)$$

$$= 25\left(1 - \frac{4}{3\pi}\right) = 14.39 \text{ mm}$$

$$= 14.4 \text{ mm}$$

$x_c = R \quad y_c = \frac{4R}{3\pi}$

$$x_c = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3}$$

$$= \frac{1250 \times 100 + 5000 \times 75 + 981.25 \times 14.4}{1250 + 5000 + 981.25}$$

$$= \frac{125000 + 375000 + 14130}{7231.25}$$

$$= \frac{514130}{7231.25}$$

$$= 71.09 \text{ mm}$$

$$y_1 = \frac{50}{3} + 50 = 66.66 \text{ mm}$$

$$y_2 = \frac{50}{2} = 25 \text{ mm}$$

$$y_3 = R = 25 \text{ mm}$$

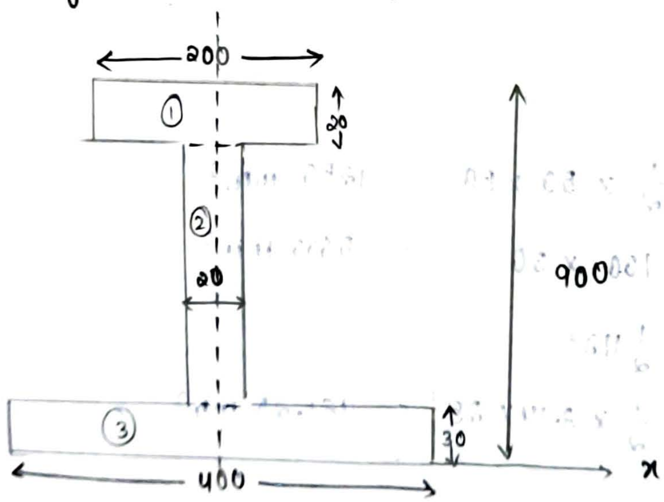
$$y_c = \frac{A_1 y_1 + A_2 y_2 + A_3 y_3}{A_1 + A_2 + A_3}$$

$$= \frac{1250 \times 66.66 + 5000 \times 25 + 981.25 \times 25}{1250 + 5000 + 981.25}$$

$$= \frac{83325 + 125000 + 24531.25}{7231.25} = \frac{232856.25}{7231.25} = 32.201 \text{ mm}$$

$$\therefore (x_c, y_c) = (71.09, 32.201) \text{ mm}$$

3)



$$A_1 = 20 \times 200 = 4000 \text{ m}^2$$

$$A_2 = 20 \times 850 = 17000 \text{ m}^2$$

$$A_3 = 30 \times 400 = 12000 \text{ m}^2$$

$$x_1 = 0$$

$$x_2 = 0$$

$$x_3 = 0$$

$$x_c = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3}$$

$$= 0$$

$$y_1 = \frac{20}{2} + 850 + 30 = 10 + 880 = 890 \text{ mm}$$

$$y_2 = \frac{850}{2} + 30 = 425 + 30 = 455 \text{ mm}$$

$$y_3 = \frac{30}{2} = 15 \text{ mm}$$

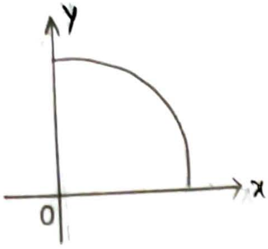
$$y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$= \frac{4000 \times 890 + 17000 \times 455 + 12000 \times 15}{4000 + 17000 + 12000}$$

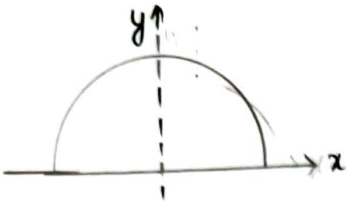
$$= \frac{3560000 + 7735000 + 180000}{33000} = \frac{11475000}{33000} = 347.72 \text{ mm}$$

$$\therefore (x_c, y_c) = (0, 347.72) \text{ mm.}$$

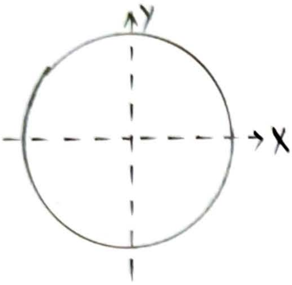
4)



$$x_c = \frac{2r}{\pi}, \quad y_c = \frac{2r}{\pi}$$

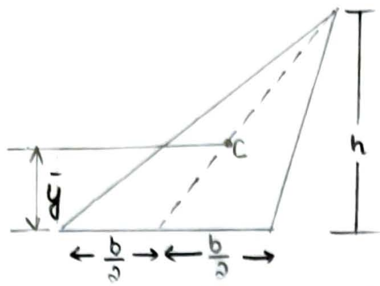
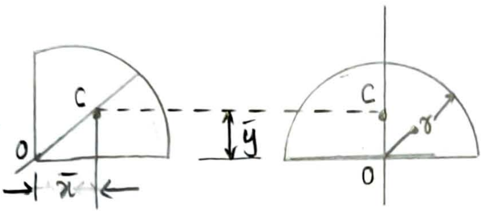
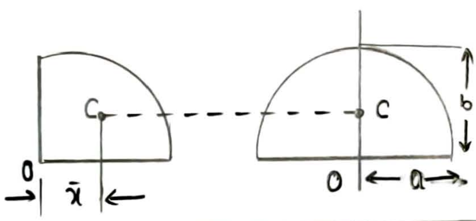
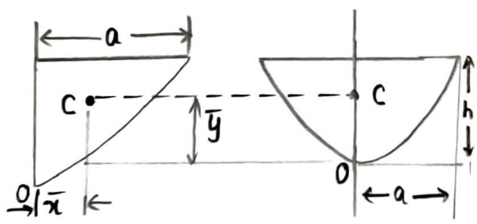
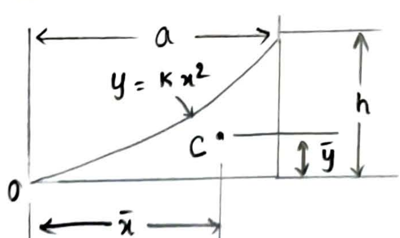
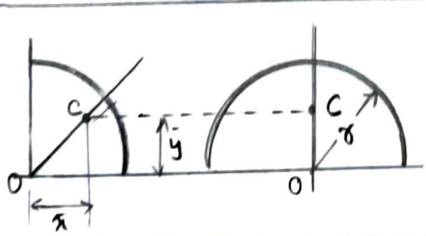
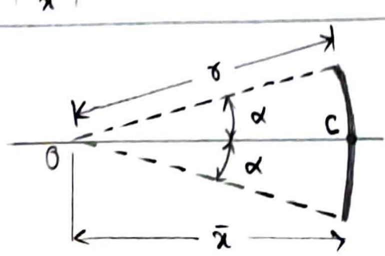


$$x_c = 0, \quad y_c = \frac{2r}{\pi}$$



$$x_c = 0, \quad y_c = 0$$

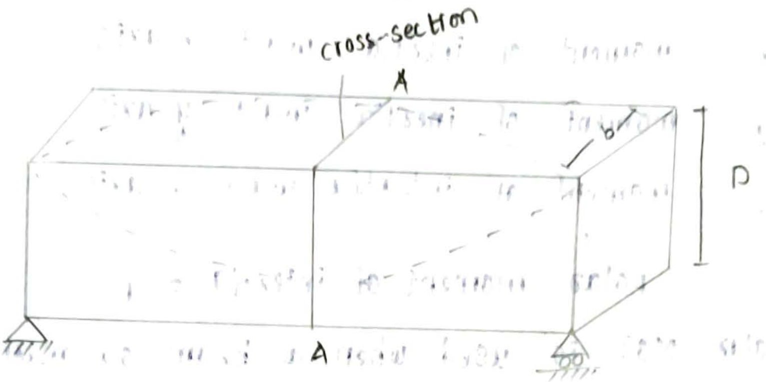
* Centroids of common shapes of areas

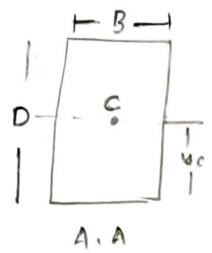
Shape	Diagram	$\bar{x}$	$\bar{y}$	Area
Triangular area			$\frac{h}{3}$	$\frac{bh}{2}$
Quarter-circular area		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{4}$
semicircular area		0	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{2}$
Quarter-elliptical area		$\frac{4a}{3\pi}$	$\frac{4b}{3\pi}$	$\frac{\pi ab}{4}$
Semi elliptical area		0	$\frac{4b}{3\pi}$	$\frac{\pi ab}{2}$
Semi parabolic area		$\frac{3a}{8}$	$\frac{3h}{5}$	$\frac{2ah}{3}$
Parabolic area		0	$\frac{3h}{5}$	$\frac{4ah}{3}$
Parabolic spandrel		$\frac{3a}{4}$	$\frac{3h}{10}$	$\frac{ah}{3}$
Quarter-circular arc		$\frac{2r}{\pi}$	$\frac{2r}{\pi}$	$\frac{\pi r}{2}$
Semicircular arc		0	$\frac{2r}{\pi}$	$\frac{\pi r}{2}$
Arc of circle		$\frac{r \sin\alpha}{\alpha}$	0	$2\alpha r$

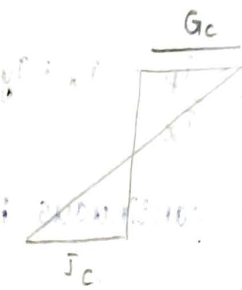
11/10/20

Moment of Inertia

It is a geometrical property.
It is used for finding the bending capacity of a structure
It is also used for finding the deflection of a structure.

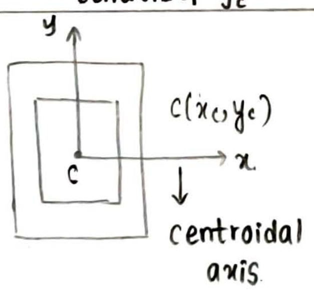






$$\frac{\text{Moment }(M)}{\dfrac{\text{Moment of Inertia}(I)}{\text{Centroid of } y_c}} = \text{Stress}$$

depth is more
= moment of inertia is more



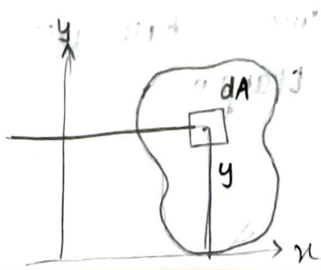
The moment of interia can be calculated by both base axis and centroidal axis as a reference.
Moment of interia is also known as second moment of Area

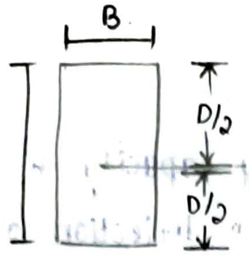
2nd moment of area = $A \times y \times y$

$I_x = Ay^2$

where, I_x = moment of inertia
A = moment of area

$$I_x = \int_A y^2 \, dA$$





I_x - moment of inertia w.r.t x-axis

I_y - moment of inertia w.r.t. y-axis

I_z - moment of intertia w.r.t z-axis

polar moment of intertia = I_p

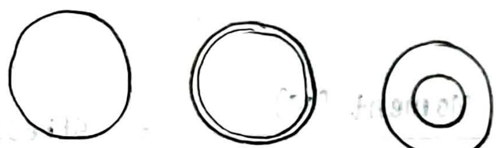
polar MOI is used when a beam or member is twisting

$$I_z = I_p = I_x + I_y$$

For a continuous body,

$$I_x = \int y^2 dA$$

$$I_y = \int x^2 dA$$

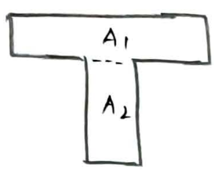


For a discontinuous body,

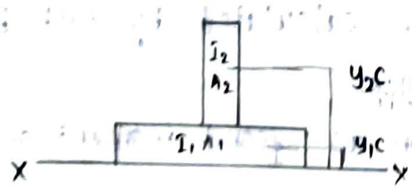
Individual MOI is used by adding area

$$I_{yx} = I_1 + I_2$$

$$= \frac{b_1 D_1^3}{12} + \frac{b_2 D_2^3}{12} + \dots$$



parallel axis theorem



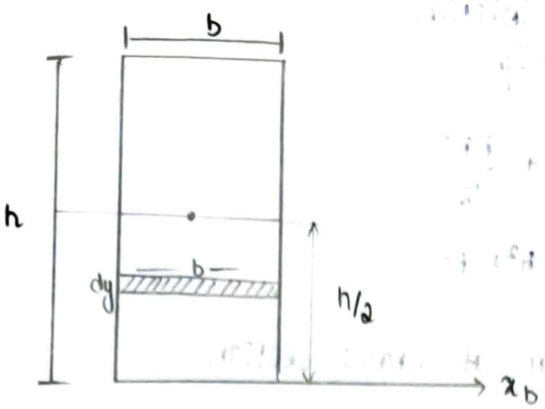
$$MOI = I_1 + I_2 + A_1 \times y_{1c}^2 + A_2 \times y_{2c}^2$$

1) Determine the Moment of interia for the rectangular section shown in figure

(a) w.r.t centroidal axis - x

(b) w.r.t base axis passing through base of the rectangle.

MOI is applied to area or cross section only but not applicable for line or surface.



(a) $I_x = \int_A y^2 \, dA$

$= \int_{-h/2}^{h/2} y^2 \cdot b \cdot dy$

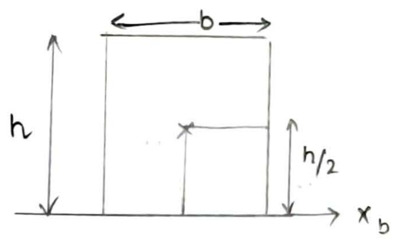
$= b\left[y^3/3 \right]_{-h/2}^{h/2} = \frac{b}{3}\left[\frac{h^3}{8} + \frac{h^3}{8} \right]$

$= \frac{2bh^3}{3 \cdot 8} = \frac{bh^3}{12}$

for scale $= \frac{2 \times 30^3}{12} = 4500$

$\Rightarrow \frac{30 \times 2^3}{12} = 20$

(b)



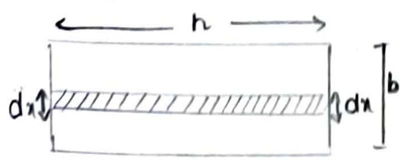
Parallel axis theorem, $I_{x_b} = I_x + A \times \left(\frac{h}{2}\right)^2$

centroid

$= \frac{bh^3}{12} + b \times h \times \frac{h^2}{4}$

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

MOI w.r.t y-axis :



$I_y = \int_A x^2 \, dA = \int_{-b/2}^{b/2} x^2 \times dx \times h = h\left[\frac{x^3}{3} \right]_{-b/2}^{b/2}$

$= \frac{h}{3}\left[\frac{b^3}{8} + \frac{b^3}{8} \right]$

$= \frac{hb^3}{12}$

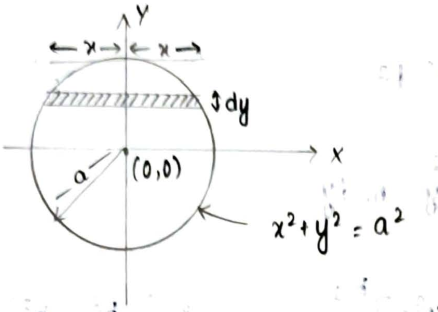
Polar moment of interia,

$$I_p = I_z = I_x + I_y$$

$$= \frac{bh^3}{12} + \frac{hb^3}{12}$$

$$= \frac{bh}{12}(h^2 + b^2)$$

Solid circular beam of cross section



$$I_x = \int_A y^2 \, dA = \int_A y^2 \cdot 2x \, dy$$

$$= \int_{-a}^{a} 2xy^2 \, dy$$

$$= 2\int_{-a}^{a} \sqrt{a^2-y^2} \cdot y^2 \, dy$$

$$= \frac{a^4}{8} \int_{-\pi/2}^{\pi/2} (\cos 4\theta - 1) d\theta$$

$$= \frac{a^4}{8} \left[\frac{\sin 4\theta}{4} - \theta \right]_{-\pi/2}^{\pi/2}$$

$I_x = \frac{\pi a^4}{4}$

Let $y = a\sin\theta$

$$\frac{dy}{d\theta} = a\cos\theta$$

$$dy = a\cos\theta \, d\theta$$

$$\int \sqrt{a^2 - a^2\sin^2\theta} \; a^2\sin^2\theta \cdot a\cos\theta \, d\theta$$

$$= \int a^2\sin^2\theta \; a^2\cos^2\theta \, d\theta$$

$$= a^4 \int \sin^2\theta \cos^2\theta \, d\theta$$

$$= a^4 \int (\sin\theta\cos\theta)^2 \, d\theta$$

$$= a^4 \int \left(\frac{\sin 2\theta}{2}\right)^2 d\theta$$

$$= \frac{a^4}{4} \int \sin^2 2\theta \, d\theta$$

$$= \frac{a^4}{4} \int \frac{\cos 4\theta - 1}{2} \, d\theta$$

$$= \frac{a^4}{8} \left[\frac{\sin 4\theta}{4} - \theta \right]$$

U.L $\Rightarrow y = a \Rightarrow a = a\sin\theta \Rightarrow \sin\theta = 1$

$\theta = \pi/2$

L.L $\Rightarrow y = -a \Rightarrow -a = a\sin\theta \Rightarrow \sin\theta = -1$

$\theta = -\pi/2$.

$$\Rightarrow \frac{a^4}{8 \cdot 4} \left[\sin 4\theta - \theta \right]_{-\pi/2}^{\pi/2} = \frac{a^4}{32} \left[\sin \cancel{4}^{2}(\pi/\cancel{2}) - \pi/2 - \left(\sin 4(-\pi/2) + \pi/2\right) \right]$$

$$= \frac{a^4}{32} \left[1 - \pi/2 + 1 - \pi/2 \right]$$

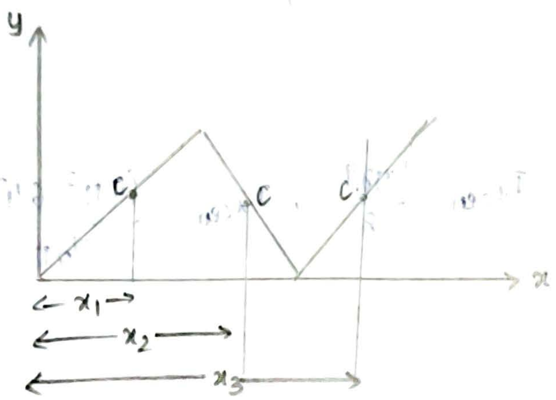
09/10/2019

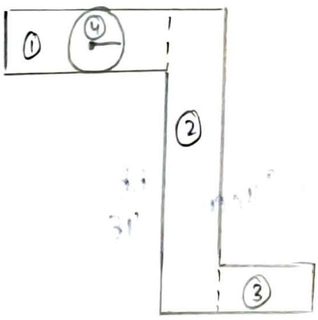
Centroid :

Line $\Rightarrow$ $x_c = \dfrac{\Sigma x_i L_i}{\Sigma L_i}$, $y_c = \dfrac{\Sigma y_i L_i}{\Sigma L_i}$

Area $\Rightarrow$ $x_c = \dfrac{\Sigma x_i A_i}{\Sigma A_i}$, $y_c = \dfrac{\Sigma y_i A_i}{\Sigma A_i}$

Volume $\Rightarrow$ $x_c = \dfrac{\Sigma x_i V_i}{\Sigma V_i}$, $y_c = \dfrac{\Sigma y_i V_i}{\Sigma V_i}$

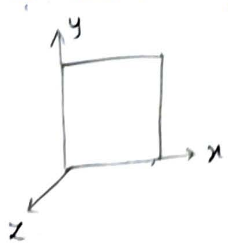




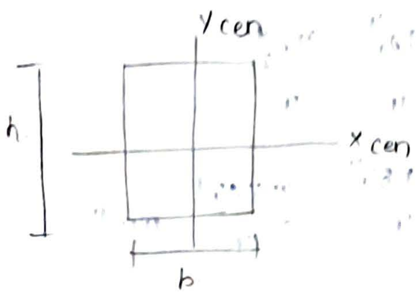
$$x_c = \frac{A_1 x_1 + A_2 x_2 + A_3 x_3 - A_4 x_4}{A_1 + A_2 + A_3 + A_4}$$

Moment of inertia :

It is meant only for areas.



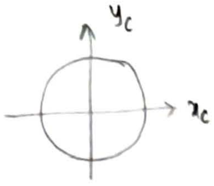
I_x, I_y, I_z



$I_{x_{cen}} = \dfrac{bh^3}{12}$

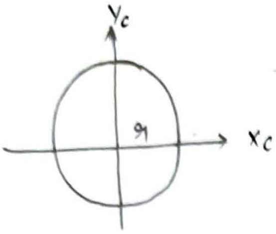
$I_{y_{cen}} = \dfrac{hb^3}{12}$

$(x_c, y_c) = \left(\dfrac{b}{2}, \dfrac{h}{2}\right)$

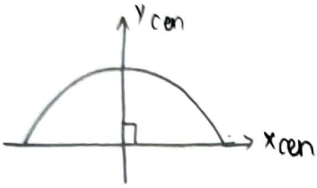


$$I_{x\,cen} = \frac{\pi a^4}{4}$$

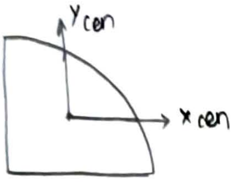
$$I_{y\,cen} = \frac{\pi a^4}{4}$$



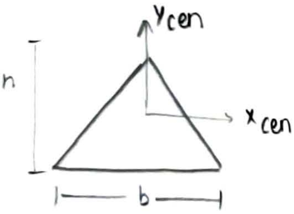
$$I_x = I_y = \frac{\pi r^4}{4}$$



$$I_{y\,cen} = \frac{\pi r^4}{8}, \quad I_{x\,cen} = \frac{(9\pi^2 - 64)r^4}{72\pi}$$

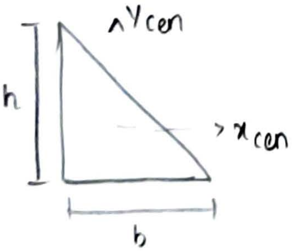


$$I_{x\,cen} = \frac{\pi r^4}{16} = I_{y\,cen}$$



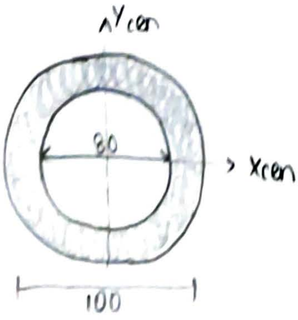
(Isoceles Δle)

$$I_{x\,cen} = \frac{bh^3}{36}, \quad I_{y\,cen} = \frac{hb^3}{48}$$



$$I_{x\,cen} = \frac{bh^3}{36}, \quad I_{y\,cen} = \frac{hb^3}{36}$$

Composite area MOI



$$I_{x\,cen} = \frac{\pi r_1^4}{4} - \frac{\pi r_2^4}{4}$$

$$= \frac{\pi \times 50^4}{4} - \frac{\pi \times 40^4}{4} \text{ mm}^4$$

$$= \frac{\pi}{4}\left[6250000 - 2560000\right]$$

$$= \frac{\pi}{4} \times 3690000$$

$$= 2896650 \text{ mm}^4$$

$$I_{x\,cen} = \frac{\pi}{4}(r_1^4 - r_2^4)$$

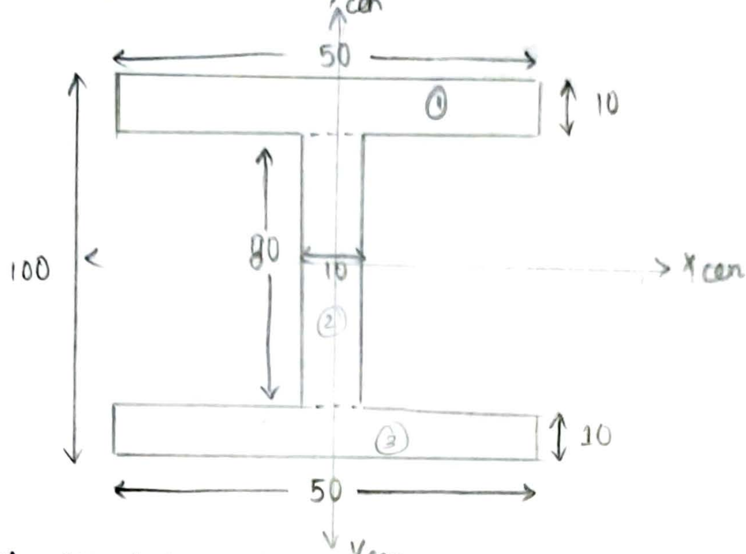
$$= \frac{\pi}{4}\left(\frac{d_1^4}{16} - \frac{d_2^4}{16}\right)$$

$$= \frac{\pi}{64}(d_1^4 - d_2^4)$$

Parallel axis theorem

$$I_{c\,x\,cen} = I_{xcen} + A \times y_c^2$$

1)



MOI with respect to centroid:

$$I_{x\,cen} = \frac{50 \times 10^3}{12} + 50 \times 10 \times (50-5)^2 + 10 \times \frac{80^3}{12}$$

$$+ \frac{50 \times 10^3}{12} \; (50-5)^2 \times 50 \times 10$$

$$= 4166.66 + 1012500 + 426666.66 + 4166.66 + 1012500$$

$$= 245999.98 \text{ mm}^4$$

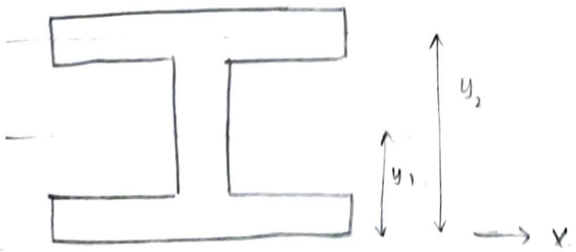
$$I_{y\,cen} = \frac{10 \times 50^3}{12} + 50 \times 10 \times (0) + \frac{80 \times 10^3}{12} + \frac{10 \times 50^3}{12} + 50 \times 10 \times 0$$

$$= \frac{10 \times 50^3}{12} + 0 + \frac{80 \times 10^3}{12} + \frac{10 \times 50^3}{12} + 0$$

$$= 1041666.66 + 6666.66 + 1041666.66$$

$$= 2089999.98 \text{ mm}^4$$

MOI with respect to base axis:



$$I_x = I_{x_1 cen} + A_1 y_c^2 + I_{x_2 cen} + A_2 y_{c_2}^2 + I_{x_3 cen} + A_3 y_{c_3}^2$$

$$= \frac{50 \times 10^3}{12} + 30 \times 10 \left(\frac{10}{2} + 90\right)^2 + \frac{10 \times 80^3}{12} + 80 \times 10 \left(\frac{80}{2} + 10\right)^2$$

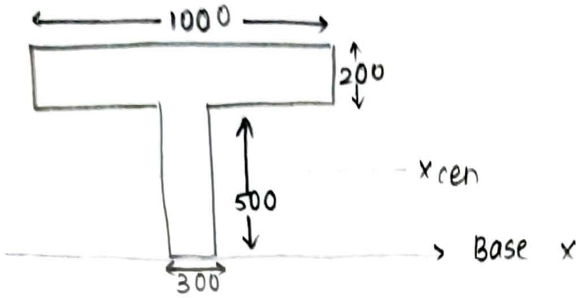
$$+ \frac{50 \times 10^3}{12} + 10 \times 50 \left(\frac{10}{2}\right)^2$$

$= 4166.66 + 4512500 + 426666.66 + 2000000 + 4166.66 +$

12500

$= 6959999.98 \ mm^4$

2)



31/10/2019

Radius of Gyration

$$r = \sqrt{\frac{I}{A}}$$

r - determines in which the structure buckles

$$r_x = \sqrt{\frac{I_x}{A}}$$

$$r_y = \sqrt{\frac{I_y}{A}}$$

If $r_y < r_x$ the buckling happens with respect to y-axis
$r_x < r_y$ the buckling happens with resped to x-axis

$I_x = 3.8 \times 10^{-5}\ m^4$

$I_y = 4.5 \times 10^{-6}\ m^4$

$A = 1.5\ m^2$

$$r_x = \sqrt{\frac{I_x}{A}}$$

$$= \sqrt{\frac{3.8 \times 10^{-5}\ m^4}{1.5\ m^2}}$$

$$= \sqrt{2.533 \times 10^{-5}}\ m$$

$$= 5.0332 \times 10^{-3}\ m$$

$$= 0.0050332\ m$$

$$r_y = \sqrt{\frac{I_y}{A}}$$

$$= \sqrt{\frac{4.5 \times 10^{-6}\ m^4}{1.5\ m^2}}$$

$$= 1.7320 \times 10^{-3}\ m$$

$$= 0.0017320\ m$$

$\therefore r_x = 0.0050332$

$r_y = 0.0017320$

$\therefore r_y < r_x$ buckling happens with respect wito y-axis