Model Question Paper- I

CBCS SCHEME

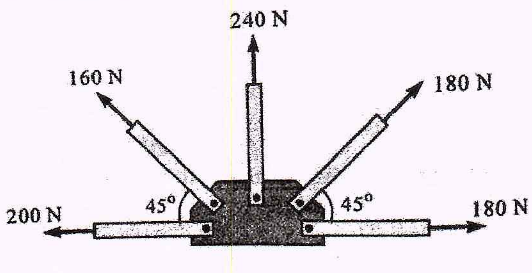
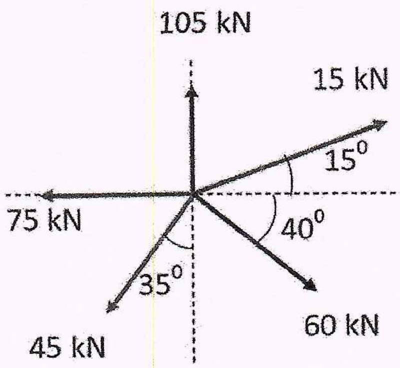
First/ Second Semester B.E Degree Examination,

ENGINEERING MECHANICS (1BCIV105/205)

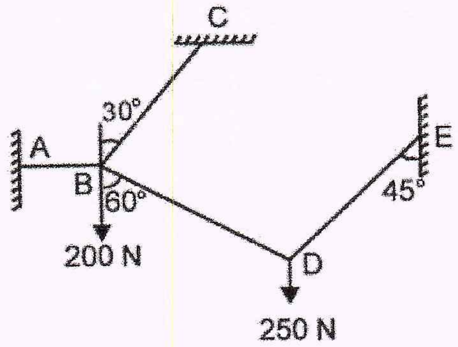
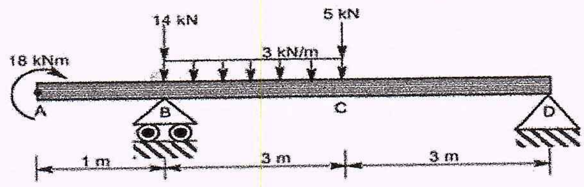
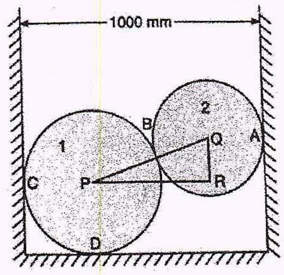
MAX TIME: 03 Hours **Max.Marks:100**

Note:

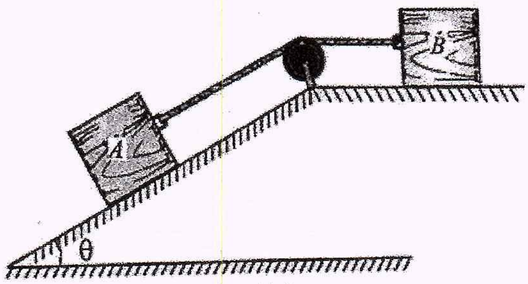
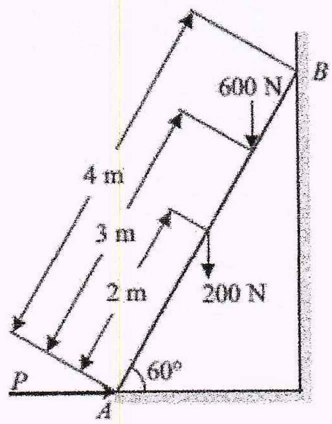
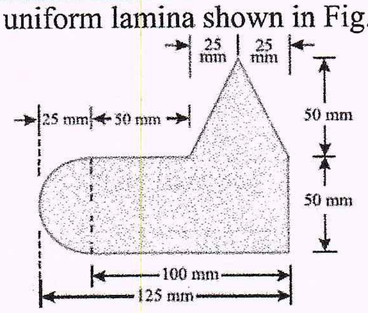
1. *Answer any FIVE full questions, choosing at least ONE question from each MODULE.*
2. *M: Marks, L: Bloom's level, C: Course outcomes.*
3. *Assume the missing data, if any and indicate clearly.*

		Module – 1	M	L	C
Q.1	a	Explain the principle of transmissibility of a force with neat sketch.	8	2	1
	b	The resultant of the two forces, when they act at an angle of 60° is 14N. If the same forces are acting at right angles, their resultant is $\sqrt{137}$ N. Determine the magnitude of the two forces.	7	3	2
	c	How do you classify the force system? Discuss with neat sketches.	5	2	1
		OR			
Q.2	a	A gusset plate of a roof truss is subjected to forces as shown in Fig.2(a). Determine the resultant force.  Fig.2(a)	8	3	2
	b	Identify the system of force from Fig.2(b) and find the resultant of force system.  Fig. 2(b)	7	3	2
	c	Discuss the basic idealizations in engineering mechanics.	5	2	1
		Module – 2			

Model Question Paper- I

Q.3	a	Explain the importance of free body diagram in engineering mechanics.	08	2	1
	b	A system of connected flexible cables shown in Fig.3(b) is subjected to two vertical forces 200 N and 250 N at points B and D. Determine the forces in various segments of the cable.  Fig.3(b)	12	3	2
		OR			
Q.4	a	A beam ABCD is supported by a roller at B and hinged at D, loaded as shown in Fig.4(a). Compute the reactions at B and D.  Fig.4(a).	08	3	2
	b	A horizontal shaft with inner clearance of 1000 mm carries two spheres of radius 350 mm and 250 mm, weighing 600N and 500N respectively are shown in the Fig. 4(b). Determine the reaction at all the points of contact.  Fig.4(b)	12	3	2
		Module – 3			
Q.5	a	Explain the following with sketches. (a) Limiting force of friction (b) Kinetic friction (c) Coefficient of friction (d) Angle of friction (e) Angle of repose	10	2	1
	b	A body, resting on a rough horizontal plane, required a pull of 180 N inclined at 30° to the plane just to move it. It was found that a push of 220 N inclined at 30° to the plane just moved the body. Determine the weight of the body and the coefficient of friction.	10	3	3
		OR			

Model Question Paper- I

Q. 6	a	Find the value of 'Θ' if the blocks 'A' and 'B' shown in Fig.6(a) have impending motion up and down the plane. Given the weights of block A = 20 kg and block B = 20 kg. Assume that $\mu_A = \mu_B = 0.25$.  Fig.6(a)	8	3	3
	b	A ladder of length 4 m, weighing 200 N is placed against a vertical wall as shown in Fig.6(b). The coefficient of friction between the wall and the ladder is 0.2 and that between floor and the ladder is 0.3. The ladder, in addition to its own weight, has to support a man weighing 600 N at an inclined distance of 3 m from A. Calculate the minimum horizontal force to be applied at A to prevent slipping.  Fig.6(b)	7	3	3
		Module – 4			
Q.7	a	Establish a relation for the position of centroid in terms of radius R for a semi-circular lamina by the method of integration.	10	2	4
	b	Locate the centroid of a uniform lamina shown in Fig.7(b).  Fig.7(b)	10	3	4
		OR			
Q.8	a	An I-section is made up of three rectangles as shown in Fig.8(a). Find the Second moment of area of the section about the horizontal axis passing through the center of gravity of the section.	10	2	4

<table>
<tr><td></td><td></td><td>

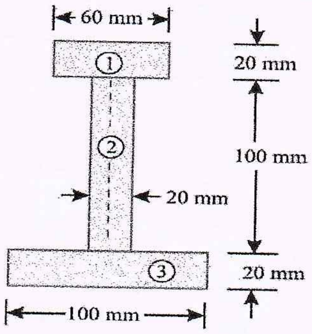


Fig.8(a)</td><td></td><td></td><td></td></tr>
<tr><td></td><td>b</td><td>Locate the position of centroid of the lamina with circular cutout as shown in Fig. 8(b).

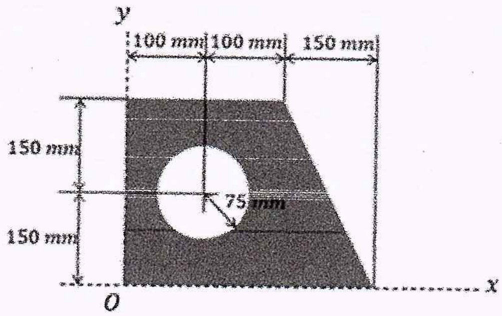


Fig. 8(b)</td><td>10</td><td>3</td><td>4</td></tr>
<tr><td colspan="6">Module – 5</td></tr>
<tr><td rowspan="2">Q.9</td><td>a</td><td>Establish a relation for moment of inertia of quarter of a circle of radius R about centroidal axes.</td><td>10</td><td>2</td><td>4</td></tr>
<tr><td>b</td><td>Find the moment of inertia of the lamina with a circular cut out of 30 mm diameter about the axis AB as shown in Fig.9(b).

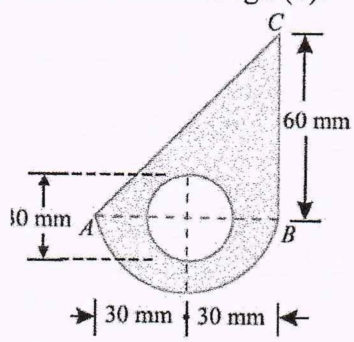


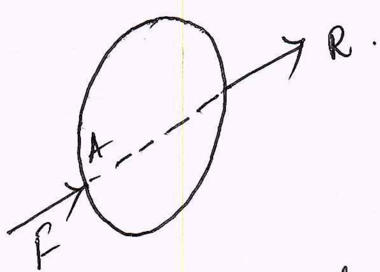
Fig.9(b)</td><td>10</td><td>3</td><td>4</td></tr>
<tr><td colspan="6">OR</td></tr>
<tr><td rowspan="2">Q.10</td><td>a</td><td>Discuss the applications of perpendicular axes theorem and radius of gyration.</td><td>10</td><td>2</td><td>4</td></tr>
<tr><td>b</td><td>A rectangular hole is made in a triangular section as shown in Fig.10(b). Determine the moment of inertia of the section about X-X axis passing through its center of gravity and the base BC.</td><td>10</td><td>3</td><td>4</td></tr>
</table>

MODEL QP SOLUTION
ENGINEERING MECHANICS (18CIV 105/205)

Q.No 1 a) Explain the Principle of transmissibility of force with neat sketch.

Ans: It states that "the state of rest or uniform motion of the body is unaltered if a force acting on a body is replaced by another force of same magnitude & direction any where on the body but along the line of action of replaced force". — 03M

Consider a rigid body as shown below in figure which is acted upon by forces F & R.



— 02M

As per the principle of transmissibility of forces the state of rest or uniform motion of the body is unaltered when F is replaced by R if and only if F = R & F & R should be along the same line of action. — 03M

Total 08M

Q.1 b) The resultant of the two forces, when they act an angle 60° is 14 N. If the same forces are acting at right angle, their resultant is $\sqrt{137}$ N. Determine the magnitude of the two forces.

Soln we have

$$R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta} \quad \text{--- (1)}$$

when $\theta < 180°$ ~~> 90°~~

Also we have

$$R = \sqrt{F_1^2 + F_2^2} \quad \text{when } \theta = 90° \text{ --- (2)}$$

In eqn (1) & (2) we have four Variable and two equations & it is not possible to find F_1 & F_2 even R & θ are given. — 7 Marks.

"So you can write answer as ~~insuff~~ insufficient data.

Q-1 c) How do you classify the force system? discuss with neat sketches.

Ans: Depending the existance of the forces in the plane, their position & their direction we can classify the force system as follows. — 02

i) System of forces in space: This is a force system in which all the forces do not lie in a single plane. Ex: Force due to wind.

ii) Coplanar force system: This a system of forces in which all the forces lie in a single plane.

Depending on the position we have following coplanar force system.

a) Coplanar parallel force system: This is a system in which all the forces lie in a single plane & parallel to each other.

* coplanar parallel like force system.
In this the direction of all the force is same.
Ex: the forces exerted by the wheels of a stationary train on the tracks — 03.

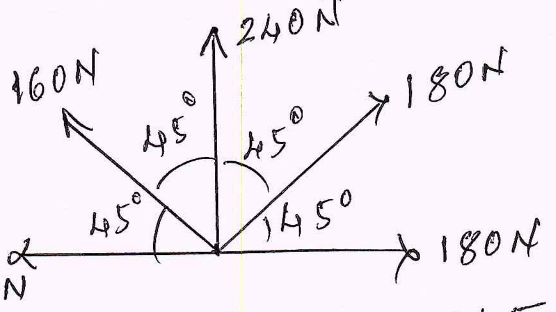
Total 05M.

(d)

OR.

Q.2 a) Refer Question & Fig in QP.

Ans: Consider the following fig.



$\Sigma F_x = +180 - 200 + 180\cos 45 - 160\cos 45$ —— 03M

$= -5.86\,N$

$\Sigma F_y = +240 + 180\sin 45 + 160\sin 45$ —— 03

$= 480.42\ N$

$R = \sqrt{(-5.86)^2 + (480.42)^2}$ —— 02M

$R = 480.45\ N$

$\alpha = \tan^{-1}\dfrac{480.42}{5.86}$ $= 89.30°$

Total 08M.

Q.2 b) Refer Question & Fig. in QP.

Ans: The given system of force is a "coplanar concurrent forces" as all the forces lie in a single plane and the line of action of all the forces passes through the single point.

$\Sigma F_x = 15\cos 15° - 75 + 60\cos 40 - 45\cos 55°$ → 03M

$= -40.36\ KN$

$\Sigma F_y = +105 + 15\sin 15 - 45\sin 55 - 60\sin 40$ —— 03M

$= +30.57\ KN$

$R = \sqrt{(-40.36)^2 + (30.57)^2}$ — 01

$R = 50.63\ KN$

$\alpha = \cancel{\tan^{-1}\dfrac{50.63}{30.57}}$ $= \tan^{-1}\dfrac{30.57}{40.36}$

$= 37.14°$ Total 07M.

(3)

Q.2c | Discuss the basic idealizations in engineering mechanics.

Ans: the assumption made regarding the size of the body, arrangement of molecules & their rigidity ~~are~~ while applying the rules or laws of mechanics to the field problems are called as "basic idealizations" of engineering mechanics". — 02M

Basic idealizations are as follows.

i) Particle: particle is a body which have mass but no size but theoritically such bodies does not exist. However such an idealization is used while dealing with ~~two~~ behavior of two distant objects.

Ex: A bomber aeroplane is a particle for a gunner who is operating from ground.

ii) Continuum: All the matters can be devided into molecules, atoms, protons etc. but in engg. mechanics the conglomeration of these discrete particles is neglected and the body is considered as continuum. — 03M.

others idealizations are,

iii) Rigid body iv) Point force. Total 05M

Q.3a) Explain the importance of Free Body Diagram in engineering mechanics.

Ans: In the analysis of the equilibrium condition of the body it becomes very necessary to isolate the body under consideration for all other contact-surfaces

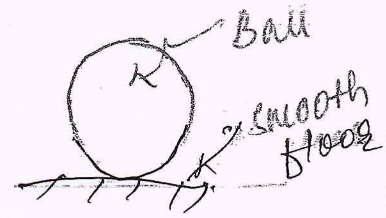
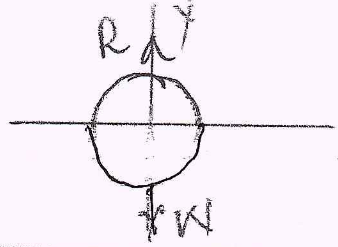
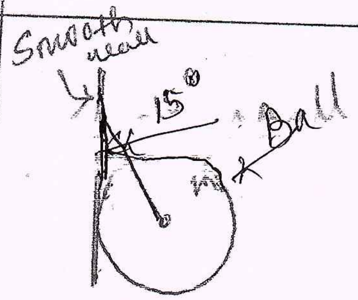
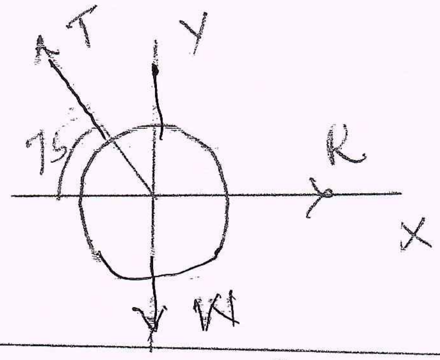
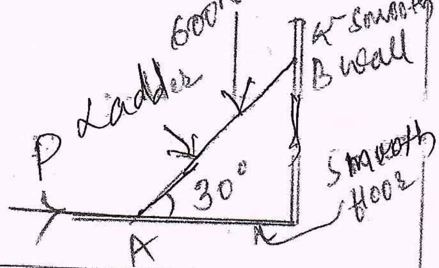
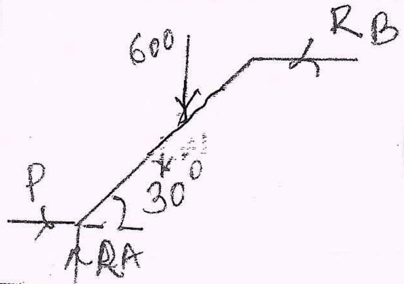
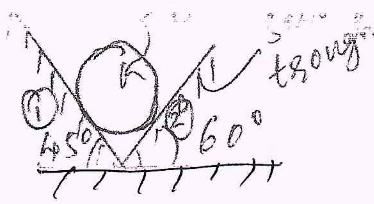
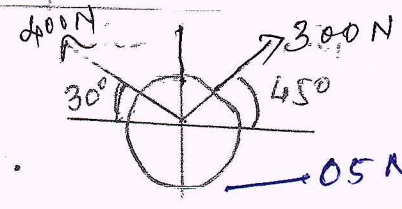
(4)

and shown with all types of forces acting on it viz applied forces & non applied forces.

Such a diagram of the body which is freed from all other contact surfaces and shown with all types of forces acting on it viz: applied forces & non applied forces i.e self wt & reactions from adjoining bodies is called FBD.

—— 03M

Examples of Free Body Diagram (FBD)

S.No	Reacting bodies	FBD eg.	FBD
1)		Ball	
2)		Ball	
3)			
4		Ball	

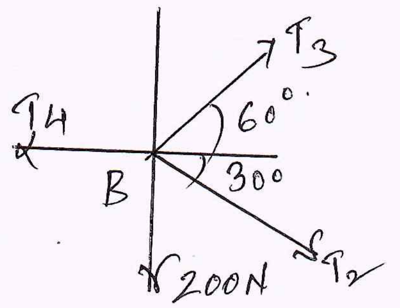
—— 05M

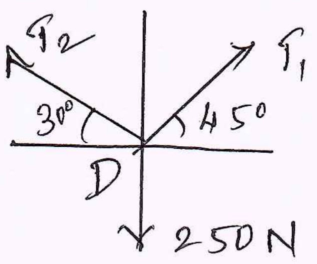
Total 08M.

5

Q. 3 b) Refer Question & figure in Q.P.

Ans: Consider FBD for the points D & B as shown below. Let T_1, T_2, T_3 & T_4 be the tensions in the cable segments DE, BD, BC & AB respectively.





Applying Lami's thm for point D

$$\frac{T_1}{\sin 120} = \frac{T_2}{\sin 135} = \frac{250}{\sin 105°} \quad \text{— 02}$$

$$\Rightarrow T_1 = \frac{250 \sin 120}{\sin 105} = 224.14\,N \text{ — Ans.} \quad \text{— 02}$$

$$T_2 = \frac{250 \sin 135}{\sin 105} = 183.01\,N \text{ — Ans} \quad \text{— 02}$$

Applying eqn of equilibrium for point B.

$\Sigma F_y = 0$

$\Rightarrow -200 - 183.01 \sin 30 + T_3 \sin 60 = 0$ — 03

$\Rightarrow T_3 = 336.60\,N$ — Ans.

$\Sigma F_x = 0$

$\Rightarrow +183.01 \cos 30 + 336.60 \cos 60 - T_4 = 0.$ — 03

$\Rightarrow T_4 = -326.79\,N$ Ans.

Total 12M.

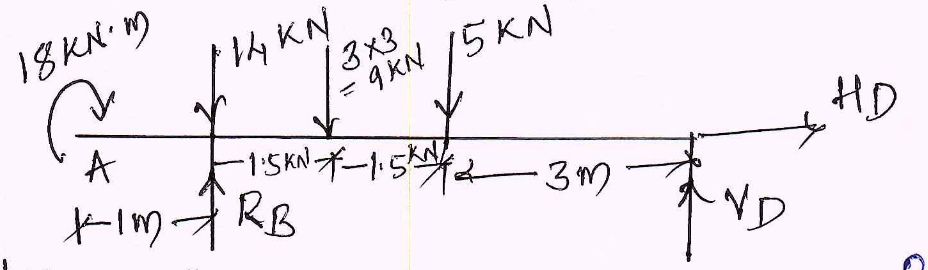
Q. 4 a) Refer the Question & Fig in QP.

* Let R_B be the normal reaction due to roller support at B & Vertical.

* Let H_D & V_D be the horizontal components of reaction in any direction due to hinged support at pt D.

(6)

Consider the following fig.



Applying eqn of eqmm. —— 02

$\Sigma M_D = 0$

$\Rightarrow +18 - 5\times3 - 9\times4.5 - 14\times6 + R_B\times6 = 0.$

$\Rightarrow 6R_B = +15 + 40.5 + 84 - 18$

$\Rightarrow R_B = 20.25\,KN$ -- Ans. —— 04

$\Sigma F_x = 0$

$\Rightarrow H_D = 0$

$\Sigma F_y = 0 \Rightarrow -14 + 20.25 - 9 - 5 + V_D = 0$

$\Rightarrow V_D = 7.5\,KN$ -- Ans. 02

$\Rightarrow R_D = 7.5\,KN$ -- Ans. 08 Marks.

Q.4 b) Refer Question & Fig in the QP.

Ans: Let R_A, R_B, R_C, R_D are the reaction developed at contact points, A, B, C & D respectively.

In Δle PQR.

$PR = 1000 - 350 - 250 = 400\,mm.$

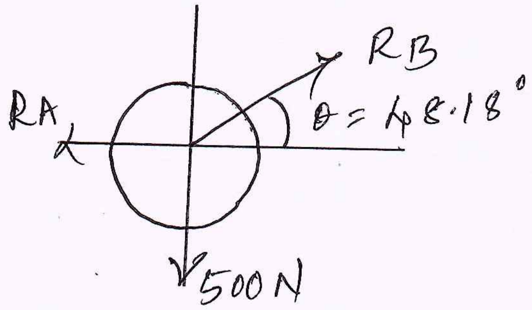
In Δle PQR.

$\cos\theta = \dfrac{PR}{PQ}$

$\cos\theta = \dfrac{400}{600} \Rightarrow \theta = 48.18^\circ$ —— 03

(7)

FBD for 250mm dia sphere.



Applying Lami's thm.

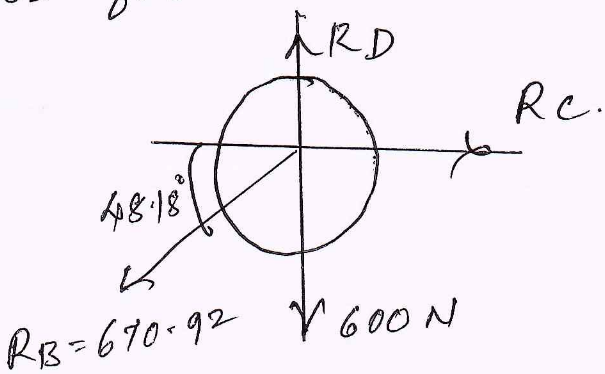
$$\frac{R_B}{\sin 90} = \frac{R_A}{\sin 138.18} = \frac{500}{\sin 131.82} \quad \text{— 02}$$

$$\Rightarrow R_A = \frac{500 \sin 138.18}{\sin 131.82} = 447.37\,N \text{ — Ans}$$

$$R_B = \frac{500 \sin 90}{\sin 138.18} = 670.92\,N \text{ — Ans}$$

01

FBD for 350mm dia



Applying eqn of equilibrium.

$\Sigma F_y = 0 \Rightarrow -600 + R_D - 670.92 \sin 48.18 = 0$

$\Rightarrow R_D \simeq 1100\,N$ — Ans. — 3

$\Sigma F_x = 0 \Rightarrow +R_C - 670.92 \cos 48.18° = 0$

$\Rightarrow R_C = 447.36\,N$ -- Ans. — 3

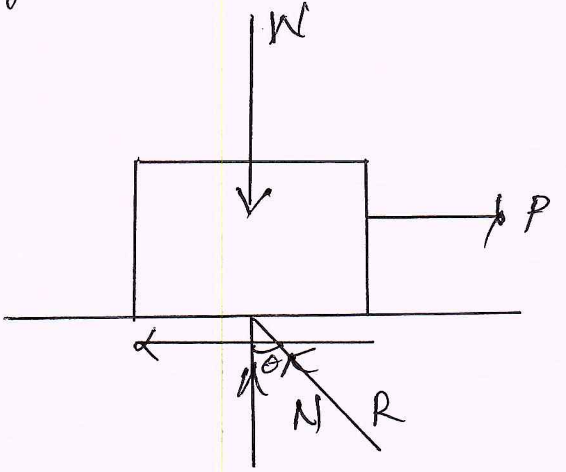
Total

8

Module - 3

Q 5 a) Explain the following with sketches.

Ans a) Limiting force of friction.



The friction developed between the two surface at the impending motion is called "Limiting force of friction.

c) As the frictional force increases and the angle θ increases ~~& the~~ & it can reach a maximum value of α when a limiting value of friction is reached thus when motion is impending

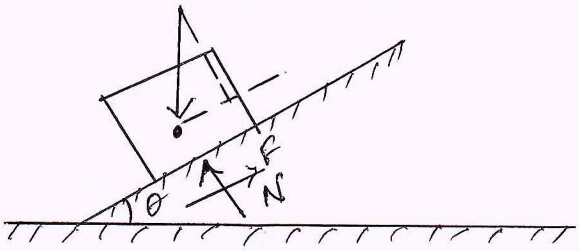
$$\tan\alpha = \frac{F}{N} = \mu$$

This is called "coefficient of Friction.

b) The Friction developed one body rolles or slides over another body is called kinetic friction.

d) The inclination between the resultant of normal & self wt force with the normal is called angle of friction in fig it is θ.

B) Angle of repose:



The maximum inclination of the plane on which the body, free from external forces, can repose is called angle of repose.

If ϕ is the value of θ when the motion is impending, frictional force will be limiting friction and hence

$$\tan\phi = \frac{F}{N}$$

$$\Rightarrow \tan\phi = \mu = \tan\alpha$$

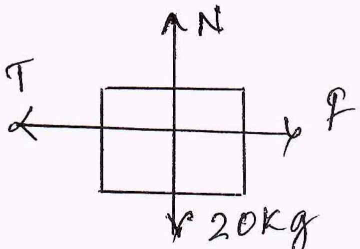
$$\Rightarrow \phi = \alpha$$

The the value of angle repose is the same as the value of the limiting angle of friction.

— 2×5 = 10M

Q.6 a) Refer the Question & given fig. in the QP.

Ans: Consider the FBD of Block B



— 02

Apply eqn of equilibrium.

$\Sigma F_y = 0 \Rightarrow N - 20 = 0 \Rightarrow N = 20\,kg.$

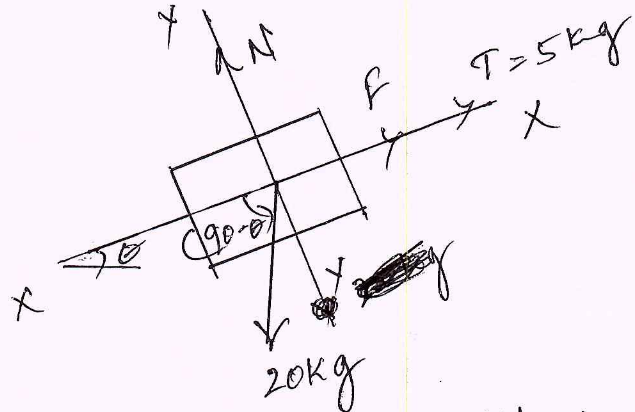
Given $\frac{F}{N} = 0.25$

$\Rightarrow F = 0.25 \times 20 = 5\,kg.$

$\Sigma F_x = 0 \Rightarrow +5 - T = 0$

$\Rightarrow T = 5\,kg.$ — 02

Now consider the FBD of block A



— 02

Applying eqn of equilibrium.

$\Sigma F_y = 0$

$\Rightarrow -20(\sin 90-\theta) + N = 0.$

$\Rightarrow N = 20\cos\theta$ — (1)

$\Rightarrow 20 = 20\cos\theta \Rightarrow \cos\theta = 1$ — (2) } 02

$\Sigma F_x = 0$

$\Rightarrow +5+5 - 20\cos(90-\theta) = 0.$

$\Rightarrow 20\sin\theta = 10$

$\Rightarrow \sin\theta = \frac{10}{20} \Rightarrow \sin\theta = 0.5$ — (3)

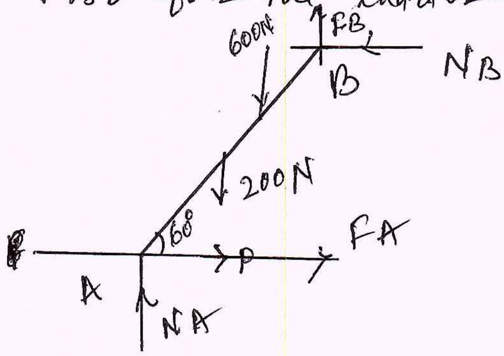
(3) ÷ (1)

$\frac{\sin\theta}{\cos\theta} = \frac{0.5}{1}$ — 02

$\tan\theta = 0.5$

$\theta = \tan^{-1} 0.5 = 26.56°$. Total 10M

Q.6 b) Refer the Question & given fig. in the QP.
Ans. Consider FBD for the ladder.



— 03M

(11)

Applying equations of equilibrium.

$\Sigma M_A = 0$

$\Rightarrow +200 \times 2\cos60 + 600 \times 3\cos60 - F_B \times 4\cos60$
$- N_B\, 4\sin60 = 0$ — (1)

Given

$\frac{F_B}{N_B} = 0.2$

$\Rightarrow F_B = 0.2 N_B$.

From (1)

$400\cos60 + 1800\cos60 - N_B\, 0.8\cos60 - 4N_B\sin60 = 0$.

$\Rightarrow N_B(4.8)\sin60 = 2200\cos60$.

$N_B = \frac{2200\cos60}{4.8\sin60} = 264.62\,N$ — 03

Sub in (1)

$2200\cos60 - 4F_B\cos60 - 4 \times 264.62\sin60 = 0$

$\Rightarrow F_B = \frac{2200\cos60 - 4 \times 264.62\sin60}{4\cos60}$

$\Rightarrow F_B = 91.66\,N$ — 03

$\Sigma F_y = 0$

$\Rightarrow +F_B + N_A - 600 - 200 = 0$.

$\Rightarrow N_A = 800 - 91.66 = 708.33\,N$

Given $\frac{F_A}{N_A} = 0.3$

$\Rightarrow F_A = 0.3 \times N_A = 212.5\,N$

$\Sigma F_x = 0$

$\Rightarrow +F_A + P - N_B = 0$.

$P = N_B - F_A$

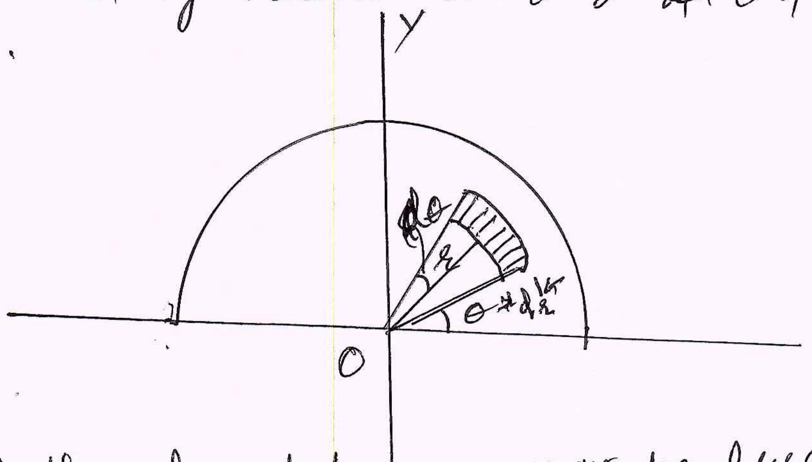
$= 264.62 - 212.5$ — 03M

$P = 52.12\,N$ --- Ans. Total 12M

(12)

Q.7 a) Establish a relation between the position of centroid in terms of radius R for a semicircular lamina by the method of integration.

Ans: Consider the semicircle of radius R as shown in fig. due to symmetry the centroid must lie on Y-axis. Let the distance from diametral axis be $\bar{y}$. To find $\bar{y}$ consider an element at a distance r from the centre O of the semi circle, radial width being dr and bound by radii at θ & $\theta + d\theta$



— 05

Now the elemental area may be treated as a rectangle of sides $r\,d\theta$ and dr, Hence.

Area of element $= r\,d\theta \times dr$

It's moment about diametral axis is given by

$r\,d\theta \times dr \times r\sin\theta = r^2 \sin\theta \, dr \, d\theta$

$\therefore$ Total moment of area about diametral axis

$$= \int_0^{\pi}\int_0^{R} r^2 \sin\theta \, dr \, d\theta = \int_0^{\pi} \left[\frac{r^3}{3}\right]_0^R \sin\theta \, d\theta$$

$$= \frac{R^3}{3}\left[1-\cos\theta\right]_0^{\pi}$$

$$= \frac{2R^3}{3}$$

Area of semicircle $= \pi R^2/2$

$$\bar{y} = \frac{\text{Moment area}}{\text{Total area}} = \frac{2R^3/3}{\pi R^2/2}$$

$\boxed{\bar{y} = 4R/3\pi}$ — Ans. — 05

Total 10 M

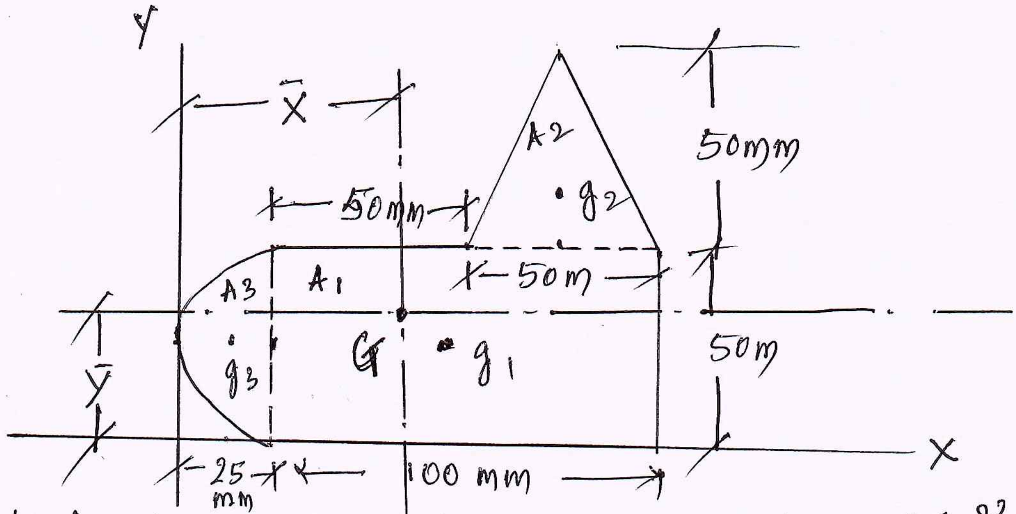
(13)

Q.7 a)

Ans:

Refer the question & Figure in the QP.

Consider the following fig.



Let A_1, A_2 & A_3 be the segmental areas & g_1, g_2 & g_3 be their positions of centroids as shown in fig.

$A_1 = 100 \times 50 = 5000\ mm^2$

$A_2 = \frac{1}{2} \times 50 \times 50 = 1250\ mm^2$

$A_3 = \frac{\pi \times 25^2}{2} = 981.74\ mm^2$

$\Rightarrow \Sigma A = A_1 + A_2 + A_3 = 5000 + 1250 + 981.74$

$\Rightarrow \boxed{\Sigma A = 7231.74\ mm^2}$ — 04M

Let $\bar{X}$ & $\bar{Y}$ be the coordinates of given area and let $\bar{x}_1, \bar{x}_2$ & $\bar{x}_3$ & $\bar{y}_1, \bar{y}_2$ & $\bar{y}_3$ be the X & Y coordinates of g_1, g_2 & g_3 respectively.

$\bar{X} = \cancel{5000 \times}\ A_1\bar{x}_1 + A_2\bar{x}_2 + A_3\bar{x}_3 / \Sigma A$

$\Rightarrow \bar{X} = \frac{5000 \times 125 + 1250 \times 100 + 981.7\left(25 - \frac{4 \times 25}{3\pi}\right)}{7231.74}$

$= \frac{625000 + 125000 + 981.7 \times 14.39}{7231.74}$ — 03 M

$\boxed{\bar{X} = 105.66\ mm.}$

$\bar{Y} = A_1\bar{y}_1 + A_2\bar{y}_2 + A_3\bar{y}_3 / \Sigma A$

$= \frac{5000 \times 25 + 1250 \times (50 + \frac{1}{3} \times 50) + 981.74 \times 25}{7231.74}$

$\bar{y} = \frac{232876.833}{7231.74} = 32.20\ mm.$ — 03M

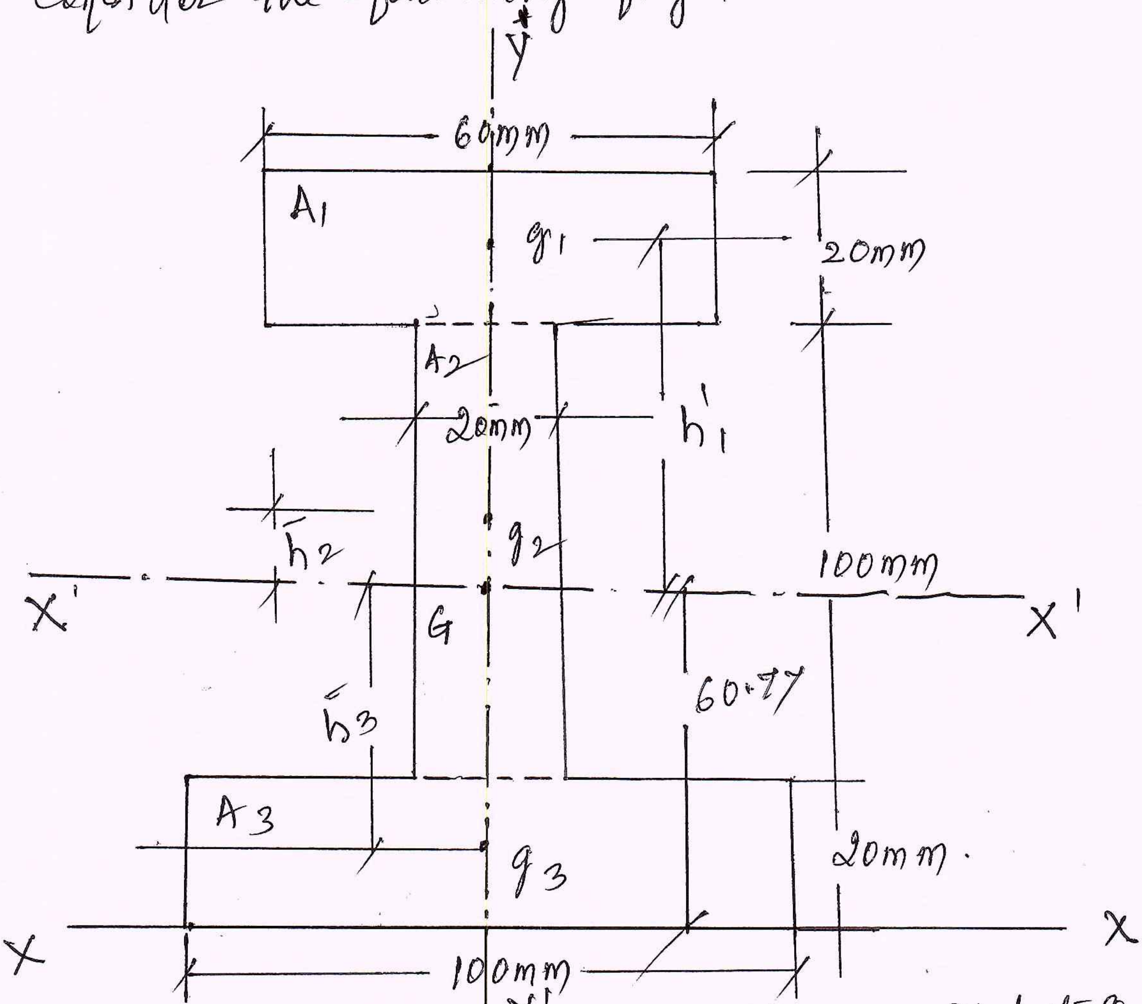
$\therefore G \equiv (105.66, 32.20)$

Total 10 M.

Q 8 a) Ans:

Refer the Question & Fig. in the QP.

Consider the following fig.



Let A_1, A_2 & A_3 be the segmental areas & Let g_1, g_2 & g_3 be their positions of centroids as shown in fig. The given section is symmetric about X axis

$\Rightarrow \quad \bar{x} = 0 \quad \& \quad \bar{y} = \dfrac{A_1\bar{y}_1 + A_2\bar{y}_2 + A_3\bar{y}_3}{\Sigma A}$ — (1)

Consider Base of I section as X-axis.

$A_1 = 60 \times 20 = 1200\ mm^2$
$A_2 = 100 \times 20 = 2000\ mm^2$
$A_3 = 100 \times 20 = 2000\ mm^2$

$\Rightarrow \Sigma A = A_1 + A_2 + A_3$
$\Sigma A = 5200\ mm^2$

$\bar{y}_1 = 130mm \quad \bar{y}_2 = 70\ mm \quad \bar{y}_3 = 10\ mm$.

Sub. in eqn (1)

$\bar{y} = 1200 \times 130 + 2000 \times 70 + 2000 \times 10 / 5200$

$\boxed{\bar{y} = 60.77\ mm} \Rightarrow G \equiv (0, 60.77)$ — 05M

Second moment of area through the centroidal axis.

Applying parallel axis theorem.

$$I_{x'x'} = I_{xx} + Ah^2$$

$$I_{x'x'} = \frac{60 \times 20^3}{12} + 1200 \times (69.23)^2 + \frac{20 \times 100^3}{12} + 2000(9.23)^2$$

$$+ \frac{100 \times 20^3}{12} + 2000(50.77)^2$$

$$= 5791351.48 + 1837052.46 + 5221852.46$$

$$\boxed{I_{x'x'} = 12.850256 \times 10^6 \text{ mm}^4}$$ — Ans.

— 03M

$$I_{y'y'} = \frac{20 \times 60^3}{12} + \frac{100 \times 20^3}{12} + \frac{20 \times 100^3}{12}$$

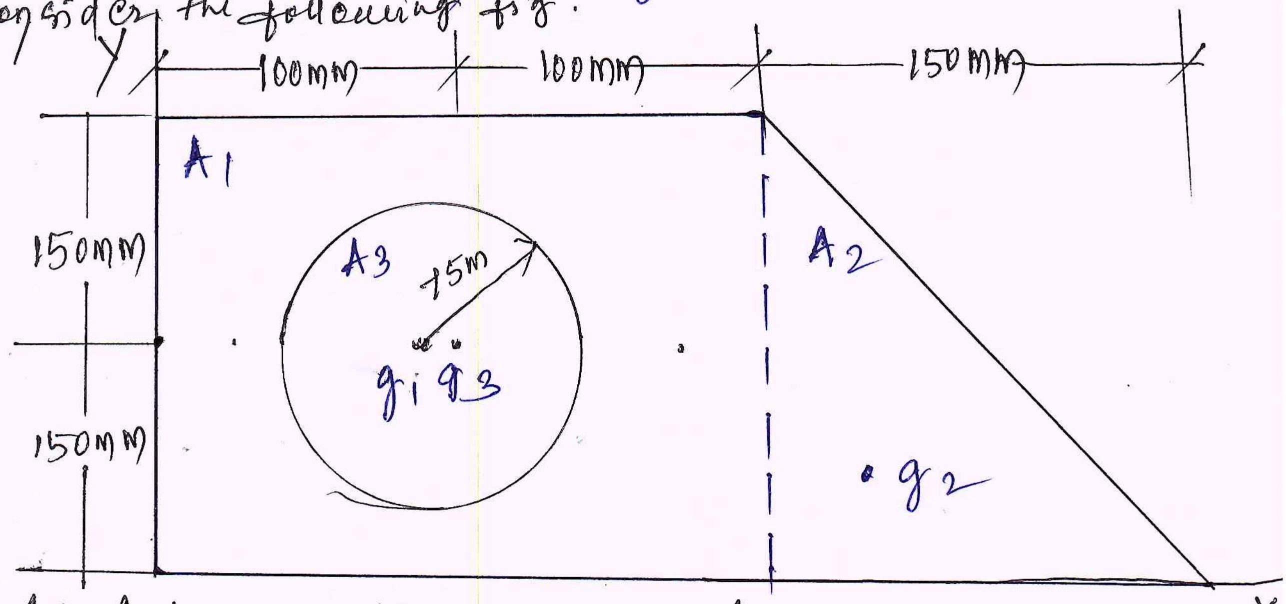
$$\boxed{I_{y'y'} = 2.093333 \times 10^6 \text{ mm}^4}$$ — Ans.

— 02M

Total 10M.

Q. 8b) Refer the question & Fig in the QP.

Ans. Consider the following fig.



Let A_1, A_2 & A_3 be the segmental areas & g_1, g_2 & g_3 be their centroids as shown in fig.

$A_1 = 200 \times 300 = 60000 \text{mm}^2$

$A_2 = \frac{1}{2} \times 150 \times 300 = 22500 \text{mm}^2$

$A_3 = \pi \times 75^2 = 17671.46 \text{mm}^2$ —— 04M

$\Rightarrow \Sigma A = A_1 + A_2 + A_3 = 100171.46 \text{mm}^2$

Let $\bar{X}$ & $\bar{Y}$ be the ~~positions~~ coordinates of centroid of given area.

$\bar{X} = (A_1\bar{x}_1 + A_2\bar{x}_2 - A_3\bar{x}_3) / \Sigma A$

where $\bar{x}_1$, $\bar{x}_2$ & $\bar{x}_3$ be the x coordinates of ~~centroid~~ g_1, g_2 & g_3 respectively.

$$\bar{X} = \frac{60000 \times 100 + 22500 \times (200 + \frac{1}{3} \cdot 150) - 17671.46 \times 100}{100171.46}$$

$\boxed{\bar{X} = 98.41 \text{mm}}$ —— 03M

$\bar{Y} = (A_1\bar{y}_1 + A_2\bar{y}_2 - A_3\bar{y}_3) / \Sigma A$

where $\bar{y}_1$, $\bar{y}_2$ & $\bar{y}_3$ be the Y coordinates of g_1, g_2 & g_3 respectively.

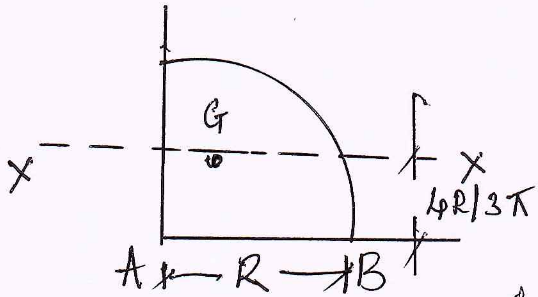
$$\bar{y} = \frac{60000 \times 150 + 22500 \times (1/3 \times 300) - 17671.46 \times 150}{100171.46}$$

$$\boxed{\bar{y} = 85.84 \text{ mm}}$$ — Ans. ——— 03 M

$\therefore$ $G \equiv (98.41, 85.84)$ Total 10M.

Q.9 a) Establish a relation for moment of inertia of a quarter of cle of radius R about centroidal axis.

Ans: Consider a quarter of circle of diameter as shown below in fig.



MI about the centroidal axis X–X

Now the distance of the centroidal axis yc from the base is given by

$$y_c = \frac{4R}{3\pi} = \frac{2d}{3\pi}$$ ——— 05M

and the area $= A = \frac{1}{4} \cdot \frac{\pi d^2}{4} = \frac{\pi d^2}{16}$

From the parallel axis theorem.

$$I_{AB} = I_{xx} + A y_c^2$$

$$\frac{\pi d^4}{256} = I_{xx} + \frac{\pi d^2}{16}\left(\frac{2d}{3\pi}\right)^2$$

$$I_{xx} = \frac{\pi d^2}{256} - \frac{\pi d^2}{36\pi} = 0.00343 d^4$$

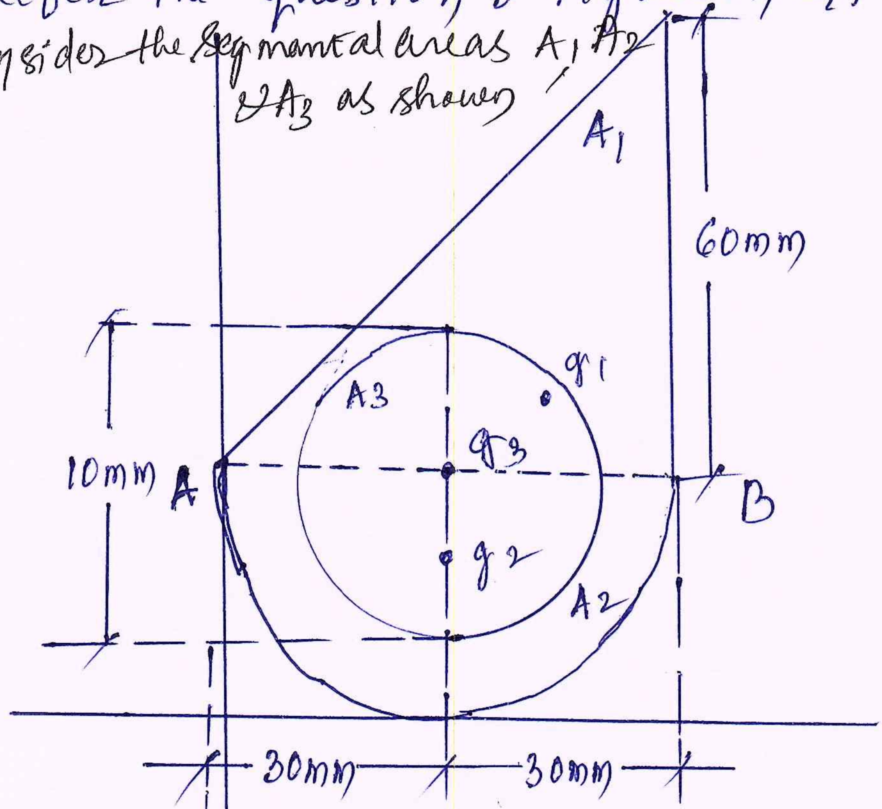
or $\boxed{I_{xx} = 0.055 R^4}$ — — Ans. ——— 05

Total 10M.

(18)

Q.9b) Refer the question & figure in QP.

consider the segmental areas A_1, A_2 & A_3 as shown



A_1 = Triangle = $\frac{1}{2} \times 60 \times 60 = 1800\ mm^2$

A_2 = Semi cle = $\frac{\pi \times 30^2}{2} = 1413.72\ mm^2$

A_3 = cle = $\pi 5^2 = 78.53\ mm^2$

$\Sigma A = A_1 + A_2 - A_3$

$= 1800 + 1413.72 - 78.53$

$\Sigma A = 3135.15\ mm^2$

Determine the coordinates of G (centroid) of given area. Let $\bar{x}$ - x coordinate & $\bar{y}$ = y coordinate

$$\bar{x} = \frac{A_1 \bar{x}_1 + A_2 \bar{x}_2 - A_3 x_3}{\Sigma A}$$

$$= \frac{1800 \times (60 - \frac{1}{3} 60) + 1413.72 \times 30 - 78.53 \times 30}{3135.15}$$

$\boxed{\bar{x} = 112.06\ mm}$ —— 03

(19)

$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2 - A_3\bar{y}_3}{\Sigma A}$$

$$= \frac{1800 \times (30 + 1/3 \cdot 60) + 1413.72 \times (30 - \frac{4 \times 30}{3\pi}) - 78.53 \times 30}{3135.15}$$

$$= \frac{1800 \times 50 + 1413.72 \times \cancel{1413.72} \times 17.26 - 78.53 \times 30}{3135.15}$$

$$\boxed{\bar{y} = 35.73\ mm}$$ ——— 03M

Applying parallel axis theorem.

$$I_{AB} = \frac{60 \times 60^3}{12} + 1800 \times 0 + \cancel{\frac{\pi 30^4}{4}} + 1413.72(30 - \frac{4 \times 30}{3\pi})^2$$

$$+ 0.11 \times 30^4 - \frac{\pi\, 30^4}{4}$$ ——— 02

$$= 1080000 + \cancel{29100}\ 113500.80 - 636172.51$$

~~$I_{AB} = 5.32927 \times 10^5\ mm^4$~~ ——— 02

$$\boxed{I_{AB} = 5.57328 \times 10^5\ mm^4.}$$

Total 10M

Q.10 a) Discuss the applications of perpendicular axis theorem & radius of gyration.

Ans: * Perpendicular Axis theorem.

Statement:

For a plain lamina lying in the xy plane the MI about an axis perpendicular the plane is

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

where

I_{xx} & I_{yy} are the MI ~~of ma~~ about mutual perpendicular axes in the plane.

It is valid only for plane lamina not for 3D bodies.

Applications:

i) Finding the Moment of Inertia of circular disc

ii) Used in rotating machinery, flywheels, gears.

iii) Finding MI of ring.

iv) Important in circular motion & gyroscopic problems.

v) Used in engineering designs of rotating plate, Flywheel, turbines and mechanical shaft.

→ 05M

* Radius of Gyration:

Definition:

Radius gyration (k) is the distance from the axis of rotation at which the entire mass of the body were concentrated, the MI would remain the same.

$$I = Mk^2$$

$$k = \sqrt{I/M}$$

Applications:

i) Comparing rotational stability of flywheels Rings Vs discs.

ii) In structural engineering to check the buckling of column

iii) Designing rotating systems of turbines rotars Automobile wheels.

→ 05

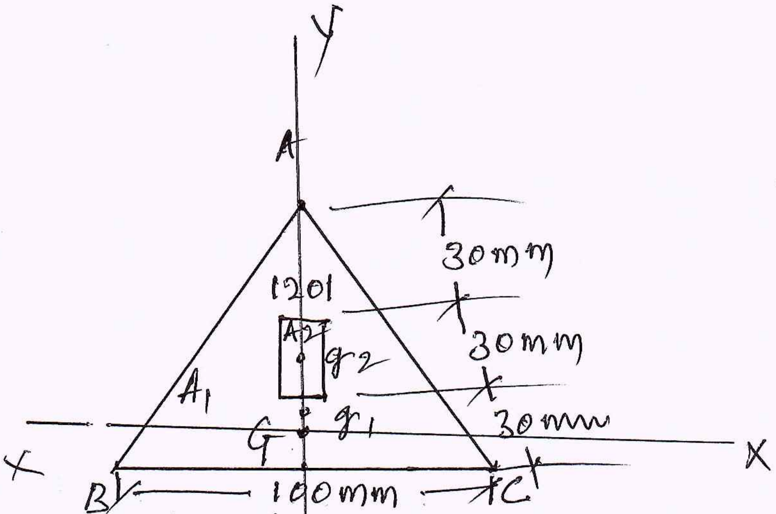
10 Marks.

Q. No. 10 b

Ans:

Refer the question & figure in the QP.

Consider the following fig.



The given area is symmetric about Y-axis.

Let A_1 & A_2 be the segmental areas and g_1 & g_2 respectively their centroids.

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

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

$\Sigma A = A_1 - A_2 = 4500 - 600 = 3900 mm^2$

$\bar{x} = 0$,

$\bar{y} = (A_1\bar{y}_1 - A_2\bar{y}_2) / \Sigma A$

where $\bar{y}_1$ & $\bar{y}_2$ are the y coordinates of g_1 & g_2

$\bar{y} = (4500 \times \frac{1}{3} \cdot 90 - 600 \times 45) / 3900$.

$\boxed{\bar{y} = 27.69 mm}$ — 04M

$I_{AB} = \frac{100 \times 90^3}{12} + \left[\frac{20 \times 20^3}{12} + 400 \times (17.31)^2\right]$

$= 6075000 + 13333.33 + 119854.44$

$= 6.21 \times 10^6 mm^4$. — 03M

Fig·10 b

Q·No 10(b)

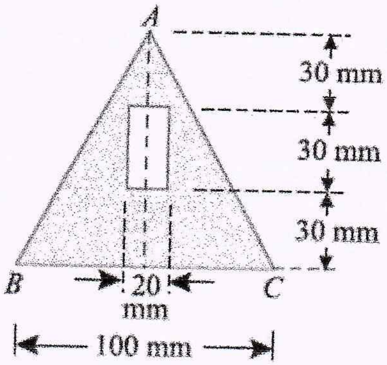


Fig.10(b)

* * *

$$I_{xx} = \frac{100 \times 90^3}{36} + 4500(2.31)^2 - \left[\frac{20 \times 30^3}{12} + 400(17.31)^2\right]$$

$$= 2025000 + 24012.45 - 45000 - 119854.44$$

$$I_{xx} = 1.884158 \times 10^6 \text{ mm}^4$$

$$I_{yy} = \frac{100 \times 90^3}{36} - \frac{30 \times 20^3}{12}$$

$$I_{yy} = 2025000 - 20000.$$

$$\boxed{I_{yy} = 2.005 \times 10^6 \text{ mm}^4.}$$ — 03 M

Total 10M.

(Staff Incharge)

17-02-2026

HOD
Dept of Civil Engg
KLS V.D.I.T, Haliyal