CBCS SCHEME

USN | | | | | | | | | | |

BESCK104A/BESCKA104

First Semester B.E./B.Tech. Degree Examination, Dec.2024/Jan.2025
Introduction to Civil Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. VTU Formula Hand Book is permitted.
3. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	List out different branches of civil engineering and explain any 4 branches briefly.	10	L1	CO1
	b.	What are cement and Mortor? What are their uses?	10	L1	CO1
		OR			
Q.2	a.	Explain briefly the structural elements of a building.	10	L1	CO1
	b.	What is RCC? Explain its advantages and disadvantages.	10	L1	CO1
		Module – 2			
Q.3	a.	Write a short note on: i) Smart city concept ii) Clean city concept.	10	L1	CO2
	b.	Why landfills are important? Explain the advantages and disadvantages of land fills.	10	L1	CO2
		OR			
Q.4	a.	Explain the importance of water supply and sanitary system.	10	L1	CO2
	b.	What is solid waste management? Explain the sources and origin of solid wastes.	10	L1	CO2
		Module – 3			
Q.5	a.	Explain the principles of superposition and transmissibility of force system.	5	L2	CO3
	b.	State and prove Varignon's theorem of moments.	5	L2	CO3
	c.	Compute the magnitude and direction of the resultant force in Fig.Q.5(c).	10	L3	CO3

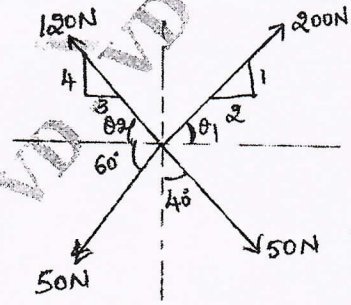


Fig.Q.5(c)

OR

Q.6	**a.**	Find the magnitude, direction and point of application of the resultant force with respect to point 0 in Fig.Q.6(a).	**12**	**L3**	**CO3**

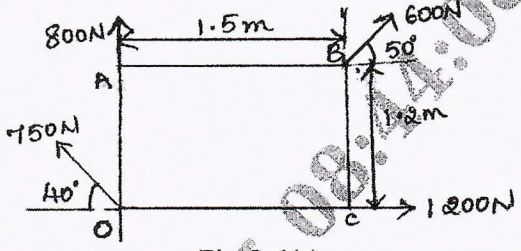


Fig.Q.6(a)

	b.	In the Fig.Q.6(b) the portion BC of the string is horizontal and pulley is frictionless. Determine the tension in different parts of the string. Also find w_1 and w_2.	**8**	**L3**	**CO3**

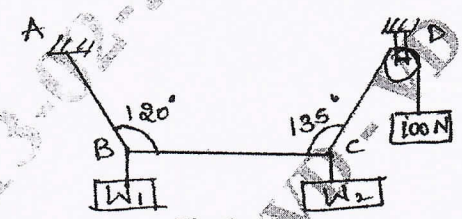


Fig.Q.6(b)

Module – 4

Q.7	**a.**	Define centroid and centre of gravity.	**4**	**L1**	**CO4**
	b.	Find the centroid of a semicircle using first principle.	**6**	**L3**	**CO4**
	c.	Locate the centroid of a shaded area shown in Fig.Q.7(c).	**10**	**L3**	**CO4**

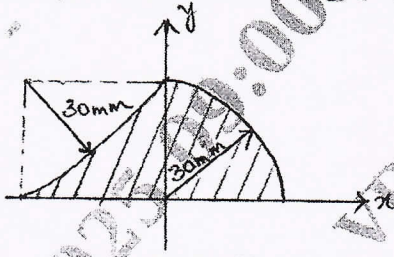


Fig.Q.7(c)

OR

Q.8	**a.**	Find the centroid of a triangle from first principle.	**8**	**L3**	**CO4**
	b.	Determine the centroid of a shaded area shown in Fig.Q.8(b).	**12**	**L3**	**CO4**

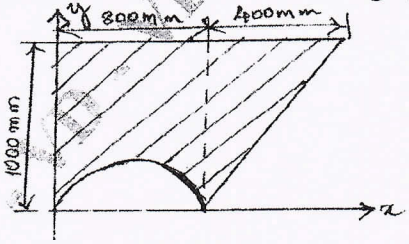
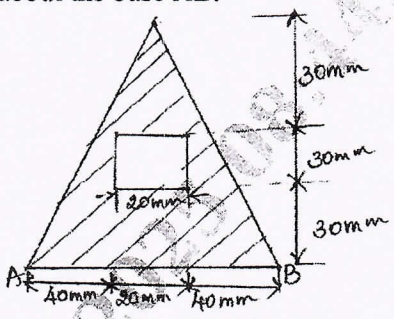
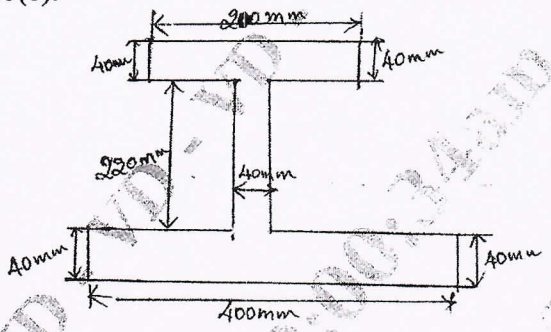


Fig.Q.8(b)

		Module – 5			
Q.9	**a.**	State and prove parallel and perpendicular axis theorem.	**10**	**L2**	**CO5**
	b.	Determine the moment of inertia and radius of gyration of the shaded area shown in Fig.Q.9(b) about the base AB.  Fig.Q.9(b)	**10**	**L3**	**CO5**
		OR			
Q.10	**a.**	Derive an expression for moment of inertia of a circle along its centroidal axis (I_{XX} and I_{YY}).	**10**	**L2**	**CO5**
	b.	Determine the polar radius of gyration about the horizontal centroidal axis for the Fig.Q.10(b).  Fig.Q.10(b)	**10**	**L3**	**CO5**

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DEC. 2024 / JAN. 2025 SEE QP. SCHEME & SOLUTION

(BESCK 104A)
INTRODUCTION TO CIVIL ENGINEERIN

Q.1 a) List out different branches of civil Engineering and explain any 4 branches briefly.

Ans. * List of any four branches among

1. Surveying
2. Building materials
3. Construction technology
4. Structural Analysis.
5. Geotechnical engineering
6. Water Resource & Irrigation engg.
7. Transportation engineering
8. Environmental engineering.
9. Regional planning & Architecture.

---- 02M.

1. Surveying: Surveying is the science of map making. The method of establishing the relation between different points on horizontal & vertical plane is also called as surveying. Measuring tapes, chains, compasses, plane table with accessories, dumpy level theodolite, total station etc are used in surveying.

--- 02M

2. Building materials: This branch mainly deals with different materials like, stones, bricks, cement, RCC, PCC, sand etc. and their suitability for different item of works.

--- 02M

3. Construction Technology: This is a branch of civil engg. which mainly deals with different item of works to be executed by the civil engineering project. Few items are VCR, BBM, RCC, PCC, plastering, finishing items etc.

---- 02

4. Transportation Engineering:

This is a branch of civil engineering which mainly deals with design, construction of transportation networks, like, roads, railways, tunnels, runways, harbours, docks etc.

--- 02

Total 10M.

Q.1 b. What are cement and mortar? what are their uses.

Ans:

Cement:

Cement is a fine, soft powder used as a binder because it hardens after contact with heater. It is produced from a mixture of limestone and clay that's charred and then ground up.

----- 02M.

Uses:

1. construction:

a) Concrete: A mixture of cement, sand and gravel that hardens over time. Used to build roads, bridges, dams and other infrastructure.

b) Mortar: A mixture of cement, sand and water that holds bricks, stones & other materials.

c) Grout: A cement based mixture that fills gaps between tiles or masonry blocks.

--- 03M

Mortar:

Mortar is a cement-based material used to bind building blocks together. It is made from a mixture of sand, water, cement and other materials. --- 02M

Uses: Mortar used in many construction applications including.

* Filling gaps: Mortar can fill gaps and cracks between bricks, stones and other building materials.

* Fixing tiles: Mortar can be used to fix tiles to walls & floor.

* Water Proofing: Mortar can be used to create water-tight seal. --- 03M

Total 10M

OR

Q.2 a) Explain briefly the structural elements of a building.

ii) Foundation:

A buiding foundation is the base of a structur that transfers weight of the building to the soil. It supports the super-structure of the building and prevents movement that could compromise the building's stability.

Purposes of foundation:

a. Foundation provide the structu's stability from the ground.

b. To distribute the weight of the structure over a large area in order to avoid overloading the underlying soil. - - - - 02M

iii) Beam: A beam is a structural element that supports loads and is often used in construction. Beams can be made of wood, steel, concrete & other materials.

Beams are used in buildings, bridges, roofs and other structures. - - - 02M.

iii) Columns: A column is a vertical structural member that supports the weight of the building and transfers it to the foundation. Columns are essential for the safety and stability of a building. Columns provide strength and prevent building from collapsing - - - 02M

iv) Masonry Walls:

A masonry wall is a structural member made of units like bricks, concrete blocks, or stones bound together with mortar.

The primary objectives of masonry include structural stability, durability, and visual appearence - - - - 02M

v) Staircase: The set of steps which facilitates the movement of human being and materials from one floor to another in a building are called stairs. The room which includes these stairs is called staircase.

Staircase provide vertical access to connected floors in multistorey buildings.

- - - - 02M

Total 10M.

Q2 b) What is RCC? Explain its advantages & disadvantages.

Ans:

Reinforced Cement Concrete (RCC) is a composite material made by combining Concrete and steel reinforcement. It is used in the construction of building, dams, bridges and other structures.

- - - 02M

Advantages of RCC:

iv) Rcc is economical because the concrete constituents are inexpensive and widely available.

v) Rcc requires less labor during erection.

vi) Rcc has good sound proofing properties.

vii) Rcc can be applied in many different ways, including hand applied, poured, pumped and sprayed. — — — O&M.

* Disadvantages of Rcc:

a) Cost: High strength concrete can be very expensive.

b) Weight: Rcc structures are heavier than those made of steel, wood or glass.

c) Time: Construction project may be delayed if they are relying on Rcc.

d) Cracking: Excessive reinforcement can lead to cracking due to the strain on the drying concrete. — — — O&M

Total 10M.

Module 2.

Q.3 a) Write a short note on
i) Smart city concept.
ii) clean city concept.

Ans: Short note on

i) Smart city concept:

A smart city is a city that uses digital technology to improve the quality of life for its citizens. Smart cities can be more efficient, environmental friendly and socially inclusive. ---- 01

Smart city works on.

* Technology: Smart cities use technologies like Internet of things (IoT) and information and communication technology (ICT) to collect and analyze data.

* Infrastructure: Smart cities use digital technology to improve infrastructure like street lights, bus shelters etc --- 02M.

Benefits of smart cities:

* Improved quality of life.
* Reduced emissions.
* Safer public spaces.
* Better resource use ---- 01

Total 05M.

ii) Clean city concept:

A "clean city" concept refers to an urban environment where waste is effectively managed, public places are kept litter free, pollution is minimized and residents actively participate in maintaining cleanliness. --- 02M

7

Key aspects of a clean city:

* Waste Management:

Efficient collection & disposal systems for household and commercial waste, including recycling program.

* Public hygiene:

Regular cleaning of streets, sidewalks and public areas with accessible sanitation.

* Community engagement:

Educating citizens about the importance of cleanliness and actively involving them in clean-up drives. ---- 03

Total 05

G.T: 10M.

Q.3 b. Why landfills are important? Explain the advantages & disadvantages of land fills.

Ans: A landfill is a site for the disposal of waste materials. It is a oldest and most common form of waste disposal, although the systematic burial with daily, intermediate and final covers only began in the 1940s. --- 02M

* Advantages of land fills:

i) Effective in waste disposal.
ii) ~~No~~ energy can be produced by burning the solid wastes.
iii) Leads in land reclamation
iv) It is a economical method of waste disposal. -- 04

6

Disadvantages of landfills:

i) It leads in the environmental degradation as landfills releases harmful pollutants.

ii) Leads in the Air pollution as land fill releases green house gases like oxides of Carbon methane etc due to degradation of organic material.

iii) Landfills acts as breeding ground for harmful bacteria.

iv) Landfills results in hazardous waste challenges. ---- 04M

Total 10M.

OR

Q.4 a) Explain the importance of water supply and Sanitary systems.

Ans: Importance of Water supply system:

A water supply system provides access to clean, safe drinking water which is essential for human survival, hygiene, agriculture, industry and overall quality of life. Without a reliable water supply Communities can face health risks, ecological damage etc. ---- 03M

Key points about the importance of a water supply system

i) Health: Access to clean water prevents waters borne diseases like cholera, typhoid etc significantly impairing public health and well being.

ii) Economic development: Reliable water is vital for various industries including aggriculture, manufacturing and tourism. Contributing to economic growth and job creation. ___ 02

Importance of Sanitary system:

Sanitary system prevents the spread of diseases by ensuring the safe collection, transportation, treatments and disposal of human waste, thereby protecting people through fecal oral transmission, this significantly improves overall quality of life within a community. ____ 03

Key points about the importance of Sanitary system.

i) It prevents spreading of diseases through waters which is contaminated through human fecal.

ii) It leads improved hygine.

___ 02

Total. 10

10.

Q.4 b. What is Solid Waste Management? Explain Sources and origin of solid wastes.

Ans: "Solid Waste Management" is process which involves. Collection, transportation, processing/ treatment and disposal of solid wastes generated from the locality of town of any city. - - - - - - 02M.

Solid wastes comes from many sources, including households, commercial places, industries, agriculture, construction & mining.

Household sources:

a) Residential Wastes: Waste from ~~Source~~ homes such as paper, plastic and other trash.

b) Commercial Wastes: Waste from businesses, such as paper plastic and other trash from Shops, offices, schools & colleges.

c) Industrial solid Wastes: Waste from factories and other industrial activities. - - - 06

Origin of waste: Wastes may be generated during extraction of raw materials, processing of raw materials into intermediate & final product, consumption of final products and other human activities. - - - - 02

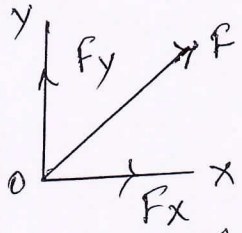
Total 10M.

Q.5 a) Explain the Principles of superposition and transmissibility of force system.

Ans: * Principle of Super Position of forces.

It states that the effect of a force on a body is same as that of it's constituent forces or in other words the effect of a resultant force on the body is equal to the effect of it's component forces.

Consider a force which ~~can~~ is acting at point ⊙ as shown below

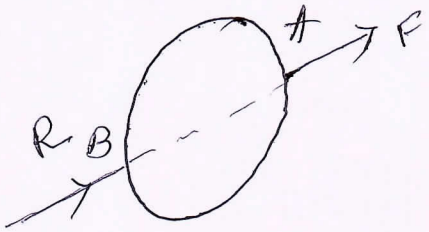


Let F be the force & Fx & Fy be its components along ⊙ x & y-axis ~~shown~~ as shown.

Then as per this principle the effect F is same as effect of Fx & Fy on the body. — — — 02 M

* Principle of transmissibility of forces:

Statement: It states that the state of rest or Uniform motion of the body is unaltered if a force acting on the body is replaced with another force of same magnitude & in the same direction anywhere on body but along the line of action of replaced force.

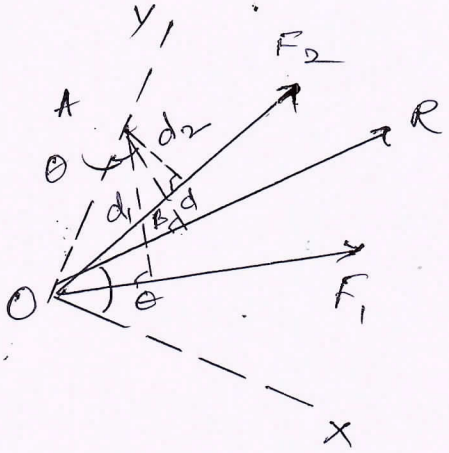


Consider a rigid body as shown in fig. Let F be the force acting at point A, then as per this principle the state of rest or Uniform motion is Unaltered if F is replaced by R along the same line of action and R must be equal to F in magnitude.

Q.5 b) State and prove Varignon's theorem of Moments -

Ans: Statement: It states that the algebraic sum of moments of coplanar forces ~~in~~ about any moment centre in the plane is equal to moment of their resultant about the same moment-centre.

--- 02 M



Let F_1 & F_2 be the two forces which are acting at point O as shown. Let R be the resultant of F_1 & F_2. Now let d_1, d_2 & d be the moment arms of F_1, F_2 & R respectively then as per this principle

$$R \cdot d = F_1 d_1 + F_2 d_2$$

Proof: Let A be any moment-centre.

Join OA and consider that as Y axis & draw X-axis perpendicular to it. Let θ be inclination of R with respect to X-axis.

Moment of R about A = R. d

In Δ^{le} OAB

$$\cos\theta = \frac{d}{OA}$$

$$\Rightarrow d = OA\cos\theta$$

$$\therefore R.d = R.OA\cos\theta$$

$$= OA\, R\cos\theta$$

$$R.d = OA\, Rx \quad \text{---} \quad (1)$$

Hhy we can prove.

$$F_1 d_1 = OA\, F_1 x \quad \text{---} \quad (2)$$

$$F_2 d_2 = OA\, F_2 x \quad \text{---} \quad (3)$$

(2) + (3)

$$F_1 d_1 + F_2 d_2 = OA\,(F_1 x + F_2 x)$$

$$= OA\, Rx$$

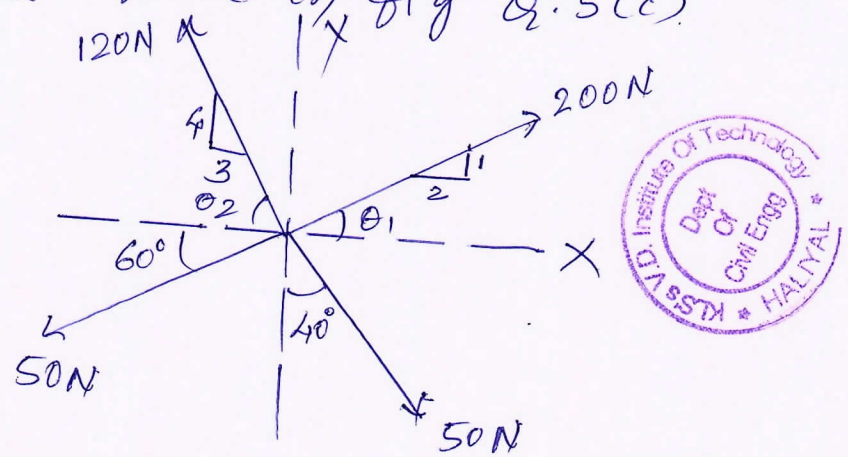
$$F_1 d_1 + F_2 d_2 = R.d$$

--- Thus proved.

--- 03 M

Total 05 M

Q.5c) Compute the magnitude and direction of the resultant force in fig Q.5(c)



Solu

from given fig.

$\theta_1 = \tan^{-1} 1/2 = 26.56°$

$\theta_2 = \tan^{-1} 4/3 = 53.13°$ ------ 02M

$\Sigma f_x = +200\cos 26.56 - 120\cos 53.13 - 50\cos 60 + 50\cos 50$

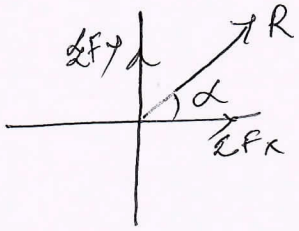
$= +99.75\,N$ ------ 03M

$\Sigma f_y = 200\sin 26.56 + 120\sin 53.13 - 50\sin 60 - 50\sin 50.$

$= 103.82\,N$ ------ 03M

$R = \sqrt{99.75^2 + 103.82^2} = 143.97\,N$

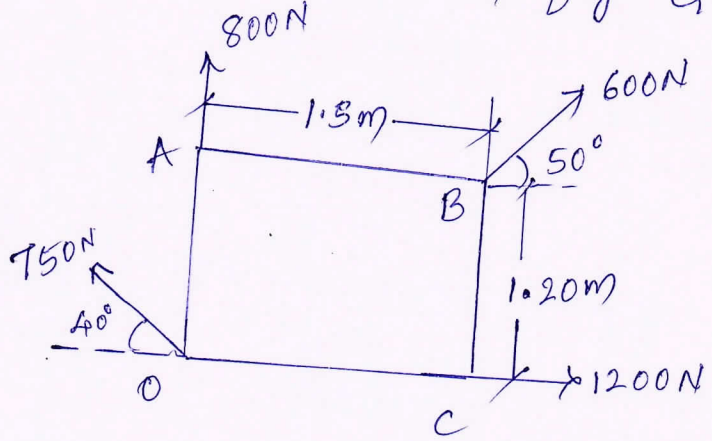
$\alpha = \tan^{-1} \frac{103.82}{99.75} = 46.14°$ ------ 02M



Total 10M.

OR

Q.6 a) Find the magnitude, direction and point of application of the resultant force with respect to point "O" in fig. Q.6(a)



Solu

$\Sigma F_x = +1200 - 750\cos 40 + 600\cos 50$

$= 1011.14\ N$ ——— 03M

$\Sigma F_y = +800 + 600\sin 50 + 750\sin 40$ ——— 03M

$= 1741.72\ N$

$R = \sqrt{1011.14^2 + 1741.72^2} = 2013.95\ N.$ $\alpha = \tan^{-1}\frac{1741.72}{1011.14} = 59.86^\circ$ 01M

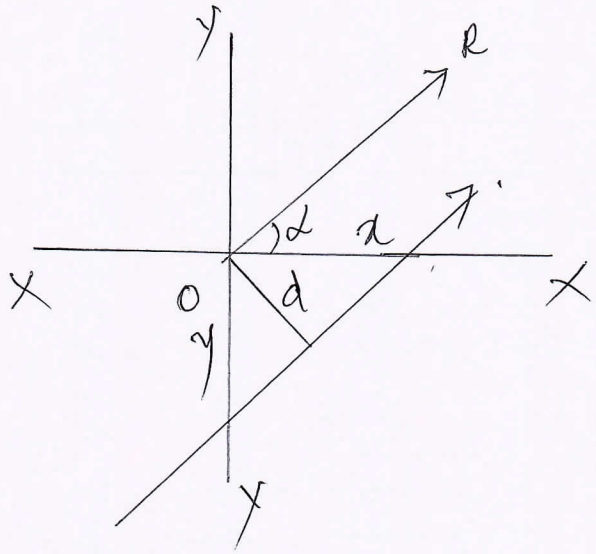
$\Sigma M_O = +600\cos 50 \times 1.2 - 600\sin 50 \times 1.5$ ——— 03M

$= -226.63\ N.m$

$d = \frac{\Sigma M}{R} = \frac{226.63}{2013.94} = 0.112m$

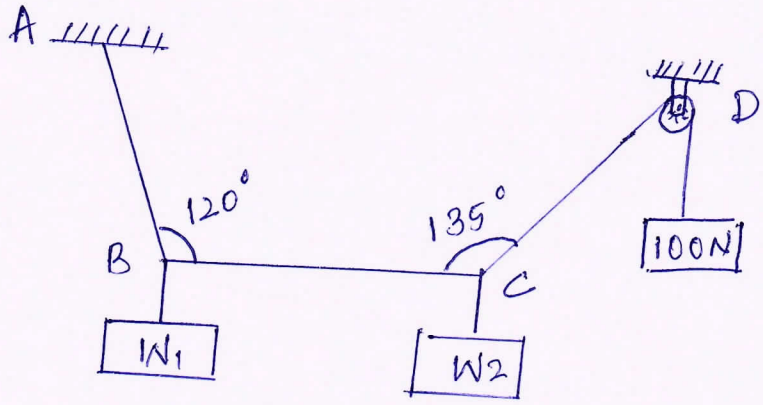
$x = \frac{\Sigma M}{\Sigma F_y} = \frac{226.63}{1741.72} = 0.13\ m$ — 03M

$y = \frac{\Sigma M}{\Sigma F_x} = \frac{226.63}{1011.41} = 0.22\ m$



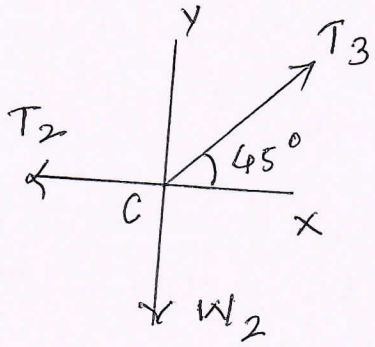
Total 12M.

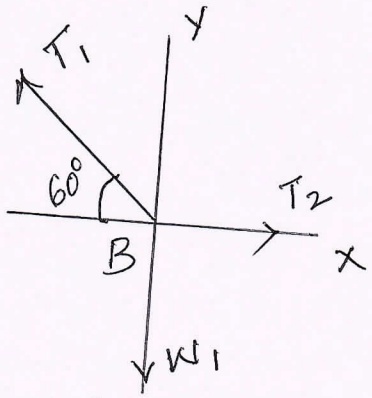
Q 6.b In the fig. Q.6(b) the portion BC of the string is horizontal and pully is frictionless. Determine the tensions in different parts of the string. Also find W_1 & W_2.



Soln Let T_1, T_2 & T_3 be the tensions developed in the string segments AB, BC & CD respectively And given $T_3 = 100N$

FBD for the points C & B are as shown below.





Applying Lami's theorem for point C ——— 02M

$$\frac{T_2}{\sin 135} = \frac{W_2}{\sin 135} = \frac{100}{\sin 90} \quad \text{——— 02M}$$

$$\Rightarrow T_2 = \frac{100 \sin 135}{\sin 90} = 70.71\,N$$

$$W_2 = \frac{100 \sin 135}{\sin 90} = 70.71\,N \quad \Big\} \text{——— 01}$$

Applying Lami's theorem for point B

$$\frac{T_1}{\sin 90} = \frac{W_1}{\sin 120} = \frac{70.71}{\sin 150} \quad \text{——— 02}$$

$$\Rightarrow T_1 = \frac{70.71 \sin 90}{\sin 150} = 141.42\,N$$

$$W_1 = \frac{70.71 \sin 120}{\sin 150} = 122.47\,N \quad \Big\} \text{——— 01}$$

Total 08M.

Q.7 a) Define centroid & centre of gravity.

Ans:

* Centroid:

Geometric centre of a line, area or volume is defined as "centroid". It is the center of mass or balance point of an object, such as a triangle or a plane figure.

– – – 02M.

* Centre of Gravity (C.G)

The centre of gravity is a point in an object where the distribution of weight is equal in all directions, and it does depend on the gravitation field. However, an object's Centre of mass and centre of gravity lies at the same point in a uniform gravitational field.

– – – – 02M

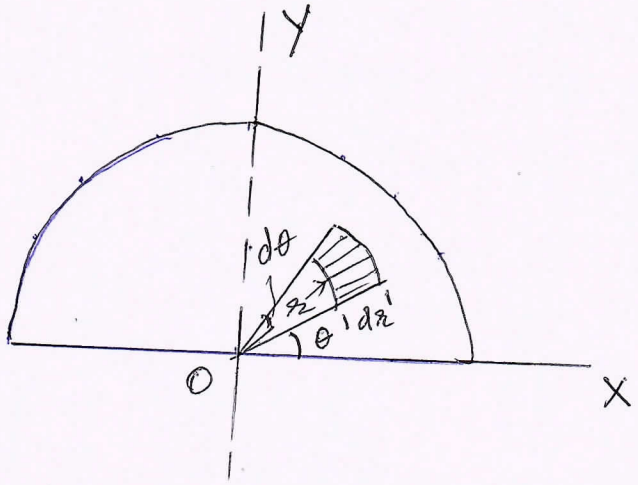
Total 04M

Q.7 b) Find the centroid of semicircle using first principle.

Ans:

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

The elemental area is treated as a rectangle of sides $r\,d\theta$ & dr



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

Its moment about diametral axis x is given by

$r\,d\theta \times dr \times r\sin\theta = r^2 \sin\theta\, d\theta\, dr$ ---- 03M

∴ Total moment of area about diametral axis

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

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

$$= \frac{R^3}{3}\left[1+1\right]$$

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

Area of semicircle $= \frac{\pi R^2}{2}$

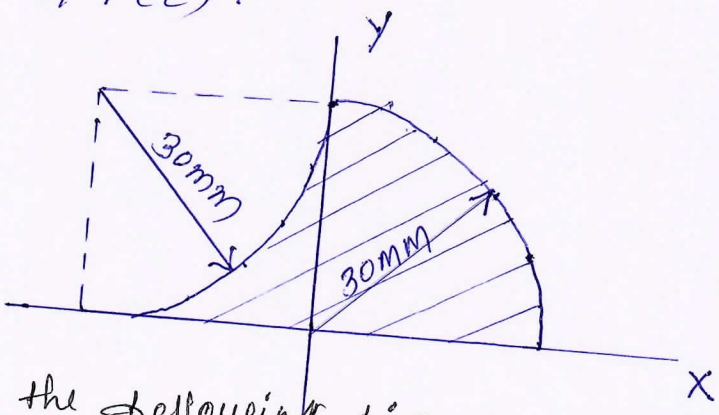
$$\bar{y} = \frac{\text{Moment of area}}{\text{Total area}}$$

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

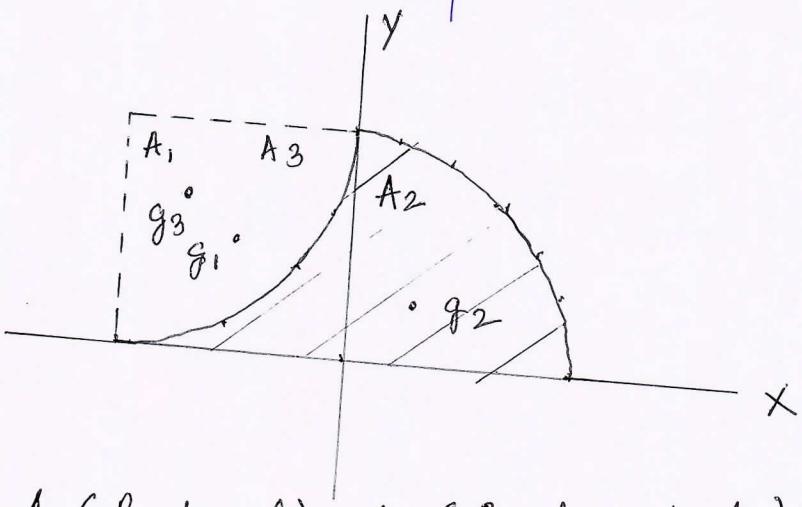
$$\Rightarrow \bar{y} = \frac{4R}{3\pi} \quad \text{---------} \quad 03M$$

Total 06M

Q.7c. Locate the centroid of a shaded area shown in fig. Q.7(c).



Soln Consider the following fig.



Let A_1 (Rectangle), A_2 (Quarter circle) & A_3 (Quarter circle) be the segmental areas & g_1, g_2 & g_3 be their positions of centroids as shown in above fig.

$$A_1 = 30 \times 30 = 900 \text{ mm}^2$$

$$A_2 = \frac{\pi (30)^2}{4} = 706.86 \text{ mm}^2$$

$$A_3 = \frac{\pi (30)^2}{4} = 706.86 \text{ mm}^2$$

$$\Sigma A = A_1 + A_2 - A_3 = 900 + 706.86 - 706.86$$

$$\boxed{\Sigma A = 900 \text{ mm}^2} \quad \text{---} \quad 04 \text{ M}$$

Let $\bar{x}$ & $\bar{y}$ be the coordinates of given composite area.

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

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

$$\Rightarrow \quad \bar{x} = \frac{900 \times 15 + 706.86 \times \frac{4\times 30}{3\pi} + 706.86 \times \frac{4\times 30}{3\pi}}{900}$$

$\bar{x} = 15$ mm — — — — 03M

$$\bar{y} = \frac{900 \times 15 + 706.86 \times \frac{4\times 30}{3\pi} - 706.86 \times \frac{4\times 30}{3\pi}}{900}$$

$\bar{y} = 15$ mm — — — — 03M

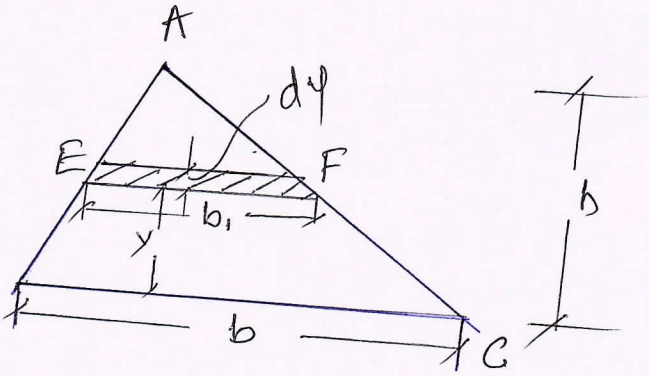
$\therefore \quad G \equiv (5, 15)$

Total 10M.

OR

Q.8 a) Find the centroid of a triangle from first Priniple.

Ans. Consider the Δ^{le} ABC of base width b and height h as shown in fig.



Let us locate the centroid from the base, B

Let b_1 be the width of elemental strip of thickness dy at a distance y from the base.

Since ΔAEF & ΔABC are similar Δ^{les}.

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

$$\Rightarrow b_1 = \left(\frac{h-y}{h}\right) b = \left(1 - \frac{y}{h}\right) b$$ ——— 03M

Area of elemental strip $= dA = b_1 \, dy$

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

Area of $\Delta^{le} = A = \frac{1}{2} bh$

$$\bar{y} = \frac{\text{Moment of area}}{\text{Total area}} = \int \frac{y \, dA}{A}$$

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

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

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

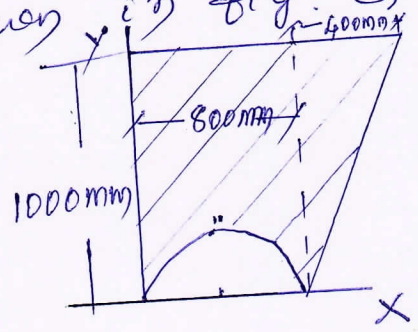
$$= \frac{bh^2}{6}$$

$$\bar{y} = \frac{bh^2}{6} \times \frac{1}{\frac{1}{2} bh}$$ ——— 05M

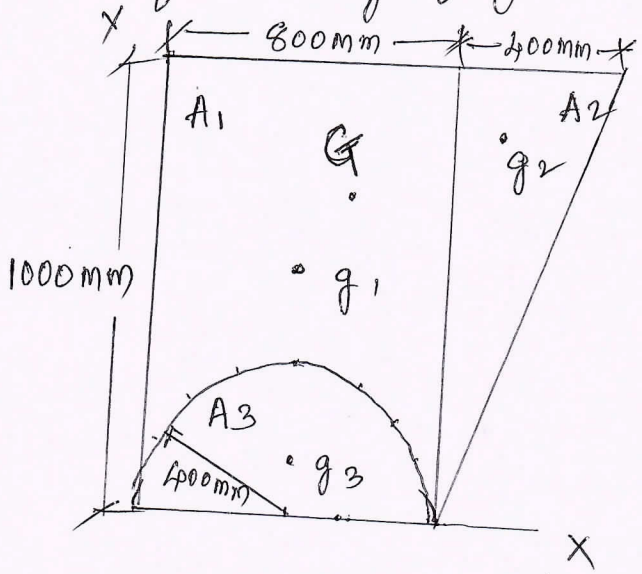
$$\boxed{\bar{y} = \frac{h}{3}}$$

Total 08M

Q.8 b. Determine the centroid of shaded area shown in fig. Q.8 (b)



Soln Consider the following fig.



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

A_1 (Rectangle) $= 1000 \times 800 = 800000\ mm^2$

A_2 (Triangle) $= \frac{1}{2} \times 400 \times 1000 = 200000\ mm^2$

A_3 (Semi ckle) $= \frac{\pi\, 400^2}{2} = 251327.41\ mm^2$

$$\Sigma A = A_1 + A_2 - A_3$$
$$= 8 \times 10^5 + 2 \times 10^5 - 2.51327 \times 10^5$$
$$\Sigma A = 7.48673 \times 10^5\ mm^2 \quad ---\ 04M$$

Let $\bar{x}$ & $\bar{y}$ be the coordinates of centroid G of given composite area.

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

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

$$\Rightarrow \bar{x} = \frac{8\times10^5\times400 + 2\times10^5\times(800+\frac{1}{3}\cdot400) - 2.51327\times10^5\times(400)}{7.48673\times10^5}$$

$$\boxed{\bar{x} = 542.47 \text{ mm}} \quad ---- \quad 04M$$

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

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

$$\bar{y} = \frac{8\times10^5\times500 + 2\times10^5\times\frac{2}{3}\cdot1000 - 2.51327\times10^5\times(\frac{4\times400}{3\pi})}{7.48673\times10^5}$$

$$= \frac{4000\times10^5 + 1333.333\times10^5 - 426.6659\times10^5}{7.48673\times10^5}$$

$$\boxed{\bar{Y} = 655.38 \text{ mm}}$$

$$\therefore \quad G \equiv (542.47, 655.38) \quad ---- \quad 04M$$

Total 12M.

Module. 5

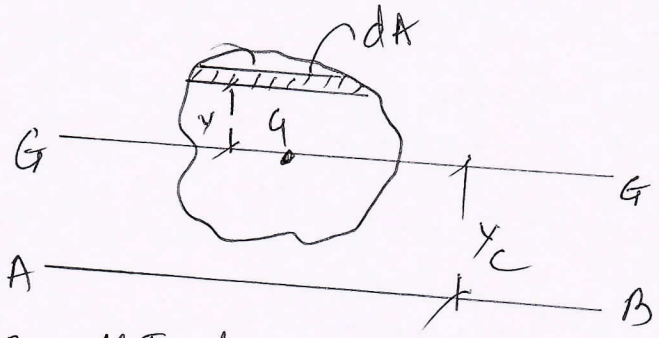
Q. 9 a) State and prove parallel & perpendicular Axis theorem.

Ans: * Parallel axis theorem:

Statement: It states that the moment of Inertia about any axis in the plane of an area is equal to the sum of MI about a parallel centroidal axis and the product of area and square

of the distance between the two parallel axis. ——— 02

Proof: Consider the following fig.



Let I_{AB} = MI about axis AB

I_{GG} = MI about centroidal axis GG parallel to AB

A = Area of plane fig.

y_c = dist bet^n AB & GG.

$$I_{AB} = \int (y + y_c)^2 dA$$

$$= \int (y^2 + y_c^2 + 2yy_c) dA$$

$$\Rightarrow = \int y^2 dA + \int 2y y_c dA + \int y_c^2 dA$$

Now $\int y^2 dA$ = MI about GG = I_{GG}

$$\int 2yy_c dA = 2y_c \int y dA$$

$$= 2y_c A \frac{\int y dA}{A}$$

In the above term $2y_cA$ is the dist of centroid from the reference axis GG. Since GG is passing through the centroid itself $\frac{\int y dA}{A}$ is zero hence the term $\int 2yy_c dA$ is zero.

$$\int y_c^2 dA = y_c^2 \int dA$$

$$\Rightarrow = A y_c^2$$

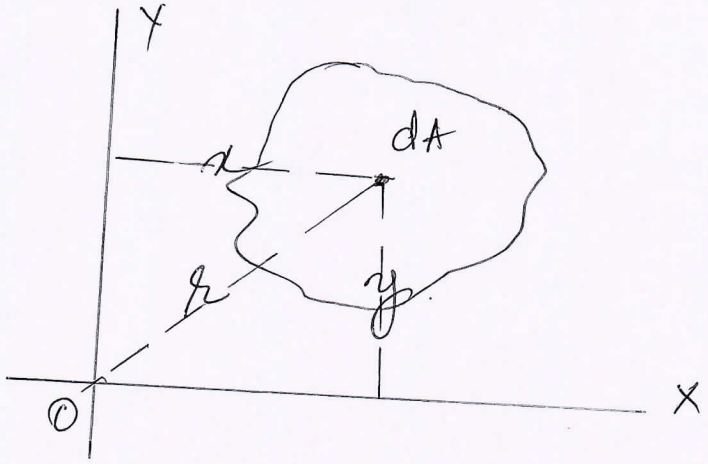
$$\therefore \boxed{I_{AB} = I_{GG} + A y_c^2}$$ — hence proved. 03M

TOTAL 15M

* Perpendicular Axis theorem:

Statement: It states that "The MI of area about an axis perpendicular to its plane (polar moment of Inertia) at any point 'O' is equal to sum of MIs about any two mutually perpendicular axis through the same point 'O' and lying in the plane of the area. ---- 02M

Proof: Consider the following figure.



Let us Consider an elemental area dA at a distance r from 'O'. Let the coordinates of dA by x & y. thus from definition

$$I_{zz} = \int r^2 dA$$

$$= \int (x^2 + y^2) dA$$

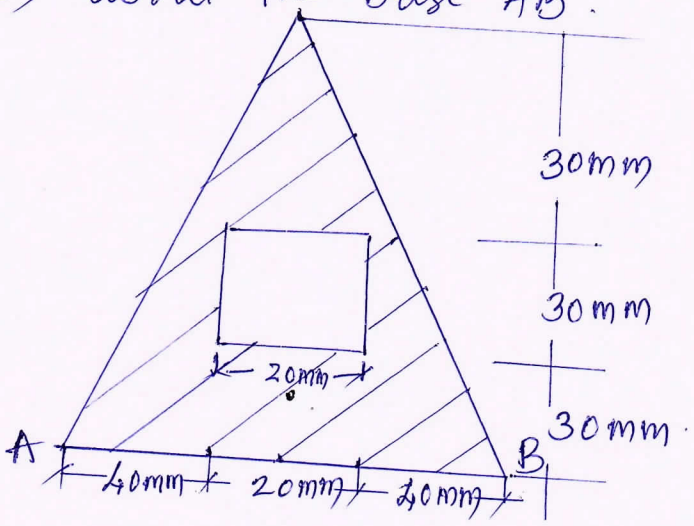
$$I_{zz} = \int x^2 dA + \int y^2 dA$$

$$I_{zz} = I_{xx} + I_{yy}$$ thus proved. ---- 03M

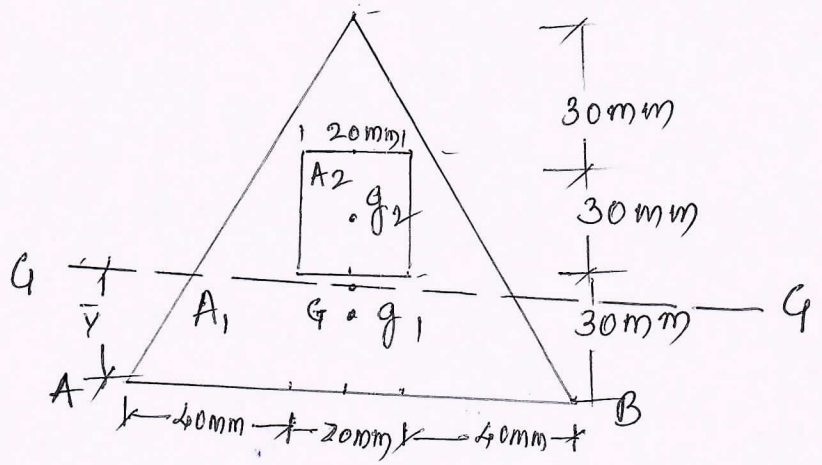
05 M

G.T 10M

Q.9 b) Determine the moment of inertia and radius of gyration of the shaded area shown in fig. 9(b) about the base AB.



Sol^{n} Consider the following figure.



Let A_1 & A_2 be the segmental areas & g_1 & g_2 be their centroids as shown in figure.

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

A_2 (Rectangle) $= 20 \times 30 = 600 mm^2$

$\Rightarrow \Sigma A = A_1 - A_2$

$= 4500 - 600$

$\Sigma A = 3900 mm^2$ ---- 03M.

Let $\bar{x}$ & $\bar{y}$ be the coordinates of centroid G of given area.

Due to symmetry about y axis.

$$\bar{x} = 0 \quad \text{and}$$

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

where $\bar{y}_1$ & $\bar{y}_2$ be the y coordinates of q_1 & q_2 respectively.

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

$$\bar{y} = 27.69 \text{ mm} \quad \text{---} \quad 03M.$$

Applying parallel axis theorem.

$$I_{AB} = \frac{100 \times 90^3}{36} + 4500 \times (30)^2 - \left[\frac{20 \times 30^3}{12} + 600(45)^2\right]$$

$$= 2025000 + 4050000 - 45000 - 1215000$$

$$= 4.8150 \times 10^6 \text{ mm}^4 \quad \text{---} \quad 03M$$

$$K_{AB} = \sqrt{\frac{I_{AB}}{A}} = \sqrt{\frac{4.8150 \times 10^6}{3900}}$$

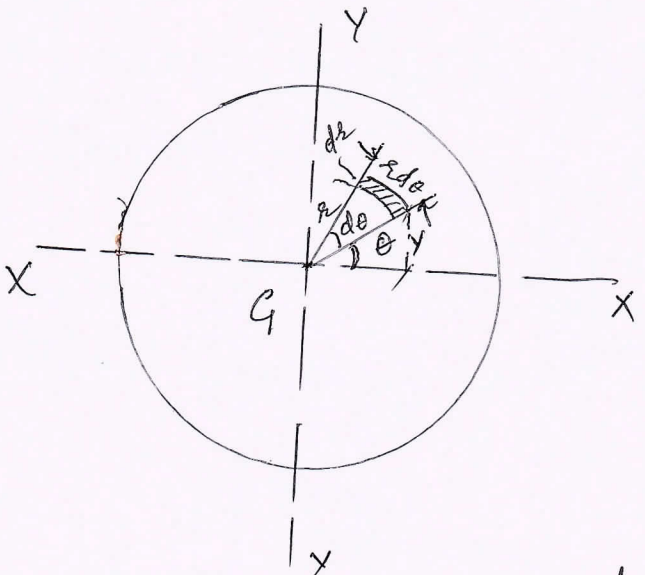
$$\Rightarrow \quad K_{AB} = 35.44 \text{ mm} \quad \text{---} \quad 01M$$

Total 10M.

OR

Q.10a.) Derive an expression for moment of inertia of a circle along it's centroidal axis. (I_{xx} and I_{yy})

Ans: Consider a Ckt of Radius R as shown below in figure.



Consider an element of sides $r\,d\theta$ & dr at distance y from $x\,x$ as shown in fig.

Its moment of inertia about the diametrical axis or centroidal axis $x-x$ is

$$= y^2\,dA$$

$$= (r\sin\theta)^2\, r\,d\theta\,dr$$

$$= r^3 \sin^2\theta\,d\theta\,dr \quad \text{---------- 04M}$$

$\therefore$ MI of circle about $x-x$ is given by

$$I_{xx} = \int_0^R \int_0^{2\pi} r^3 \sin^2\theta\,d\theta\,dr$$

$$= \int_0^R \int_0^{2\pi} r^3 \frac{(1-\cos 2\theta)}{2}\,d\theta\,dr$$

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

$$= \left[\frac{r^4}{8}\right]_0^R \left[2\pi - 0 + 0 - 0\right]$$

$$= \frac{2\pi}{8} R^4$$

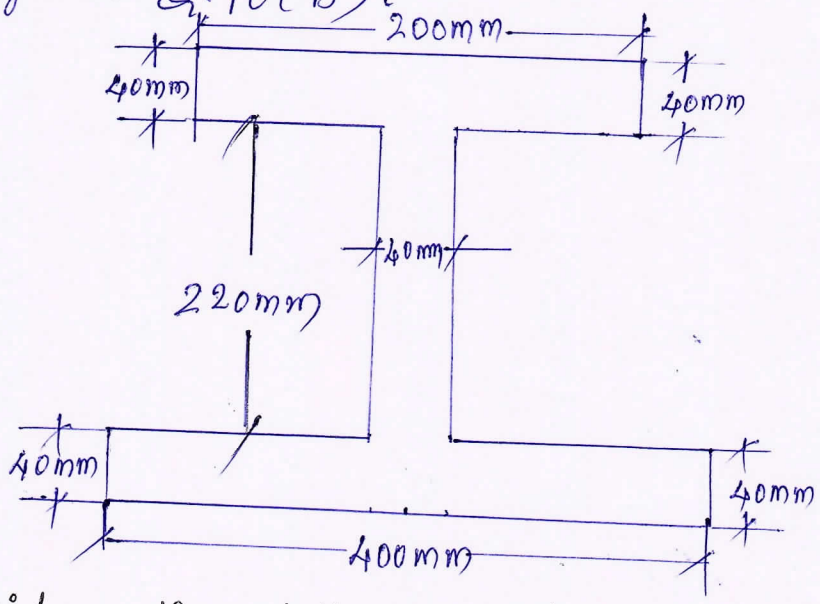
$$\Rightarrow I_{xx} = \frac{\pi R^4}{4} \quad \text{---------- 05M}$$

Similarly we can prove x as distance of element from $x-y$

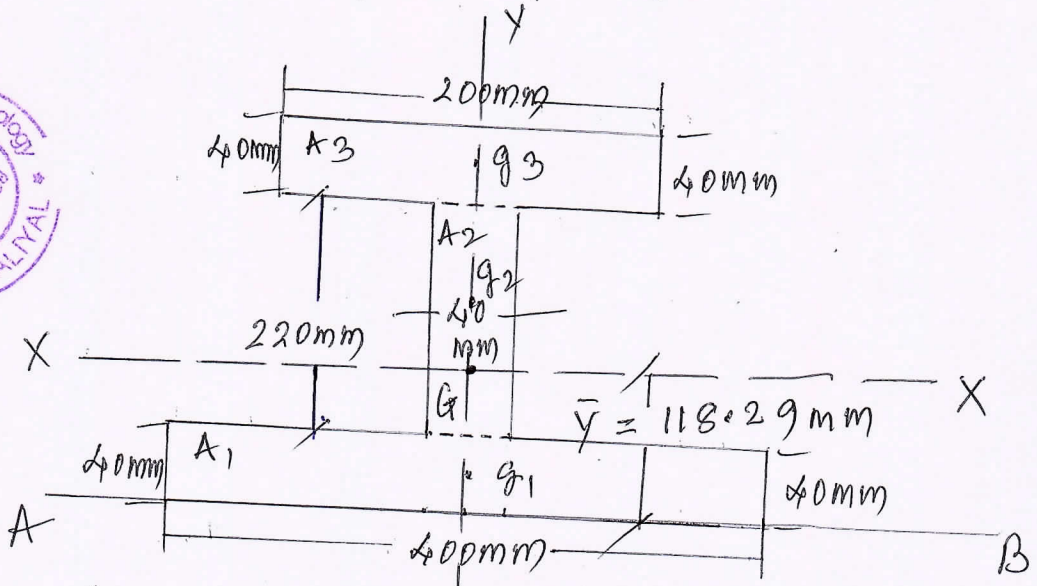
$$I_{yy} = \frac{\pi R^4}{4} \quad \text{---------- 01M}$$

Total 10M

Q.10 b) Determine the polar radius of gyration about the horizontal Centroidal axis for the figure. Q.10(b).



Solu Consider the following fig.



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

$A_1 = 400 \times 40 = 16000\ mm^2$

$A_2 = 220 \times 40 = 8800\ mm^2$

$A_3 = 200 \times 40 = 8000\ mm^2$

$\Sigma A = A_1 + A_2 + A_3 = 16000 + 8800 + 8000$

$\Rightarrow \quad \Sigma A = 32800\ mm^2$ ——— 02M

Let $\bar{x}$ & $\bar{y}$ be the coordinates of centroid G of given composite area.

Due to symmetry

$$\bar{X} = 0.$$

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

$$= \frac{16000 \times 20 + 8800 \times 150 + 8000 \times 280.}{32800.}$$

$$\boxed{\bar{Y} = 118.29 \text{ mm}} \quad \text{---------- 02M}$$

Applying parallel axis theorem.

$$I_{xx} = \frac{400 \times 40^3}{12} + 16000(118.29 - 20)^2$$

$$+ \frac{40 \times 220^3}{12} + 8800(150 - 118.29)^2$$

$$+ \frac{200 \times 40^3}{12} + 8000(280 - 118.29)^2$$

$$= 2.1333 \times 10^6 + 154.574 \times 10^6 + 35.493 \times 10^6$$

$$8.848 \times 10^6 + 1.066 \times 10^6 + 209.200 \times 10^6$$

$$\boxed{I_{xx} = 411.314 \times 10^6 \text{ mm}^4.} \quad \text{---------- 03M}$$

$$I_{yy} = \frac{40 \times 400^3}{12} + \frac{220 \times 40^3}{12} + \frac{40 \times 200^3}{12}$$

$$= 2.56 \times 10^9 + 0.01173 \times 10^9 + 0.26666 \times 10^9$$

$$= 2.83839 \times 10^9 \text{ mm}^4.$$

$$\boxed{I_{yx} = 2.83839 \times 10^9 \text{ mm}^4.} \quad \text{---------- 01M}$$

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

$$= 0.411314 \times 10^9 + 2.83839 \times 10^9$$

$$\boxed{I_{zz} = 3.249704 \times 10^9 \text{ mm}^4.}$$ ——— 01M

$$K_{zz} = \sqrt{\frac{I_{zz}}{A}}$$

$$= \sqrt{\frac{3.249704 \times 10^9}{32800.}}$$

$$\boxed{K_{zz} = 314.76 \text{ mm}.}$$ ——— 01 M

Total 10M.

(Staff Incharge)

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

(Dr. G Hatti)