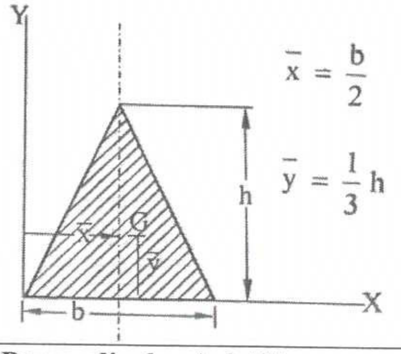
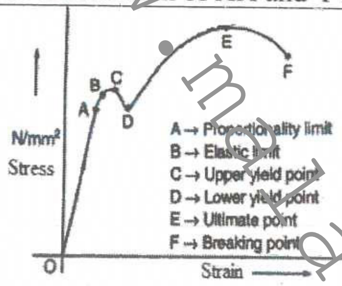
Version - B.

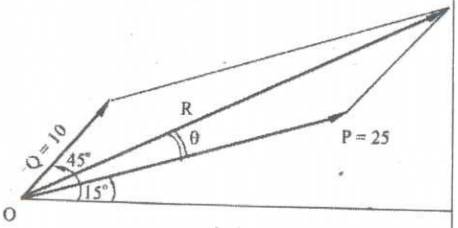
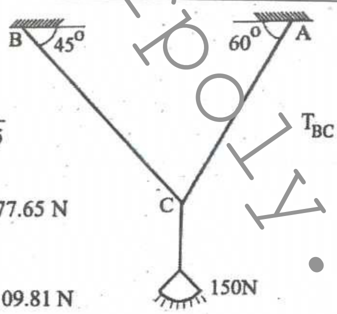
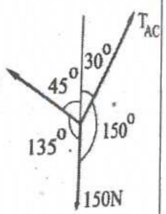
Scoring Indicator

Course Name: **Engineering Mechanics**

Course Code: **Rev (21)-2021** QID: 2106220011

Q.No	Scoring Indicator	Split Score	Sub Total	Total Score
	PART - A			9
I.1	Concurrent		1	
I.2	Newton		1	
I.3	Normal		1	
I.4	Limiting Friction		1	
I.5	Centre of Gravity		1	
I.6	Centroidal axis		1	
I.7	Strain		1	
I.8	Brittleness		1	
I.9	Poisson's ratio		1	
	PART - B			24
II.1	**Vector Quantity-** quantity which is completely specified by magnitude and direction, is known as a vector quantity. Examples: velocity, acceleration, force and momentum **Scalar Quantity.** A quantity, which is completely specified by magnitude only, is known as a scalar quantity. Examples: mass, length, time and temperature.	1.5 1.5	3	
II.2	The product of a force and the perpendicular distance of the line of action of the force from a point is known as moment of the force about that point.	3	3	
II.3	It states, " if three coplanar forces acting at a point be in equilibrium, then each force is proportional to the sine of the angle between the other two forces." Mathematically, $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$, where P,Q,R are the three forces and α, β, γ are the angles.	Statement -3 mark	3	
II.4	Simple, Roller, Pin joint (hinged), smooth surface, fixed (built-in) supports.	Any 3 - 3 mark	3	
II.5	It is the angle between the normal reaction at the contact surface and the resultant of normal reaction and limiting friction. It is denoted by 'ϕ'. $\tan\phi = F/R_N$. Angle of friction, $\phi = \tan^{-1}\mu$	3	3	

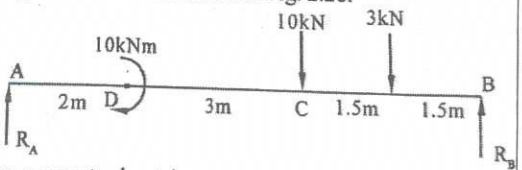
II.6		Eqn - 1.5 Fig- 1.5	3	
II.7	**Perpendicular Axis Theorem**: If I_{XX} and I_{YY} are the moment of inertia of an area A about mutually perpendicular axis XX and YY, in the plane of the area, then the moment of inertia of the area about the ZZ axis which is perpendicular to XX and YY axis and passing through the point of intersection of XX and YY axis is given by $I_{ZZ} = I_{XX}+I_{YY}$.	3	3	
II.8		Fig- 1.5 mark. Labeling any 3 points- 1.5 mark	3	
II.9	(a) Hardness: It is defined as the ability of a material to resist abrasion, scratching or indentation. (b) Toughness: The ability of a material to absorb energy before fracture is called toughness	1.5 mark 1.5 mark	3	
II.10	**Modulus of Rigidity:** it is the ratio of shear stress to shear strain with in the elastic limit and is denoted by "G" or "C" or "N". it is also called shear modulus. Mathematically, $\tau \alpha \varphi$.	3 mark	3	
	PART - C			42

III.1	Solution : P = 25 N Q = 10 N $\alpha = 45 - 15 = 30^0$  Resultant, $R = \sqrt{P^2 + Q^2 + 2PQ\cos\alpha}$ $= \sqrt{25^2 + 10^2 + 2 \times 25 \times 10 \times \cos 30}$ R = 34.03 N. The inclination of resultant force with the direction of force P, $\theta = \tan^{-1}\dfrac{\sin\alpha}{\cos\alpha + \dfrac{P}{Q}}$ $\theta = \tan^{-1}\dfrac{\sin 30}{\cos 30 + \dfrac{25}{10}}$ $\theta = 8.45^0$ Inclination of resultant with horizontal is $15^0 + \theta$ $= 15^0 + 8.45^0$ $= 23.45^0$	Resultant- 4 marks & Angle – 3 marks. (Fig not necessary)	7	7
III.2	Solution Using Lami's theorem $\dfrac{150}{\sin 75} = \dfrac{T_{BC}}{\sin 150} = \dfrac{T_{AC}}{\sin 135}$ $T_{BC} = \dfrac{150 \times \sin 150}{\sin 75} = 77.65\ N$ $T_{AC} = \dfrac{150 \times \sin 135}{\sin 75} = 109.81\ N$   	Finding Tensions- 3 mark each, Fig- 1 mark	7	7

III.3

Solution.

Consider the free- body diagram of the beam shown in Fig. 2.28.



For $\Sigma F_V = 0$

$R_A - 10 - 3 + R_B = 0$

$R_A + R_B = 13$ kN

For $\Sigma M = 0$, taking moments about A,

$10 + 10 \times 5 + 3 \times 6.5 - R_B \times 8 = 0$

$R_B = 9.94$ kN

$R_A + 9.94 = 13$

$R_A = 13 - 9.94$

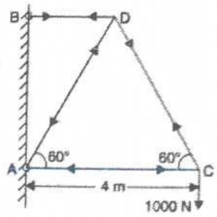
$= 3.06$ kN

FBD- 3 mark, Reactions – 2 each | 7 | 7

III.4

Sol. Here the calculations can be started from end *C*. Hence consider the equilibrium of the joint *C*.

Joint C



Let F_{CD} = Force in member *CD*, and

F_{CA} = Force in member *CA*.

Their assumed directions are shown in Fig. 6.20.

Resolving the force vertically, we get

$F_{CD} \times \sin 60° = 1000$

$\therefore \quad F_{CD} = \frac{1000}{\sin 60°} = \frac{1000}{0.866} = 1154.7$ N (Tensile)

Resolving the forces horizontally, we get

$F_{CA} = F_{CD} \times \cos 60°$

$= 1154.7 \times 0.5$

$= 577.35$ N (Compressive)

Now consider the equilibrium of the joint *D*.

Joint D

[See Fig.]

The force $F_{CD} = 1154.7$ N (tensile) is already calculated.

Let F_{AD} = Force in member *AD*, and

F_{BD} = Force in member *BD*.

Their assumed directions are shown in Fig.

Resolving the forces vertically, we get

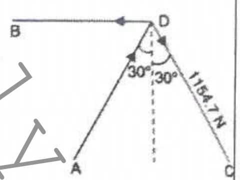


Fig.

$F_{AD} \cos 30° = 1154.7 \cos 30°$

$\therefore \quad F_{AD} = \frac{1154.7 \cos 30°}{\cos 30°} = 1154.7$ N

(Compressive)

Resolving the forces horizontally, we get

$F_{BD} = F_{AD} \sin 30° + F_{DC} \sin 30°$

$= 1154.7 \times 0.5 + 1154.7 \times 0.5$

$= 1154.7$ N (Tensile)

Now the forces are shown in a tabular form below :

Member	*Force in the member*	*Nature of force*
AC	577.35 N	Compressive
CD	1154.7 N	Tensile
AD	1154.7 N	Compressive
BD	1154.7 N	Tensile

Forces- 1.5 marks each & Fig: 1 | 7 | 7

III.5

TYPES OF LOADING

The following are the important types of loading:

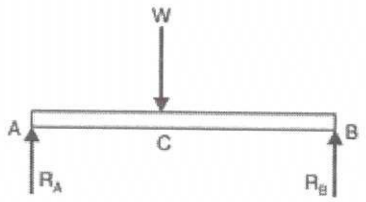
(a) Concentrated or point load,

(b) Uniformly distributed load, and

(c) Uniformly varying load

3 + 2 + 2 | 7 | 7

Concentrated or point load: When loads are applied at certain points in the beam, the loads are said to be point loads or concentrated loads.



Uniformly Distributed Load.

Uniformly Distributed Load (UDL) is a load which has the same intensity of load over a certain length of the beam. The total load will be w * x, where w is the intensity of load and x is the loaded length. For calculating reaction at supports this load can be assumed to be acting as a point load at the middle of the loaded length.

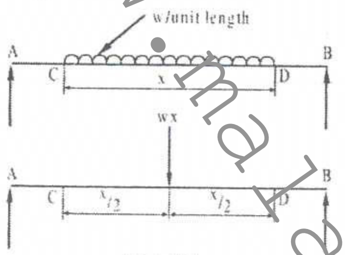
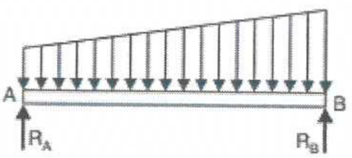
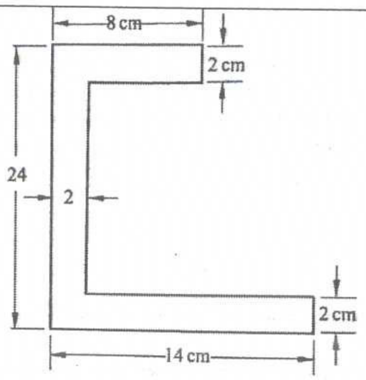
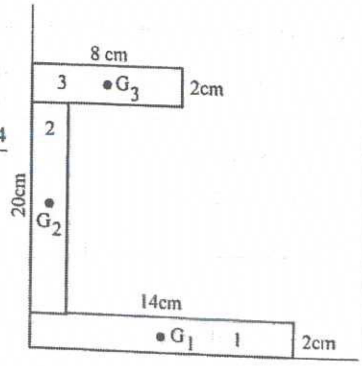


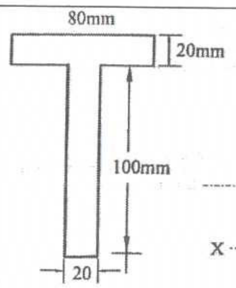
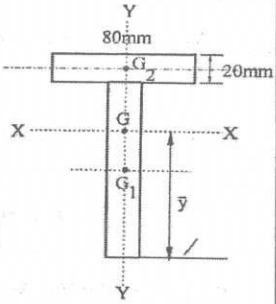
Fig.1.157

Uniformly Varying Load: A beam AB, which carries load in such a way that the rate of loading on each unit length of the beam varies uniformly. This type of load is known as uniformly varying load. The total load on the beam is equal to the area of the load diagram. The total load acts at the C.G. of the load diagram



III.6	Whenever a body moves or tends to move over another body, a force opposite to the direction in which the body moves or tends to move is developed at the constant surfaces. This force is called frictional force or simply friction. Laws of dry friction 1) The force of friction always acts in a direction opposite to the direction in which the body moves or tends to move. 2) Till the limiting value is reached, the magnitude of friction is equal to the force which tends to move the body. 3) The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two contact surfaces. 4) The force of friction depends upon the roughness of the surfaces in contact. 5) The force of friction is independent of the area of contact between the two surfaces. 6) For low velocities, the frictional force is independent of magnitude of velocity. But generally, the dynamic friction is less than the limiting friction.	Definition- 1 mark, each law -1 mark	7	7

III.7	Solution $a_1 = 14 \times 2 = 28\ cm^2$; $a_2 = 20 \times 2 = 40\ cm^2$ $a_3 = 8 \times 2 = 16\ cm^2$ $x_1 = \frac{14}{2} = 7\ cm$ $x_2 = \frac{2}{2} = 1\ cm$ $x_3 = \frac{8}{2} = 4cm$  $y_1 = \frac{2}{2} = 1cm \quad y_2 = 2 + \frac{20}{2} = 12\ cm$ $y_3 = 2 + 20 + \frac{2}{2} = 23cm$ $\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3}{a_1 + a_2 + a_3}$ $= \frac{28 \times 7 + 40 \times 1 + 16 \times 4}{28 + 40 + 16}$ $= 3.57\ cm$  $\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3}{a_1 + a_2 + a_3}$ $= \frac{28 \times 1 + 40 \times 12 + 16 \times 23}{28 + 40 + 16}$ $= 10.43\ cm$	Finding centroid- 3 marks each, Fig- 1 mark	7	7

III.8	axes. Solution.  $A_1 = 100 \times 20 = 2000\ mm^2$ $A_2 = 80 \times 20 = 1600\ mm^2$ $y_1 = \frac{100}{2} = 50mm$ $y_2 = 100 + \frac{20}{2} = 110mm$  $\bar{y} = \frac{A_1y_1 + A_2y_2}{A_1 + A_2} = \frac{2000 \times 50 + 1600 \times 110}{(2000 + 1600)}$ $= 76.67\ mm$ Moment of inertia of section (i) about its own horizontal centroidal axis is IG_{1XX} $IG_{1XX} = \frac{20 \times 100^3}{12} = 1666666.67\ mm.$ Moment of inertia of section (2) about its own horizontal centroidal axis is $IG_{2XX} = \frac{80 \times 20^3}{12} = 53333.33\ mm^4$ $IG_{XX} = (IG_{1XX} + A_1h_1^2) + (IG_{2XX} + A_2h_2^2)$ h_1 and h_2 are the vertical distances of G_1 and G_2 from G $h_1 = \bar{y} - y_1 = 76.67 - 50 = 26.67$ $h_2 = y_2 - \bar{y} = 110 - 76.67 = 33.33$ $IG_{XX} = 1666666.67 + (2000 \times 26.67^2) + 53333.33 + (1600 \times 33.33^2)$ $= 4.92 \times 10^6\ mm^4$ Since G_1, G_2 and G are on the same YY axis, $IG_{YY} = IG_{1YY} + IG_{2YY}$ IG_{1YY} is the M.I of section (1) about its own vertical centroidal axis, and IG_{2YY} is the M.I of section (2) about its own vertical centroidal axis. $IG_{YY} = \frac{100 \times 20^3}{12} + \frac{20 \times 80^3}{12}$ $= 9.2 \times 10^5\ mm^4$	Finding IGxx and I Gyy- 3 marks each, Fig- 1 mark	7	7

III.9

Solution.

$a_1 = 80 \times 40 = 3200\ mm^2$

$a_2 = \frac{1}{2} \times 40 \times 40 = 800\ mm^2$

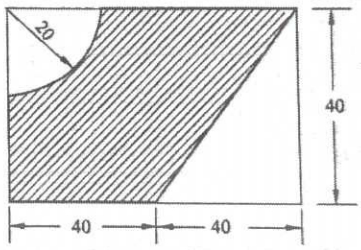
$a_3 = \frac{\pi r^2}{4} = \frac{\pi \times 20^2}{4} = 314.16 mm^2$

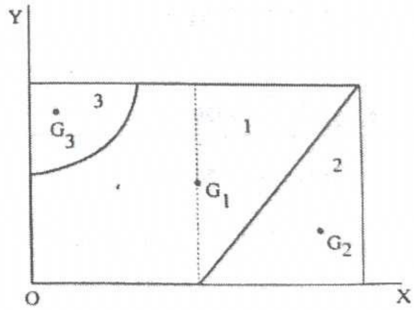
$x_1 = \frac{80}{2} = 40\ mm$

$x_2 = (80 - \frac{1}{3} \times 40) = 66.67 mm$

$x_3 = \frac{4r}{3\pi} = \frac{4 \times 20}{3\pi} = 8.49 mm$

$y_1 = \frac{40}{2} = 20\ \ mm$





$y_2 = \frac{1}{3} \times 40 = 13.33\ mm$

$y_3 = (40 - \frac{4 \times 20}{3\pi}) = 31.51 mm$

$\bar{x} = \frac{a_1 x_1 - a_2 x_2 - a_3 x_3}{a_1 - a_2 - a_3} = \frac{3200 \times 40 - 800 \times 66.67 - 314.16 \times 8.49}{3200 - 800 - 314.16}$

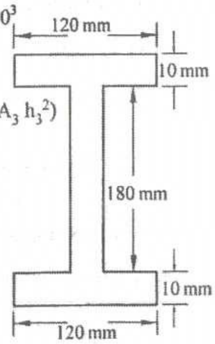
$= 34.52\ mm$

$\bar{y} = \frac{a_1 y_1 - a_2 y_2 - a_3 y_3}{a_1 - a_2 - a_3} = \frac{3200 \times 20 - 800 \times 13.33 - 314.16 \times 31.51}{(3200 - 800 - 314.16)}$

$= 20.82\ mm$

Finding centroid- 3 marks each, Fig- 1 mark

7 | 7

III.10	Solution The section is symmetrical with respect to centroidal X X and YY axes. Since G_1, G_2, G_3 and G are on the same Y – Y axis, $I_{G_{YY}} = I_{G_{1YY}} + I_{G_{2YY}} + I_{G_{3YY}}$. $= \frac{1}{12}\times10\times120^3 + \frac{1}{12}\times180\times10^3 + \frac{1}{12}\times10\times120^3$ $= 2895000 \text{ mm}^4$  $I_{G_{XX}} = (I_{G_{1XX}} + A_1h_1^2) + (I_{G_{2XX}} A_2h_2^2) + (I_{G_3XX} + A_3 h_3^2)$ h_1, h_2 and h_3 are the vertical distance GG_1, GG_2 and GG_3. $I_{G_{1XX}} = I_{G_{3XX}} = \frac{1}{12} \times 120 \times 10^3 = 10000 \text{ mm}^4$ $I_{G2_{XX}} = \frac{1}{12} \times 10 \times 180^3 = 4860000 \text{ mm}^4$ $h_1 = h_3 = 100 - 5 = 95 \text{ mm}, \; h_2 = 0$ $I_{G_{XX}} = (10000 + 1200 \times 95^2) \times 2 + (4860000 + 180 \times 10 \times 0)$ $= 26540000 \text{ mm}^4$	Finding IGxx -5 marks, Fig- 2 mark	7	7
III.11	**Solution:** Given Diameter of a steel specimen, d = 14 mm Length of a steel specimen, l = 200 mm Extension of the steel rod δl = 0.2 mm Tensile load, P = 40 kN = 40 $\times 10^3$ N Area of the rod, A $= \frac{\pi}{4}d^2 = \frac{\pi}{4}\times14^2 = 153.94 \text{ mm}^2$ We know that stress, $\sigma = \frac{Load}{Area} = \frac{40\times10^3}{153.94} = 259.84 \text{ N/ mm}^2$ Strain is given by the equation, $\varepsilon = \frac{\delta l}{l} = \frac{0.2}{200} = 0.001$ Youngs Modulas, E $= \frac{Stress}{Strain} = \frac{259.84}{0.001} = 259840 \text{ N/mm}^2$	Finding stress- 2, strain -2, Youngs Modulus -3 marks.	7	7

III.12	**Solution:** Given Width of the bar, b = 50mm Thickness of the bar, t = 12mm Length of the bar, l = 300 mm Load, P = 84kN = 84×10^3 N E = 2×10^5 N/ mm² Poissons ratio, μ = 0.32 Area of the bar, A = b × t = 50 × 12 = 600 mm² We know that $\delta l = \frac{Pl}{AE} = \frac{84 \times 10^3 \times 300}{600 \times 2 \times 10^5} = 0.021$ mm Strain, $\varepsilon = \frac{\delta l}{l} = \frac{0.021}{300} = 0.00007$ Lateral strain, $\varepsilon_L = \mu \times \varepsilon = 0.32 \times 0.00007 = 0.0000224$ $\delta b = b \times \varepsilon_L = 50 \times 0.0000224 = 0.00112$ mm $\delta t = t \times \varepsilon_L = 12 \times 0.0000224 = 0.00268$ mm	Finding length- 2, width -2, Thickness -3 marks	7	7