ANSWER KEY

ENGINEERING MECHANICS

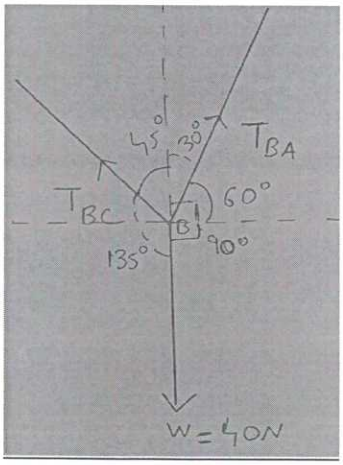
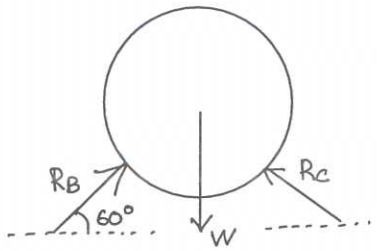
PART A

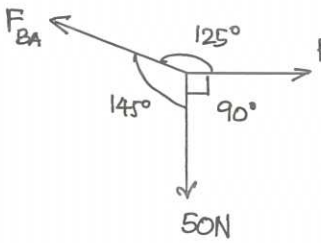
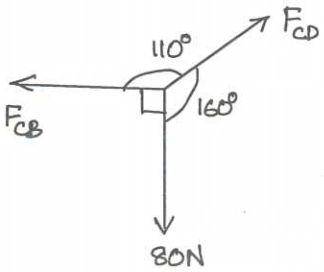
I **Answer all the following questions** **(9 x 1 = 9 Marks)**

Q.No	Answer	Split up	Total Mark
1	Forces may be defined as any action that tends to change the state of rest or motion of a body to which it is applied.	1	1
2	Varignon's theorem states that the moment of a force about any point is equal to the sum of the moments of the components of the force about the same point.	1	1
3	3	1	1
4	A truss is a framed structure consisting of several members joined together to withstand applied loads on the truss.	1	1
5	Limiting friction	1	1
6	Moment of inertia of plane area is a geometrical property of an area which reflects how its points are distributed with regard to an arbitrary axis. **OR** Moment of inertia is the sum of the products of each area in the lamina with the square of its distance from the axis of rotation.	1	1
7	h/3	1	1
8	Deformation	1	1
9	Young's modulus or modulus of elasticity	1	1

II. **PART B**

Q.No	Answer	Split up	Total Mark
1	a) Resultant is a single force that will replace a system of forces and produces the same effect on the rigid body as that of the system of forces. b) If the resultant force is not equal to zero, then the particle can be brought to rest by applying a force equal and opposite to resultant force called the equilibrant. c) The tendency of a force to rotate the body in the direction of its application about a point that is not on the line of application of the force is called moment of a	1 1 1	3

2	 Applying Lami's theorem, $W/\text{Sin } 75 = T_{BC}/\text{Sin } 150 = T_{BA}/\text{Sin } 135$ $T_{BC} = 20.70$ N, $T_{BA} = 29.28$ N	1 1 1	3
3		1 mark for each reaction	3
4	A simply supported beam is supported at both ends. One end of the beam is supported by hinged support and the other end byroller support. A cantilever beam is a structural member of which one end isfixed and other end is free	1.5 1.5	3
5	1. Dry friction – friction which develops between dry surfaces. a) Static friction- friction experienced by the body when it is at rest. b) Dynamic friction- friction experienced by the body when it is in motion. Again classified as sliding and rolling friction. 2. Fluid friction- friction which develops when the contacting surfaces are separated by fluid medium.	1 1 1 1	3
6	Radius of gyration- radius of gyration of an area about an axis is the distance to a long narrow strip whose area is equal to the area of the lamina and whose moment of inertia remain the same as that of the original area. Polar moment of inertia- the moment of inertia of a plane lamina about an axis perpendicular to the lamina and passing through the centroid is called polar moment of inertia.	1.5 1.5	3

	OR		
2.	Considering equilibrium at point B  Applying Lami's theorem $\frac{F_{BC}}{\sin 145} = \frac{F_{BA}}{\sin 90} = \frac{50}{\sin 125}$ -(1) $F_{BC} = 35\ kN$ $F_{BA} = 61\ kN$  Applying Lami's theorem $\frac{F_{CD}}{\sin 90} = \frac{F_{CB}}{\sin 160} = \frac{80}{\sin 110}$ $F_{CD} = 85.13\ kN$ $F_{CB} = 29.11\ kN$	1.5 1 1 1.5 1 1	7

6.

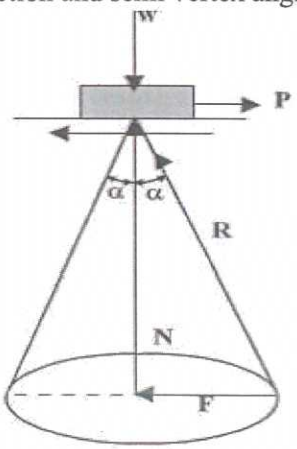
a) Coefficient of friction- Ratio of limiting force of friction to the normal reaction between the two bodies.

$$\mu_s = \frac{\text{Limiting force of Friction}}{\text{Normal Reaction}} = \frac{Fs}{N}$$ — 2

b) Angle of friction- angle made by the resultant of the normal reaction and frictional force to the normal reaction. Denoted by ϕ — 1.5

c) Angle of repose- maximum inclination of a plane at which a body remains in equilibrium over the inclined plane by assistance of friction alone. — 15

d) Cone of friction – right circular cone with vertex at the point of contact of two surfaces, axis in the direction of the normal reaction and semi vertex angle equal to the angle of friction. — 2



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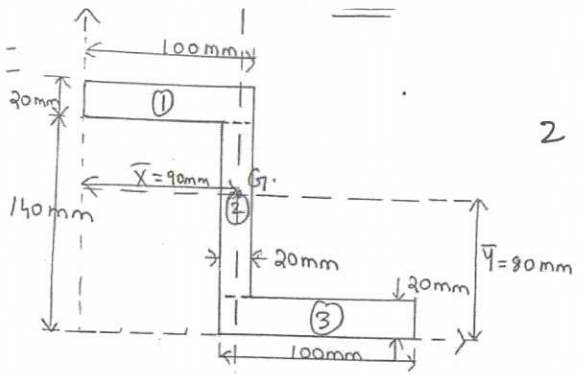
7.



2

$a_1 = 2000\,mm^2$

$a_2 = 2400\,mm^2$

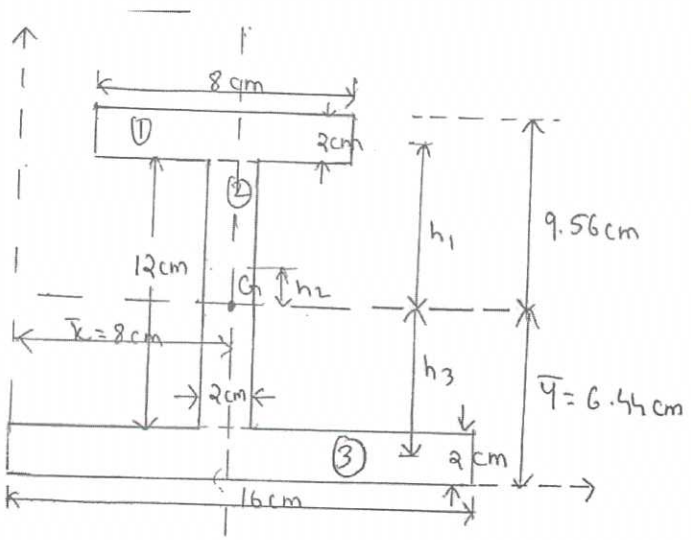
$a_3 = 2000\,mm^2$

$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3}{a_1 + a_2 + a_3} = 90\,mm$$ — 2½

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3}{a_1 + a_2 + a_3} = 80\,mm$$ — 2½

7

8.



$a_1 = 16\ cm^2$

$a_2 = 24 cm^2$

$a_3 = 32 cm^2$

$\bar{x} = 8cm$ — 1

$\bar{y} = \frac{a_1 y_1 + a_2 y_2 + a_3 y_3}{a_1 + a_2 + a_3} = 6.44cm$ — 1

7

$I_{1xx} = 1177.7 cm^2$

$I_{2xx} = 346.4 cm^2$

$I_{3xx} = 957.66 cm^2$

$I_{xx} = I_{1xx} + I_{2xx} + I_{3xx} = 2481.76 cm^4$ — 2

$I_{yy} = I_{1G} + I_{2G} + I_{3G}$

$I_{1G} = 85.33 cm^4$

$I_{2G} = 8 cm^4$

$I_{3G} = 682.67 cm^4$ $\quad I_{yy} = 776 cm^4$ — 2

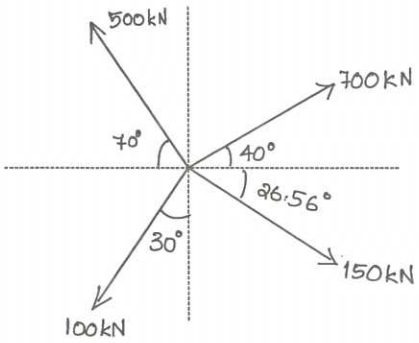
3.	$\Sigma F_y = 0$ $R_A + R_B = 11kN$ $\Sigma M_A = 0 \; ; \; R_B \times 5 - 6(2+1.5) - 5\times 1 = 0$ $\Rightarrow R_A = 5.8kN$ $R_B = 5.2kN$	2 1 2 2	7
4.	Friction is defined as the force that opposes the motion of a solid object over another. There are mainly four types of friction: static friction, sliding friction, rolling friction, and fluid friction. 1. Friction always acts in the direction opposite to the motion or impending motion. 2. The limiting friction is directly proportional to the normal reaction. 3. Until the motion starts the static frictional force adjust itself to just balance the force tending to produce motion. 4. Friction is independent of the area of contact between the two surfaces but depends on the roughness of the surface. 5. Kinetic friction also bears a constant ratio with normal reaction but this ratio is slightly less than that in the case of limiting friction. For moderate speeds, friction remains constant but it decreases slightly for higher speeds.	2 5	7

7	Parallel axis theorem- Parallel axis theorem states that the moment of inertia of a plane lamina about any axis is equal to the sum of the moment of inertia about a parallel axis passing through the centroid and the product of area and square of the distance between the two parallel axes. $I_x = \bar{I}_x + Ah^2$	2 1	3
8	a) Poisson's ratio- ratio of lateral strain to longitudinal strain. b) Rigidity modulus- ratio of shearing stress to shearing strain within elastic limit. c) Bulk modulus- ratio of identical pressure acting at three mutually perpendicular directions to corresponding volumetric strain.	1 1 1	3
9	a) Elasticity: The ability of an object or material to resume or regain its normal shape or original shape after being stretched or compressed called Elasticity. b) Hardness: property by which the material can resist localized plastic deformation due to abration or penetration. c) Toughness: t is the state of being strong enough in order to withstand adverse conditions or rough handling called Toughness	1 1 1	3
10	$E = 2G(1+\mu) \Rightarrow \mu = 0.25 \quad E = 3K(1-2\mu) \Rightarrow K = 133.3\text{kPa}$	1.5X2	3

III

PART C

1.



$\Sigma F_x = 449.39$ kN — 2

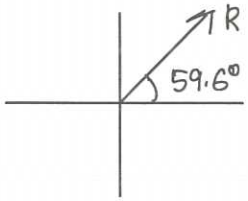
$\Sigma F_y = 766.12$ kN — 2

Resultant, $R = \sqrt{F_x^2 + F_y^2} = 888.195$ kN — 1

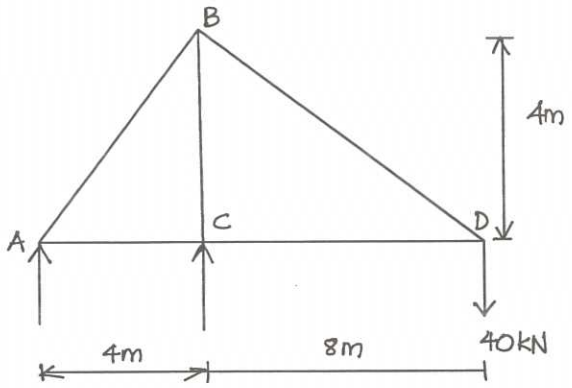
Direction of resultant, $\tan\theta = \left|\frac{\Sigma F_y}{\Sigma F_x}\right| = \frac{766.12}{449.39}$

$\theta = \tan^{-1}\left(\frac{766.12}{449.39}\right)$ — 2 — 7

$= 59.6°$



5.



$R_A + R_B = 40\,kN$

$\Sigma M_A = 0$; $R_C = 120\,kN$; $R_A = -80\,kN$ — 1

Analysing Joint A, $F_{AB} = 113.137\,kN\,(T)$

$\theta = 45^\circ$

$F_{AC} = 80\,kN\,(C)$ — 2

Analysing Joint C, $F_{CD} = 80\,kN\,(C)$

$F_{BC} = 120\,kN\,(C)$ — 2

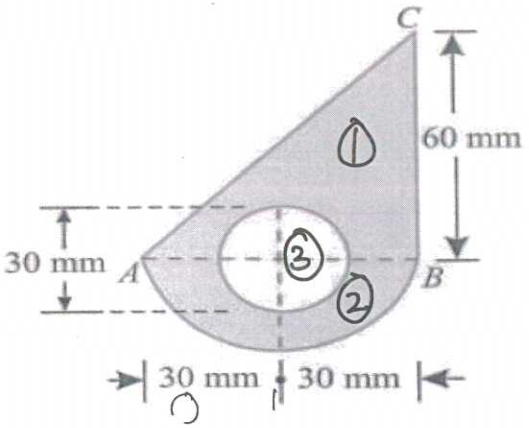
Analysing Joint D, $F_{DB} = 89.44\,kN\,(T)$

$F_{CD} = 80\,kN\,(C)$ — 2

$\theta = 26.565^\circ$

7

9.



$\bar{x}, \bar{y}$ → equation

$a_1 = 1800\,mm^2$, $a_2 = 1413.17\,mm^2$, $a_3 = 706.85\,mm^2$ 1

Find $x_1, x_2, x_3, y_1, y_2, y_3$

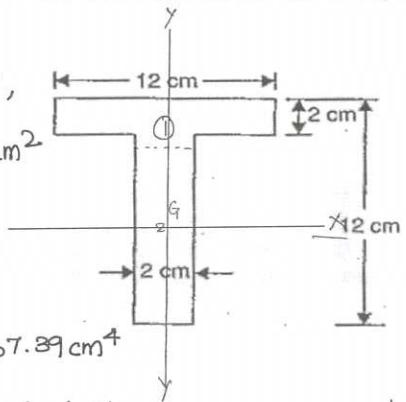
and substitute in following equation

$$\bar{x} = \frac{a_1x_1 + a_2x_2 - a_3x_3}{a_1 + a_2 + a_3} = 23.773$$ 3

$$\bar{y} = \frac{a_1y_1 + a_2y_2 - a_3y_3}{a_1 + a_2 + a_3} = 4.592$$ 3 7

10. $a_1 = 24cm^2$, $a_2 = 20cm^2$, 1

$\bar{x} = 6cm$, $\bar{y} = 8.272cm^2$ 2



Using parallel axis theorem, 7

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

$I_{xx} = I_{xx_1} + I_{xx_2} = 567.39cm^4$ 2

Since the given section is symmetric about YY axis.

$I_{yy} = I_{1yy} + I_{2yy}$ 2

$= 288 + 6.67 = 294.67cm^4$

11. Given data and convertion 1

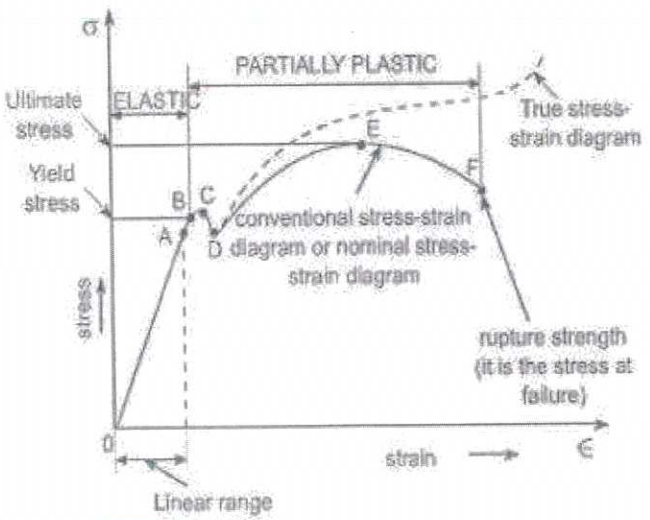
(i) Stress = P/A = $20000/100\pi = 63.662N/mm^2$ 2

(ii) Strain e = $\sigma/E = 63.662/2\times10^5 = 0.000318$ 2 7

(iii) Elongation dL= e × L = 0.000318 × 150 = 0.0477cm 2

12. Sketching 3

Explaining the salient features 4



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