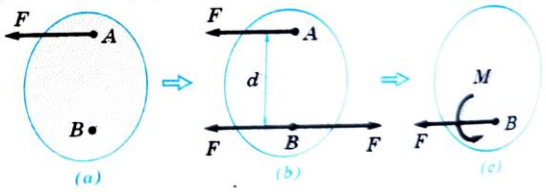
SOMAIYA VIDYAVIHAR UNIVERSITY

Semester: Jan 2025 – April 2025		
Maximum Marks: 30	**Examination: In-Semester Examination**	**Duration:** 1 Hr. 15 Min.
Programme code: 06 **Programme:** B. Tech	**Class:** FY	**Semester:** II **(SVU R-2023_24-07-2023)**
Name of the Constituent College: K. J. Somaiya School of Engineering	**Name of the department:** All	
Course Code: 216U06C104	**Name of the Course:** Engineering Mechanics	

Question No.		Max. Marks
Q1	**Attempt any two.** i. Explain with a suitable example the resolution of a force into a force and couple. **Explanation (03 marks)** **Diagram (02 marks)** Consider a force F acting on a body at point A. This is to be replaced by a force and couple at some point B as shown Introduce two equal and opposite forces at B, each of magnitude F and acting parallel to the force at A. Of the three equal forces, consider the two forces acting in opposite directions at points A and B. They form a couple of moment, $M = F \times d$(↺) Thus the original force F acting at point A can be replaced. **(i)** By a single force F and **(ii)** A couple $M = F \times d$  ii. A car starts from rest at t = 0 along a circular track of radius 200 m. The rate of increase in speed of the car is uniform. At the end of 90 seconds, the speed of car is 36 kmph. Find the tangential and normal components of acceleration at t = 30 seconds. **Tangential component (02 marks)** **Normal components of acceleration at t = 30 seconds (03 marks)** ***Solution :*** Given data : Initial velocity, $u = 0$ Radius of curvature, $\rho = 200$ m Final velocity, $v = 36 \times \frac{5}{18} = 10$ m/s Time of travel, $t = 90$ s To find : Tangential acceleration, $a_t = ?$ at $t = 30$ s Normal acceleration, $a_N = ?$ at $t = 30$ s In this problem, car is moving with a uniform tangential acceleration. Hence tangential acceleration at any time remain constant.	10

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Using the equation of motion

$$v = u + a_t \times t$$
$$10 = 0 + a_t \times 90$$
$$\therefore\ a_t = 0.1111\ \text{m/s}^2$$

To find speed when $t = 30$ s. Use again

$$v = u + a_t \times t$$
$$v = 0 + 0.1111 \times 30$$
$$\therefore\ v = 3.333\ \text{m/s}$$

$$\text{Normal acceleration, } a_N = \frac{v^2}{\rho} = \frac{3.333^2}{200} = 0.056\ \text{m/s}^2$$

$\therefore$ Tangential acceleration at $t = 30$ s is $a_t = 0.1111\ \text{m/s}^2$

Normal acceleration at $t = 30$ s is $a_N = 0.056\ \text{m/s}^2$

iii. A force acts at the origin in the direction defined by angles $\Theta_y = 65^0$ and $\Theta_z = 40^0$. Knowing that the x component of force is -750 N find the value of Θ_x and magnitude of the force.

value of Θ_x (03 marks)
Magnitude of the force (02 marks)

Solution : Given : $\theta_y = 65°$, $\theta_z = 40°$ and $F_x = -750$ N.

Using the equation $\cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1$

$$\cos^2\theta_x + \cos^2 65° + \cos^2 40° = 1$$
$$\cos^2\theta_x = 0.2346$$
$$\cos\theta_x = \pm 0.4843$$
$$\theta_x = 61.03° \text{ or } 180 - 61.03 = 118.97°$$
$$\theta_x = 118.97° \text{ since } F_x = -750 \text{ N has negative magnitude}$$

We know that $F_x = |F| \cos\theta_x$

$$-750 = |F| \cos 118.97°$$
$$\therefore\ |F| = 1548.46\ \text{N}$$
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<td>Q2</td>
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A machine part is subjected to forces as shown in the figure below. Find the resultant force in magnitude and direction. Also, locate the point where the resultant cuts the center line of bar AB.

Calculation of resultant and orientation (04 marks)
Moment, X and Y intersepts (05 marks)
Location of resultant (01 mark)
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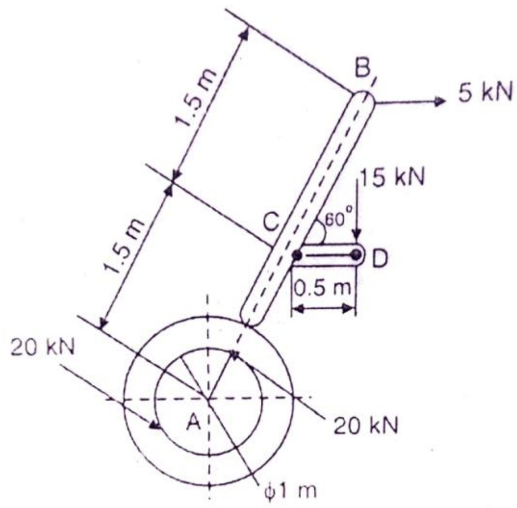
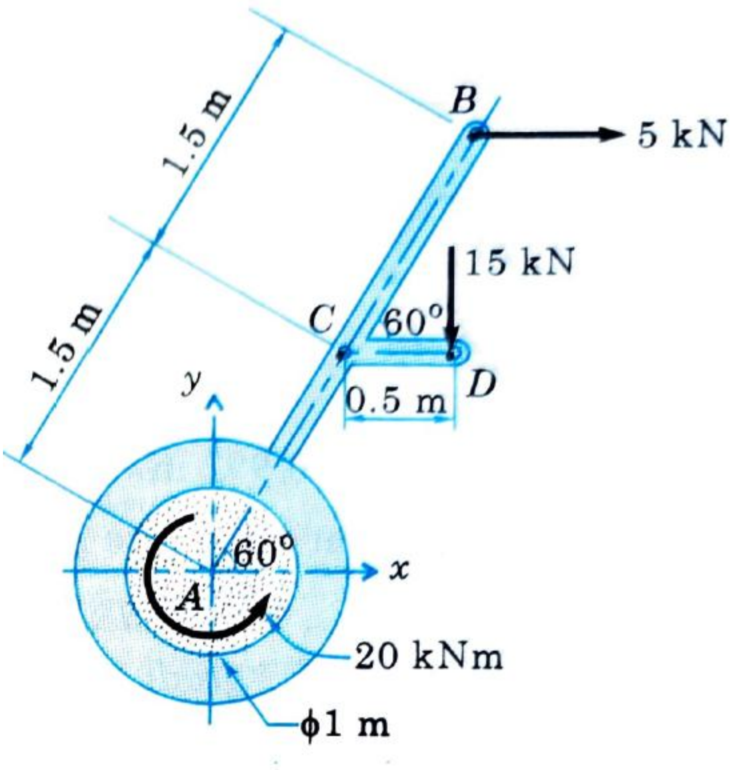
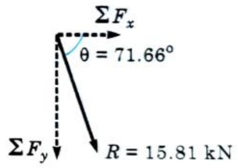
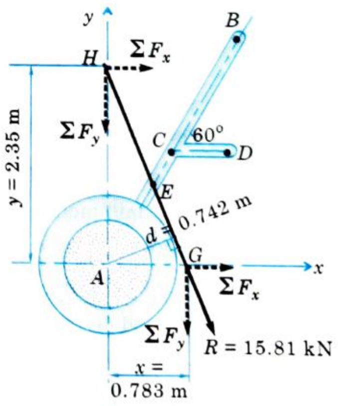
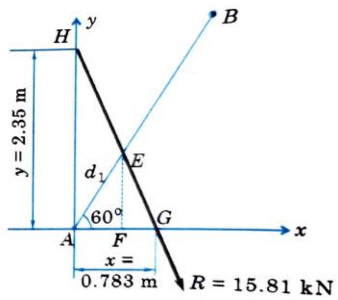
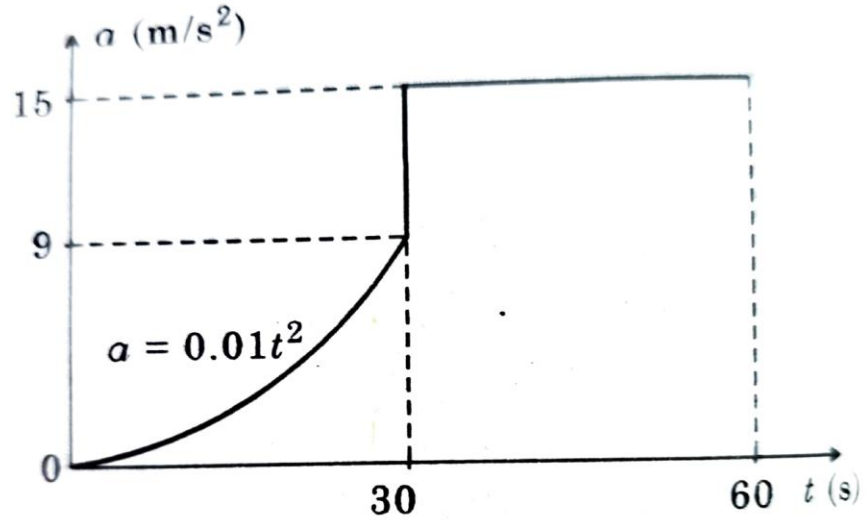


B
5 kN
1.5 m
15 kN
1.5 m
C
60°
D
0.5 m
20 kN
A
20 kN
ϕ1 m



1.5 m
B
5 kN
15 kN
1.5 m
C
60°
D
0.5 m
y
60°
x
A
20 kNm
ϕ1 m

	Solution : Two 20 kN forces acting on the periphery of circular portion of diameter 1 m produces an anticlockwise couple of magnitude 20 × 1 = 20 kN.m. Hence these two forces can be replaced by a couple of 20 kN.m as shown Now, $(+\rightarrow)\ \Sigma F_x = 5\text{ kN }(\rightarrow)$ $(+\downarrow)\ \Sigma F_y = -15\text{ kN} = 15\text{ kN }(\downarrow)$  $R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2} = \sqrt{(5)^2 + (-15)^2} = 15.81\text{ kN}$ $\theta = \tan^{-1}\left\|\frac{\Sigma F_y}{\Sigma F_x}\right\| = \tan^{-1}\left\|\frac{15}{5}\right\| = 71.56^\circ$ θ lies in fourth quadrant as ΣF_x is positive and ΣF_y is negative. Resultant is represented as shown  To locate the position of resultant, we use Varignon's theorem as $\|\Sigma M_A\| = \|\Sigma F_x \times y\| = \|\Sigma F_y \times x\| = \|R \times d\|$ ..... (I) Now, $(+\circlearrowleft)\ \Sigma M_A = 20 - 5 \times 3 \sin 60^\circ - 15[1.5 \cos 60^\circ + 0.5]$ $= -11.74\text{ kN.m} = 11.74\text{ kN.m }(\circlearrowright)$ Now using equation (I), we get $11.74 = 5 \times y = 15 \times x = 15.81 \times d$ $\therefore\ x = 0.783\text{ m}, y = 2.35\text{ m}$ and $d = 0.742\text{ m}$ The position of the resultant is represented as shown To find the distance $AE = d_1$ on AB where the resultant cuts the line AB. Using geometry of the *figure* , we have from similar triangles EFG and HAG. $\frac{FG}{FE} = \frac{AG}{AH}$ But $FG = AG - AF = 0.783 - d_1 \cos 60^\circ = 0.783 - 0.5\, d_1$ and $FE = d_1 \sin 60^\circ = 0.866\, d_1$ $\therefore\ \frac{0.783 - 0.5\, d_1}{0.866\, d_1} = \frac{0.783}{2.35}$ $\therefore\ d_1 = 0.992\text{ m}$  Resultant R cuts the line AB at a distance $d_1 = 0.992$ m	
Q3	A two-stage rocket is fired vertically from rest at s = 0 with an acceleration as shown in the figure below. After 30 seconds, the first stage A burns and stage B ignites. Plot v-t and s-t graphs, which describe the motion, and find the distance traveled in 60 seconds.  **<u>V-t Diagram (02 marks)</u>** **<u>Calculations (03 marks)</u>** **<u>S-t Diagram (02 marks)</u>** **<u>Calculations (03 marks)</u>**	10

Solution : Given initial condition.

At $t = 0$, $x_0 = 0$, $v_0 = 0$

Area under a-t diagram = Change in velocity (Δv)

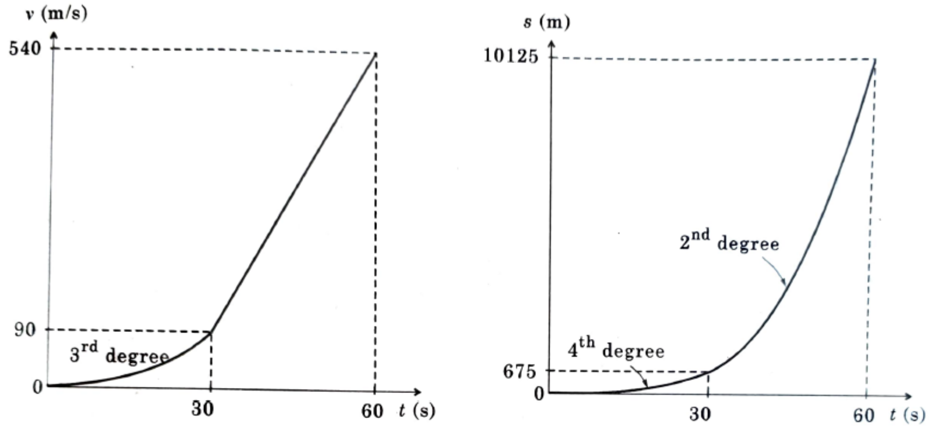
For $0 \le t \le 30$ s, Area $A_1 = \frac{ab}{n+1}$. Here $a = 30$, $b = 9$, $n = 2$ (degree)

$$\therefore\ A_1 = \frac{30 \times 9}{2+1} = 90 = v_{30} - v_0 = v_{30} - 0$$

$$\therefore\ v_{30} = 90 \text{ m/s}$$

For $30 \le t \le 60$ s, Area $A_2 = 30 \times 15 = 450 = v_{60} - v_{30} = v_{60} - 90$

$$\therefore\ v_{60} = 540 \text{ m/s}$$



For drawing s-t diagram from v-t diagram, we use

Area under v-t diagram = Change in position (Δs)

For $0 \le t \le 30$ s, Area $A_1 = \frac{ab}{n+1}$. Here $n = 3$, $a = 30$, $b = 90$

$$\therefore\ A_1 = \frac{30 \times 90}{3+1} = 675 = s_{30} - s_0 = s_{30} - 0$$

$$\therefore\ s_{30} = 675 \text{ m}$$

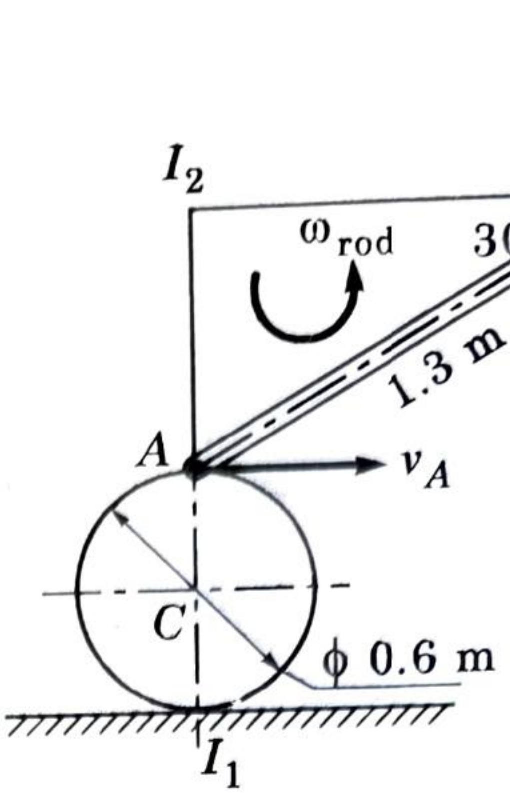
For $30 \le t \le 60$ s, Area $A_2 = \left(\frac{90 + 540}{2}\right) \times 30 = 9450 = s_{60} - s_{30} = s_{60} - 675$

$$\therefore\ s_{60} = 10125 \text{ m}$$

OR

C is a uniform cylinder to which rod AB is pinned at A and the other end of the rod is moving along a vertical wall as shown in the figure below. If end B of the rod is moving upwards along the wall with the speed of 3.3 m/s find the angular velocity of the wheel and rod assuming that the cylinder is rolling without slipping.

Location of ICR (04 marks)
angular velocity of the wheel (03 marks)
angular velocity of the rod (03 marks)



Solution : Since velocity of point B of rod is upward, velocity of point A is rightwards. Point A is common to rod AB and cylinder C which rolls on horizontal surface. I_1(point of contact with horizontal surface) is the instantaneous centre of rotation for the cylinder. Intersection of lines drawn perpendicular to velocity v_B and velocity v_A [along line I_1A] gives the point of rotation I_2 for the rod.

$$v_B = I_2B\,\omega_{rod} \quad \text{i.e. } 3.3 = I_2B\,\omega_{rod} \quad \text{..... (I)}$$

$$v_A = I_2A \times \omega_{rod} = I_1A \times \omega_C \quad \text{..... (II)}$$

To find lengths I_2A and I_2B, we use geometry.

From triangle I_2AB

$$\cos 30^\circ = \frac{I_2B}{AB} = \frac{I_2B}{1.3} \quad \therefore\ I_2B = 1.126 \text{ m} \quad \text{and} \quad \sin 30^\circ = \frac{I_2A}{AB} = \frac{I_2A}{1.3} \quad \therefore\ I_2A = 0.65 \text{ m}$$

Put these values in equation (I) and (II) to get

From equation (I) $\quad 3.3 = I_2B \times \omega_{rod} = 1.126 \times \omega_{rod} \quad \therefore\ \omega_{rod} = 2.931$ r/s

From equation (II) $\quad v_A = I_2A \times \omega_{rod} = I_1A \times \omega_C$

$$v_A = 0.65 \times 2.931 = 0.6 \times \omega_C \qquad \omega_{cylinder} = 3.175 \text{ r/s}$$