B.E. MECHANICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM – 2025

Subject: ENGINEERING MECHANICS: STATICS **Time: Three Hours** **Full Marks: 100**

The value of the acceleration due to gravity (g) can be taken as 10 m/s^2, if it is not specified. Any missing information may be suitably assumed with appropriate justification.

Group A *(Answer any two questions from this group)*

Q1a. Replace the three forces shown in the **Fig. Q1a** by an equivalent force–couple system at point A. If the forces are replaced by a single resultant force, determine the distance d above or below point A to its line of action. **[10]**

Q1b. The rectangular plate is supported by hinges along its side BC and by the cable AE, as shown in **Fig Q1b**. If the cable tension is **300-N**, determine the projection onto line BC of the tension force exerted by the cable on the plate. Note that E is the midpoint of the horizontal upper edge CF of the structural support. **[10]**

Q1c. Replace the two forces which act on the **3-m** cube, as shown in **Fig Q1c**, by an equivalent single force F at A and a couple M. Express F and M as vectors. **[10]**

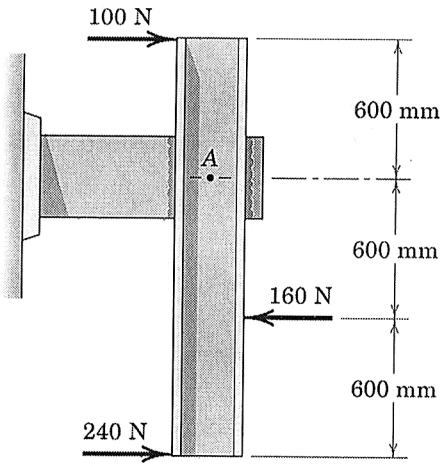

Fig. Q1a

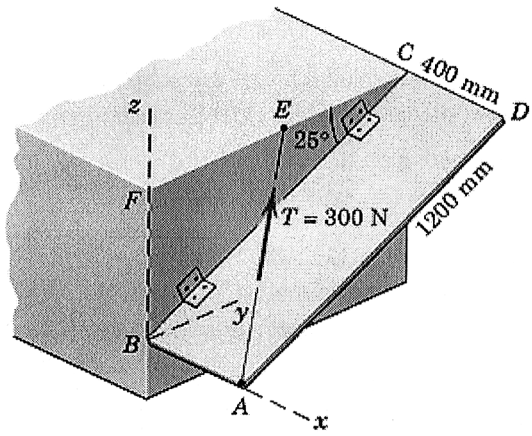

Fig. Q1b

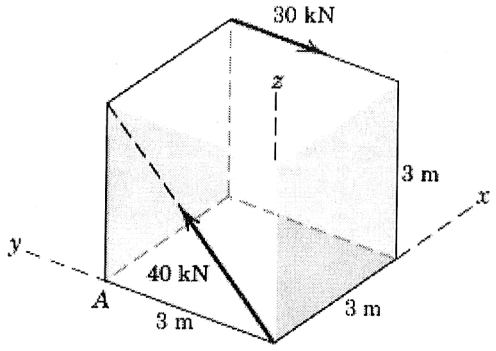

Fig. Q1c

Group B (*Answer any four questions from this group*)

Q2a. For the truss shown in **Fig. Q2a**, find the horizontal and vertical components of reactions at the supports A and C. Also find out the forces in the member BD, BE and DE. **Draw the necessary free body diagram(s).** **[10]**

Q2b. For what value M of the clockwise couple will the horizontal component A_x of the pin reaction at A be zero? If a couple of that same magnitude M were applied in a counterclockwise direction, what would be the value of A_x? **Draw the necessary free-body diagram(s).** **[10]**

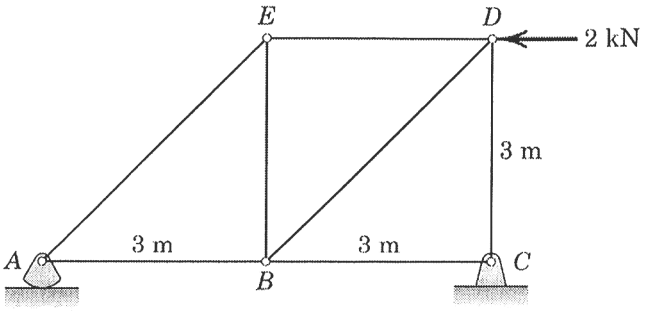

Fig. Q2a

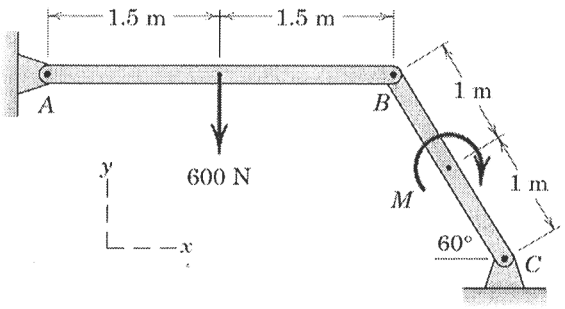

Fig. Q2b

Q2c. A rigid horizontal boom AB is supported with the help of a ball and socket joint at a point A in the wall and two cables as shown in the **Fig. Q2c**. Considering the weight of the boom is negligible compared to the **30-kN** vertical force which is acting on it, find out the tensions $\boldsymbol{T}_1$ and $\boldsymbol{T}_2$ (in vector format) in the cables as shown in the figure. **Draw the necessary free body diagram(s).** **[10]**

Q2d. The light bracket ABC is freely hinged at A and is constrained by the fixed pin in the smooth slot at B, as shown in **Fig Q2d**. Calculate the magnitude of the force supported by the pin at A under the action of the **80-N·m** applied couple. **Draw the necessary free body diagram(s).** **[10]**

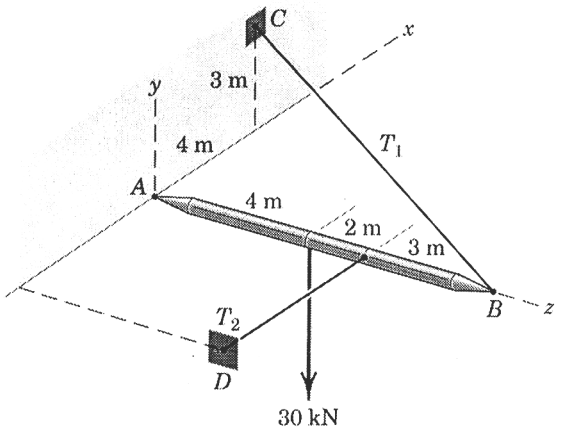

Fig. Q2c

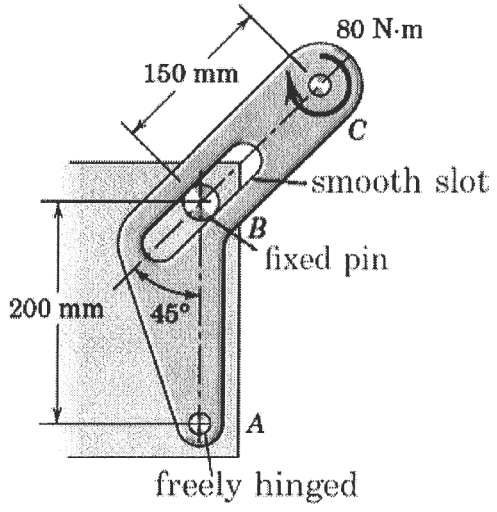

Fig. Q2d

Q2e. With necessary sketches and free body diagram(s), show that a flexible cable of uniformly distributed self-weight, hanging in the vertical plane **under the influence of its own weight only**, forms a curve given by the equation $\boldsymbol{y = \frac{T_0}{\mu}\left[\cosh\left(\frac{\mu x}{T_0}\right) - 1\right]}$, where $\boldsymbol{x}$ and $\boldsymbol{y}$ are the coordinate of any point of the hanging cable and origin of the

coordinate system is located at the lowest point of the cable. T_0 is the tension of the cable at its lowest point and μ is the self-weight of the cable per unit length of the curve described by the cable. **[10]**

Q2f. Using the **method of virtual work,** determine the magnitude of the force Q required to maintain the equilibrium of the mechanism as shown in **Fig. Q2f**. Express your results in terms of θ and P, the vertical force applied at point 'F'. **Draw the necessary active force diagram and show the relevant virtual displacement terms.** **[10]**

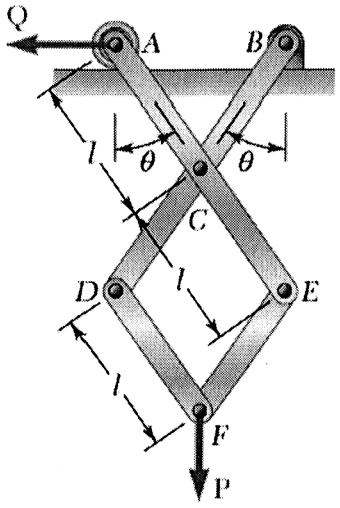

Fig. Q2f

Group C (*Answer any two questions from this group*)

Q3a. Calculate the magnitude of the clockwise couple M required to turn the **50-kg** cylinder in the supporting block shown in **Fig. Q3a**. The coefficient of friction is **0.30**. **Draw the necessary free body diagram(s).** **[10]**

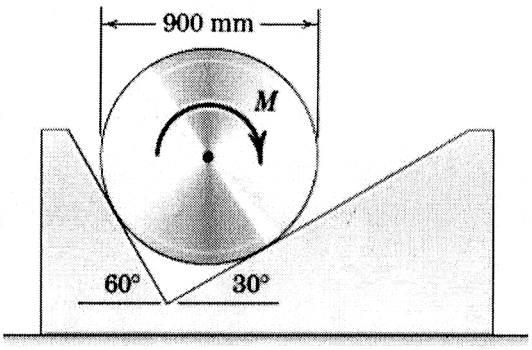

Fig. Q3a

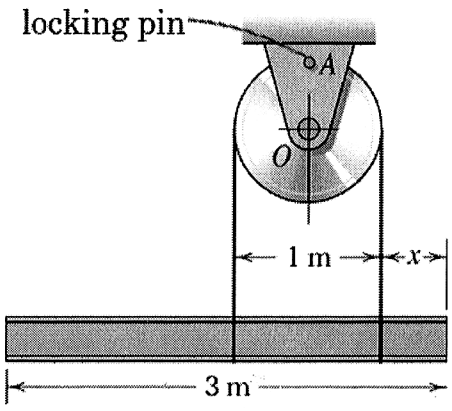

Fig. Q3b

Q3b. The **3-m** uniform beam is suspended by the flexible belt which passes over the large pulley as shown in **Fig. Q3b**. A locking pin 'A' prevents the rotation of the pulley. If the coefficient of friction between the belt and the pulley is **0.25**, determine the minimum value of x for which the belt will not slip on the pulley. **Draw the necessary free body diagram(s).** **[10]**

Q3c. With necessary sketches and free body diagram(s), show that in a square threaded screw jack, the expression of moment required to be applied about the axis of the screw, which is just enough to raise a load of W, will be $M = Wr\tan(\alpha + \varphi)$, where r, α and φ are the mean radius of the screw, helix angle of the screw and the angle of static friction between the screw and nut surfaces respectively. **[10]**

Group D (*Answer any two questions from this group*)

Q4a. Write short notes on the following:

(i) Parallel axes theorem for moments of inertia of a plane area. **[5]**

(ii) Theorems of Pappus on surface of revolution and volume of revolution. **[5]**

Q4b. For the shaded area shown in **Fig. Q4b**, find the coordinates of the centroid with respect to given x- and y-axes. **[10]**

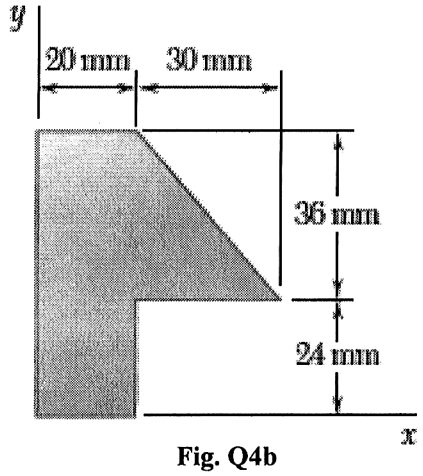

Fig. Q4b

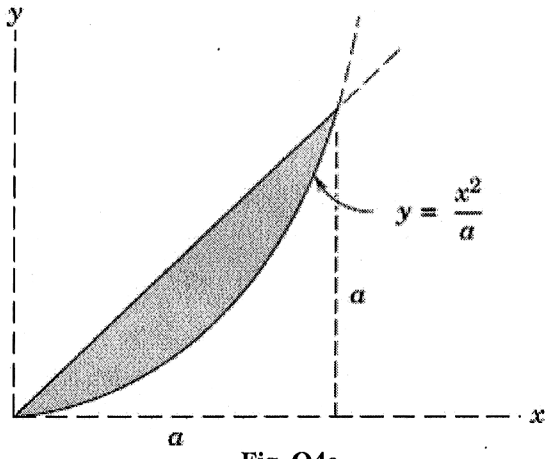

Fig. Q4c

Q4c. Determine the area moment inertia of the shaded area shown in **Fig. Q4c**, about x-axis and y-axis. **[10]**