B.E. MECHANICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM – 2024

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/s², 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 two forces and a couple acting on the cantilever beam as shown in **Fig. Q1a** by an equivalent system of a single resultant force and a couple at the left end of the beam. Find the distance (along ***x***-axis) from the left end of the beam to the point through which a single resultant force equivalent to the given force system (with zero couple moment) will pass. **[10]**

Q1b. Replace the three forces acting on the structure shown in **Fig. Q1b** by an equivalent system of a single force and single couple at the base '***O***'. Express the force and the couple moment as vectors. Also mention the magnitude of the equivalent resultant force and the couple moment reduced at '***O***'. **[10]**

Q1c. A **50 N** horizontal force is applied to the handle of the industrial water valve as shown in **Fig. Q1c**. The force is acting perpendicular to the vertical plane containing line '***OA***' of the handle. Determine the moment of the force about point '***O***'. Express the results in vector form. **[10]**

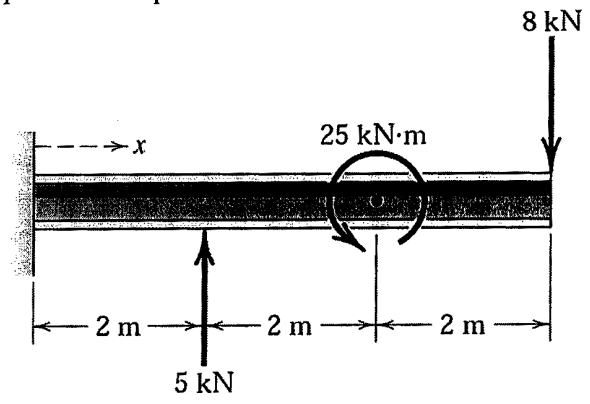

Fig. Q1a

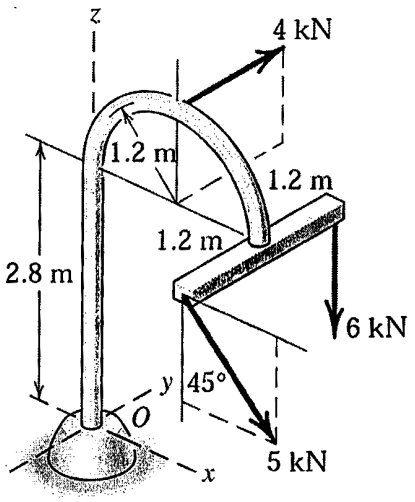

Fig. Q1b

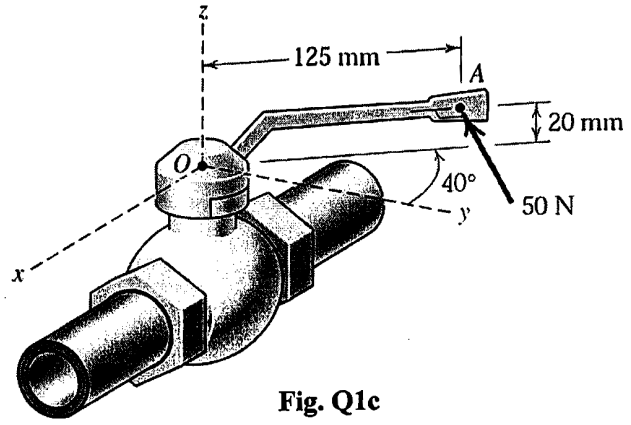

Fig. Q1c

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

Q2a. For the truss shown in **Fig. Q2a**, find out the forces in the members '*CG*' and '*CF*'. **Draw the necessary free body diagram(s).** **[10]**

Q2b. A force P applied to the midpoint '*D*' of the link '*BC*' as shown in **Fig. Q2b**. Find the value of the couple M which would cause the horizontal force transmitted by the pin '*B*' zero. Find the components of reaction forces at the supports '*A*' and '*C*', respectively. Consider $P = 50$ N and $R = 1$ m. **Draw the necessary free body diagram(s).** **[10]**

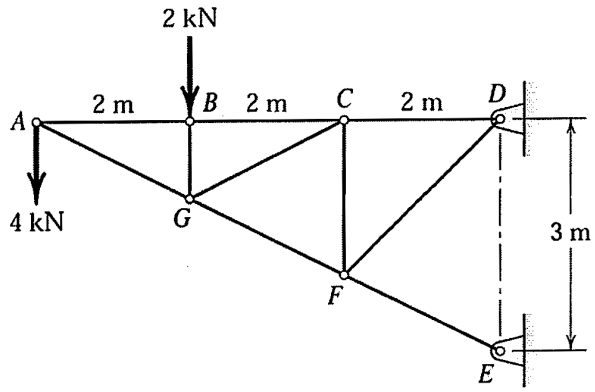

Fig. Q2a

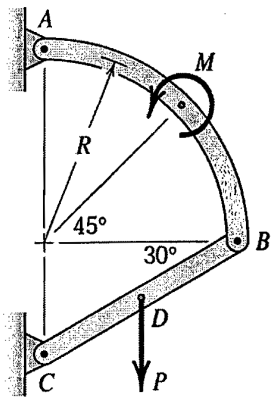

Fig. Q2b

Q2c. The boom shown in **Fig. Q2c** lies in the vertical y-z plane and is supported by a ball-and-socket joint at '*B*' and by the cables connected to the boom at '*A*'. Calculate the tension in each cable resulting from the **20 kN** force acting in the horizontal plane applied at the midpoint '*M*' of the boom. The self-weight of the boom is negligible compared to the applied **20 kN** force. **Draw the necessary free-body diagram(s).** **[10]**

Q2d. The bar '*OC*' has a total mass m distributed uniformly over its entire length L as shown in **Fig. Q2d**. The bar can freely pivot about a horizontal axis passing through '*O*'. If the spring of modulus k is unstretched when the point '*C*' is coincident with the point '*A*', determine the tension T required to hold the bar in the **45°** position as shown. Diameter of the small pulley at '*D*' is negligible. Consider that $m = 10$ kg, $L = 1$ m and $k = 1000$ N/m. **Draw the necessary free body diagram(s).** **[10]**

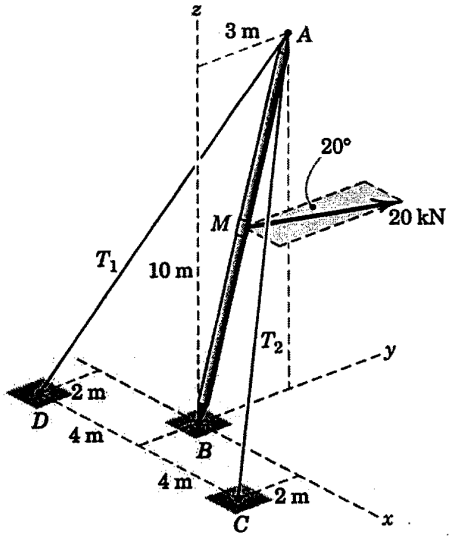

Fig. Q2c

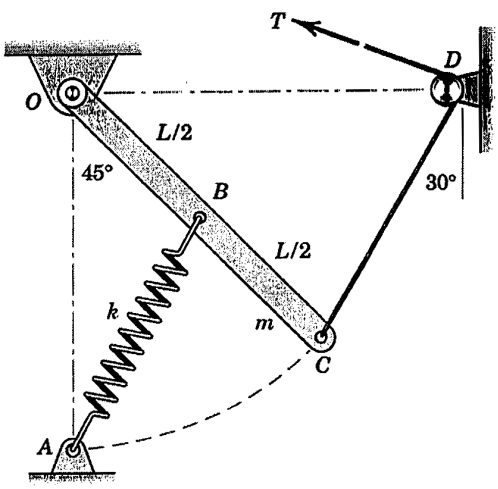

Fig. Q2d

Q2e. Using the **method of virtual work,** determine the magnitude of the couple M required to maintain the equilibrium of the mechanism as shown in **Fig. Q2e**. Express your results in terms of θ, l and P, the horizontal force applied at point 'D'. **Draw the necessary active force diagram and show the relevant virtual displacement terms.** **[10]**

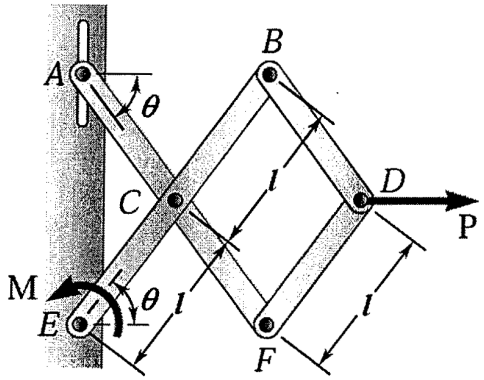

Fig. Q2e

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

Q3a. A slender rod of length L is lodged between peg 'C' and the vertical wall and supports a load P at end 'A' as shown in **Fig. Q3a**. Knowing that the coefficient of static friction is **0.20** at both 'B' and 'C', determine the largest value of the ratio L/a for which equilibrium is maintained avoiding any upward slipping of the rod at the end 'B'. **Draw the necessary free-body diagram(s).** **[10]**

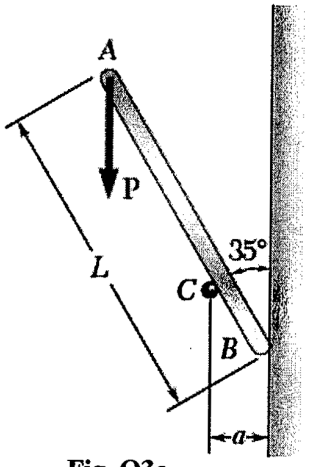

Fig. Q3a

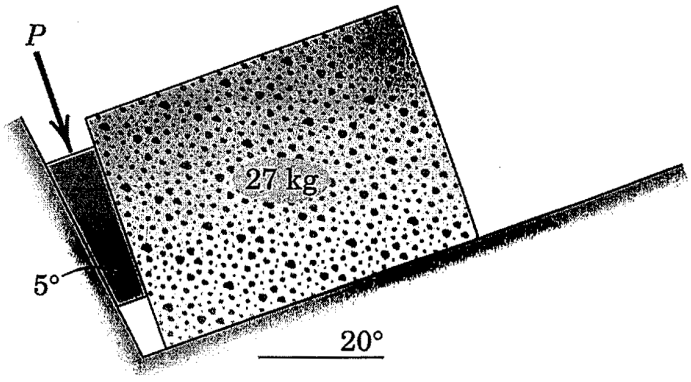

Fig. Q3b

Q3b. The coefficient of friction for both wedge-surfaces is **0.4** and that between the **27 kg** block and **20°** incline is **0.7**, as shown in **Fig. Q3b**. Determine the minimum value of the force P required to begin moving the block up the incline. Neglect the weight of the wedge. **Draw the necessary free body diagram(s).** **[10]**

Q3c. Prove that the ratio between the tight side tension T_2 and the slack side tension T_1 of flexible belt driven by a pulley is $\frac{T_2}{T_1} = e^{\mu\theta}$, where μ is the coefficient of static friction between the belt and pulley surface and θ is the angle of wrap. **Draw the necessary free body diagram(s).** **[10]**

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

Q4a. Write short notes on the following:

(i) Polar moment of inertia of a plane area and the perpendicular axes theorem. **[5]**

(ii) Principal moments of inertia of a plane area. **[5]**

Q4b. Find the x and y coordinate of the centroid of the plane area shown in the **Fig. Q4b.** **[10]**

Q4c. Determine the radii of gyration of the shaded area about x- and y-axes as shown in **Fig. Q4c.** **[10]**

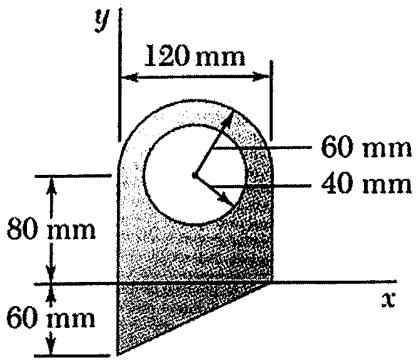

Fig. Q4b

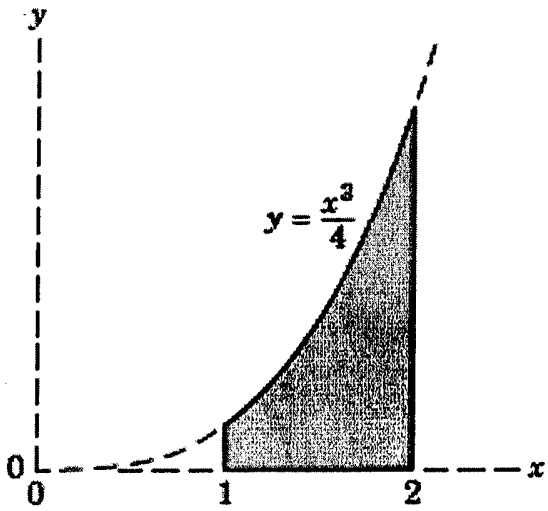

Fig. Q4c