B.E. MECHANICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM – 2022

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 two forces acting on the bent pipe as show in **Fig. Q1a** by an equivalent force-couple system at the point '***A***'. Find the distance from the point '***A***' to the point on ***y***-axis through which a single resultant force equivalent to the given force system (with zero moment) will pass. **[10]**

Q1b. The access door in **Fig. Q1b** is held in the **30°** open position by the chain ***AB***. The tension in the chain is known to be **100 N**. Express this tension as a vector with the suitably defined axes system. Find the component of this force along the direction parallel to the line ***CD***. **[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]**

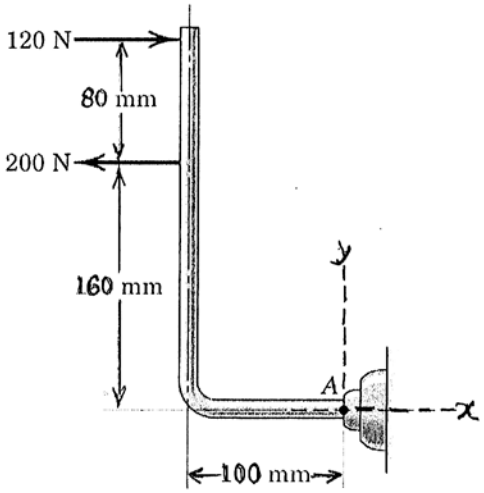

Fig. Q1a

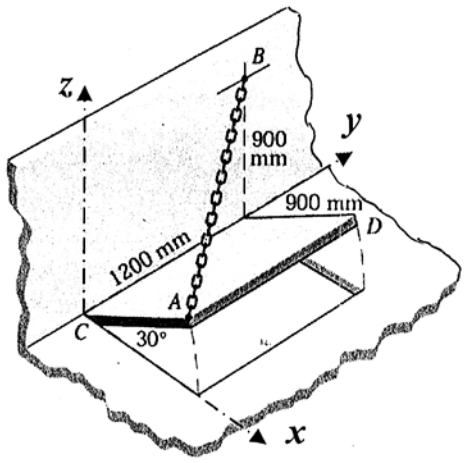

Fig. Q1b

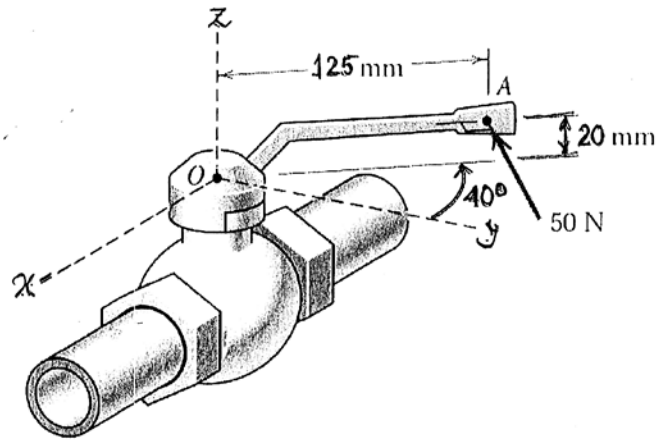

Fig. Q1c

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]**

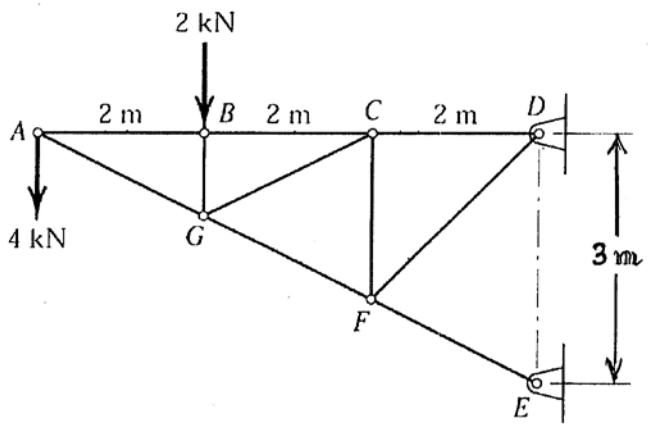

Fig. Q2a

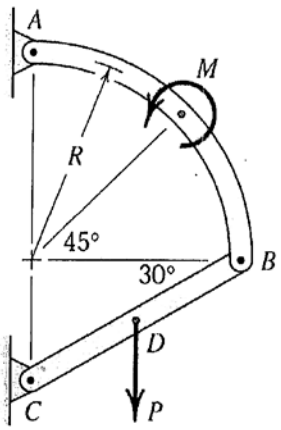

Fig. Q2b

Q2c. Determine the tensions in the three cables which support the uniform **80-kg** plate ***ABC*** whose shape is that of an equilateral triangle. The mass centre G of the plate is located one-third of the distance MC from M. **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***', which is perpendicular to this plane of the page. 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]**

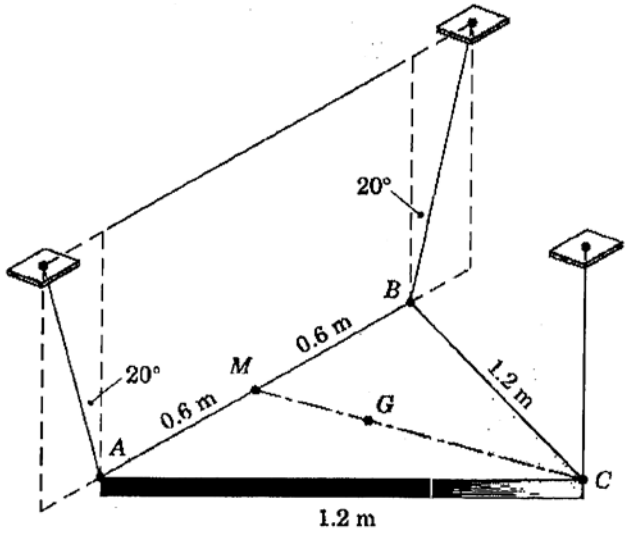

Fig. Q2c

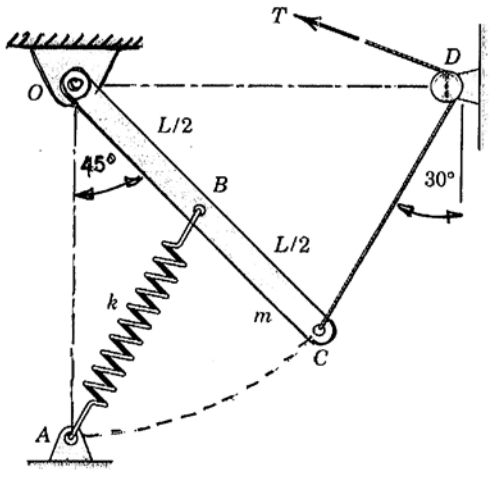

Fig. Q2d

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]**

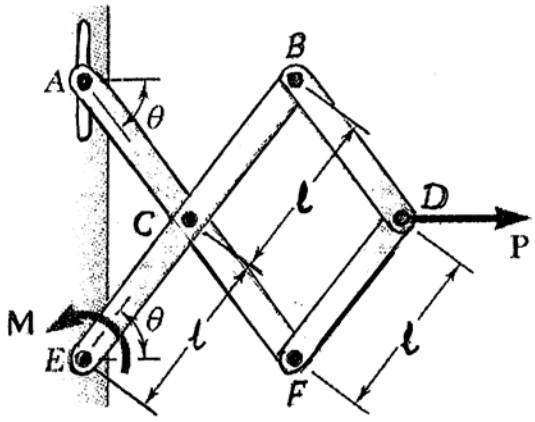

Fig. Q2e

Q2f. With necessary sketches and free body diagram(s), show that a flexible cable with negligible self-weight hanging in vertical plane **under uniformly distributed vertical load μ per unit horizontal distance** forms a parabolic arc given by the equation $y = \dfrac{\mu x^2}{2T_0}$, where x and 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 horizontal component of cable tension at any point of its length. **[10]**

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]**

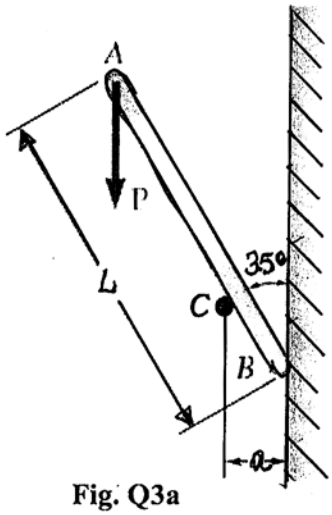

Fig. Q3a

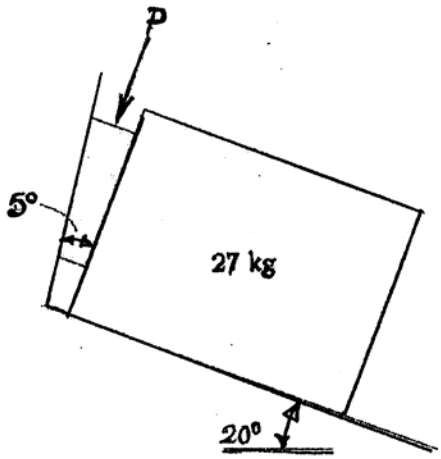

Fig. Q3b

Q3b. The coefficient of static friction for both wedge surfaces is **0.40** and that between the **27-kg** concrete block and the incline is **0.70**, as shown in **Fig. Q3b**. Determine the minimum value of the force P required to begin moving the block down 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. For the section shown in the **Fig. Q4b**, determine the y-coordinate of the centroid and use Pappus theorem to determine the volume of revolution about the x-axis. **[10]**

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

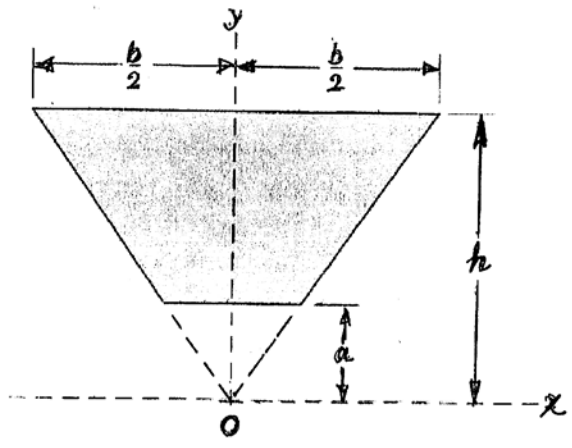

Fig. Q4b

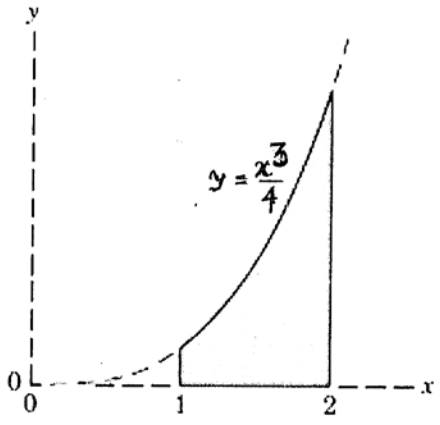

Fig. Q4c