B. E. MECHANICAL ENGINEERING (PART TIME) FIRST YEAR FIRST SEMESTER – 2023
Subject: ENGINEERING MECHANICS – III

Time: 3 Hours **Full Marks: 100**

Question No. 1 is compulsory. Answer any three (3) from the rest.
All the parts of a question should be answered together.
Missing data (if any) should be assumed reasonably with suitable justification.

1. Answer the following questions (**any 5**). **[05×5 = 25]**

(a) An elastic body of volume V is subjected to uniaxial stress σ_x. Show that the total strain energy (U) of the body can be expressed as $U = \int_V \left(\sigma_x^2/2E\right) dV$, where E is the modulus of elasticity of the material of the body. What will be the expression of U if a rod of length L and uniform cross section A is subjected to equal and opposite forces of magnitude P at its ends?

(b) What is a statically indeterminate beam? Draw a statically indeterminate beam and its free body diagram.

(c) Write the expressions for critical buckling load and critical stress from Euler's formula for a column with pin support at both ends. Plot critical stress vs slenderness ratio for columns (both ends pinned) made of a material with modulus of elasticity 110 GPa and tensile yield strength 33.5 MPa.

(d) Briefly discuss about singularity functions. Plot the singularity function $\langle x-b\rangle^0$ vs x and $\langle x-b\rangle^1$ vs x.

(e) Derive the equation of kinetic energy (T) for a mass system about a point 'O' fixed in the Newtonian reference system.

(f) In a rigid container, mass flows in a steady stream at a constant rate through two openings. Show that the resultant force on the steady flow system can be expressed as $\Sigma \boldsymbol{F} = m'\Delta \boldsymbol{v}$, where m' is the steady mass flow rate and $\Delta \boldsymbol{v}$ is the change in velocity vector.

2. The compound beam shown in **Fig. Q2(a)** is fixed at A, pin connected at B, and supported by a roller at C. The beam dimensions and loading are also shown. The cross section of the beam is shown in **Fig. Q2(b)**.
(a) Neatly draw the free body diagrams of each part and calculate the support reactions.
(b) Derive the equations of shear force (V) and bending moment (M) using equations of static equilibrium. Draw the shear force and bending moment diagrams for the beam.
(c) Compute the magnitude of maximum bending stress generated in the beam? **[10+10+05]**

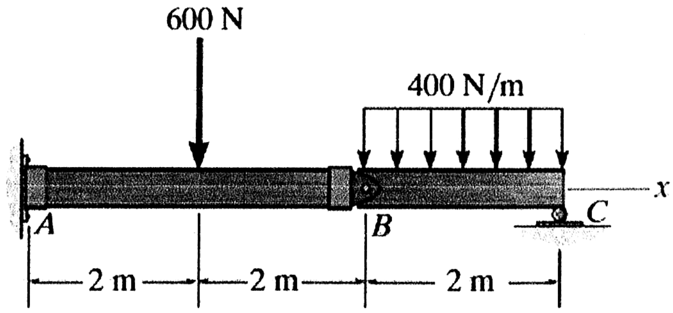

Fig. Q2(a)

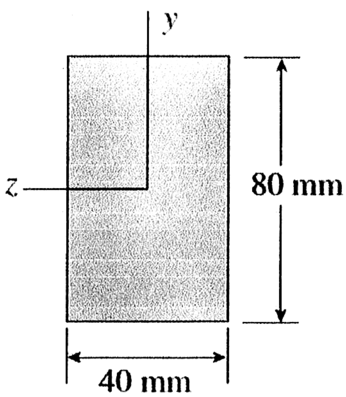

Fig. Q2(b)

[Turn over

3. A simply supported beam is subjected to distributed load $w(x)$ as shown in **Fig. Q3**.

(a) Starting from the fourth order governing differential equation for the beam, determine the equation of the elastic curve.

(b) Compute the slope at end A.

(c) Find the deflection at the midpoint of the span. **[15+05+05]**

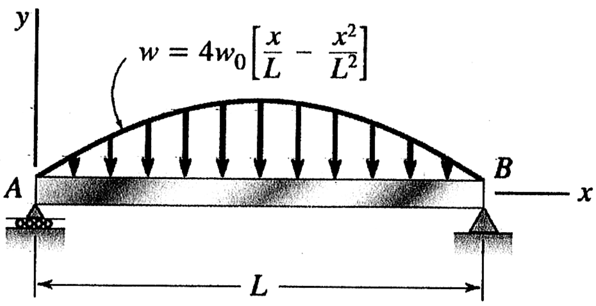

Fig. Q3

4. (a) A statically indeterminate beam and its loading is shown in **Fig. Q4(a)**. Draw the necessary free body diagram and use singularity functions to determine the support reactions at the fixed end A and the deflection at midpoint C. **[15]**

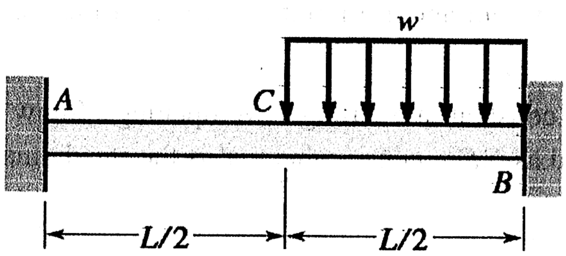

Fig. Q4(a)

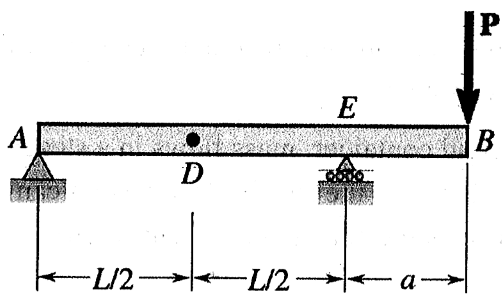

Fig. Q4(b)

(b) Use Castigliano's theorem to determine the slope at D for the beam and loading shown in **Fig. Q4(b)**. **[10]**

5. (a) A rocket takes the position in its trajectory as shown in **Fig. Q5(a)**. It has a mass of 4 Mg and is beyond the effect of the earth's atmosphere. Gravitational acceleration is 9.50 m/s^2. Fuel is being consumed at the rate of 150 kg/s, and the exhaust velocity relative to the nozzle is 530 m/s. Draw the necessary free body diagram to compute the n- and t-components of acceleration of the rocket. **[10]**

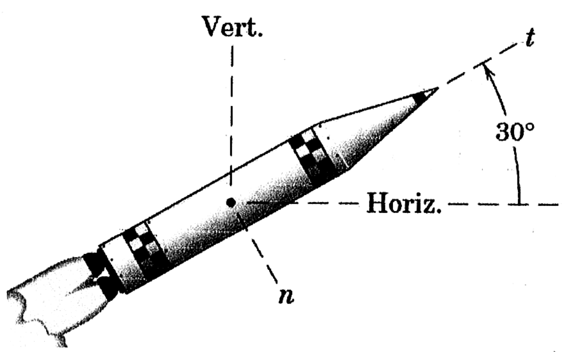

Fig. Q5(a)

(b) Fresh water issues from the nozzle A with a velocity of 45 m/s at the rate of 0.06 m^3/s and is split into two equal streams by the fixed vane and deflected through 60° as shown in **Fig. Q5(b)**. Calculate the force F required to hold the vane in place. The density of water is 1000 kg/m^3. **[05]**

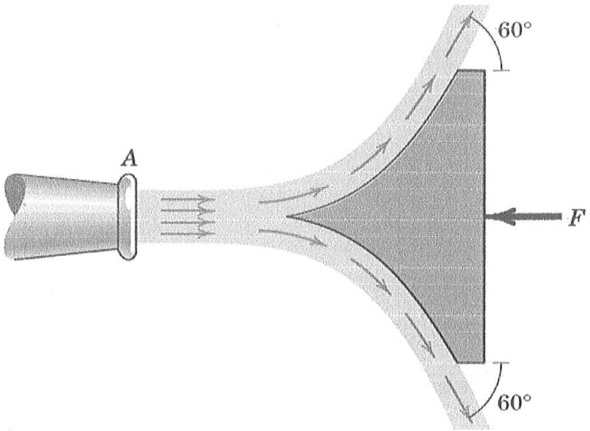

Fig. Q5(b)

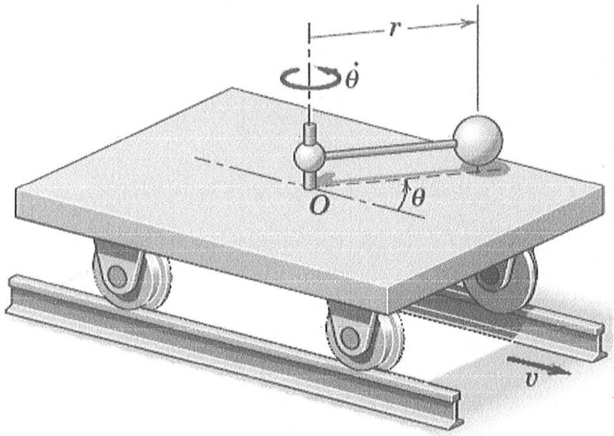

Fig. Q5(c)

(c) A small car is shown in **Fig. Q5(c)**. It has a mass of 25 kg, rolls freely on the horizontal track and carries the 4 kg sphere mounted on the light rotating rod with $r = 0.5$ m. A geared motor drive maintains a constant angular speed $\dot{\theta}$ = 5 rad/s of the rod. If the car has a velocity v = 0.6 m/s when θ = 0°, calculate v when θ = 60°. Neglect the mass of the wheels and any friction. **[10]**