B. E. MECHANICAL ENGINEERING (PART TIME) FIRST YEAR FIRST SEMESTER – 2025

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 must be answered together.
Missing data (if any) should be assumed reasonably with suitable justification.

1. Answer **any 5** from the following questions. **[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) Draw schematic diagrams of a compound beam and a statically indeterminate beam. Show the corresponding free body diagrams. Define differences among them.

(c) What is the effective length of a column? Neatly draw and show the effective length for fixed-free, fixed-pinned and fixed-fixed columns.

(d) Write the expressions and draw the plots of shear force and bending moments of a beam with uniformly distributed load and triangular distributed loading, respectively, in terms of singularity functions.

(e) Derive the equation of angular momentum (H_P) for a mass system about an arbitrary point P.

(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** has three segments connected by pin joint at B and D. (a) Draw the free body diagram and compute all reaction forces at A, C and E. (b) Draw the bending moment and shear force diagram for the beam. (c) What is the maximum bending stress generated in the beam if it has a rectangular cross section with 100mm height and 50mm width? **[10+10+05]**

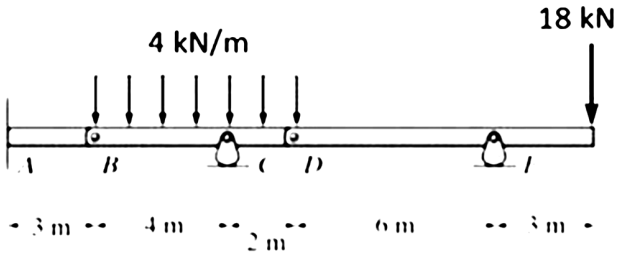

Fig. Q2

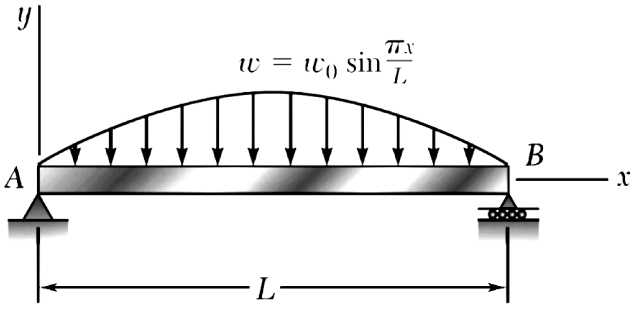

Fig. Q3

3. A simply supported beam is subjected to distributed load $w(x)$ as shown in **Fig. Q3**. The modulus of elasticity of the beam material is E and the area moment of inertia of the beam cross section is I.
(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]**

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]**

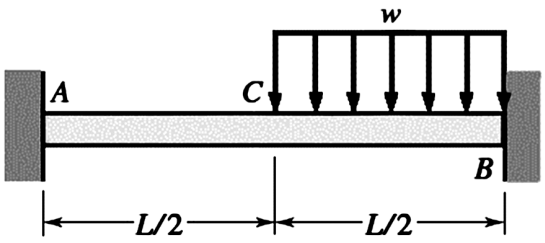

Fig. Q4(a)

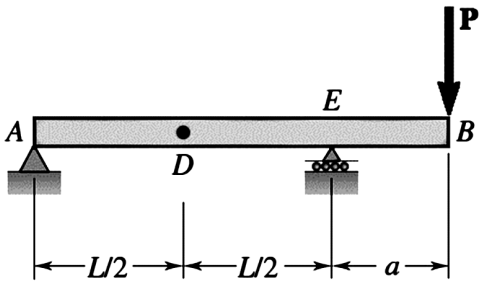

Fig. Q4(b)

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

5. (a) The system of three particles in **Fig. Q5(a)** has the indicated particle masses, velocities and external forces with respect to the given *x*–*y*–*z* coordinate system. Determine $\bar{\mathbf{r}}$, $\dot{\bar{\mathbf{r}}}$, $\ddot{\bar{\mathbf{r}}}$, T, $\bar{\mathbf{H}}_O$, $\dot{\bar{\mathbf{H}}}_O$, $\bar{\mathbf{H}}_G$ and $\dot{\bar{\mathbf{H}}}_G$ for this three–dimensional system. All the symbols have their usual meaning. **[10]**

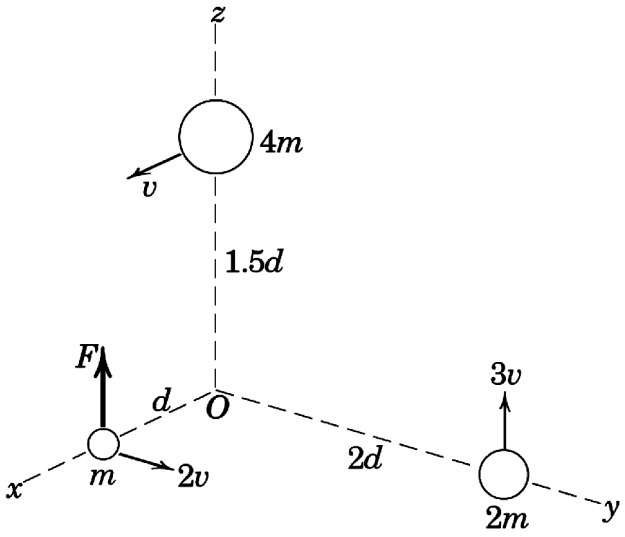

Fig. Q5(a)

(b) Fresh water issues from the nozzle *A* with a velocity of 30 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]**

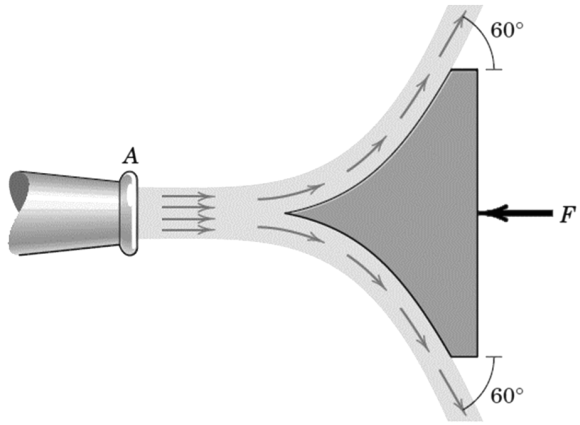

Fig. Q5(b)

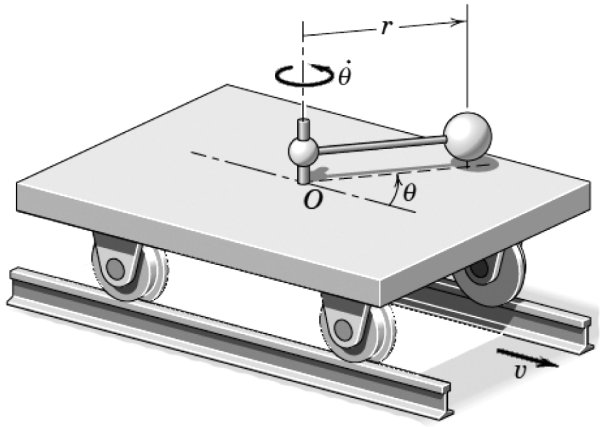

Fig. Q5(c)

(c) A small car is shown in **Fig. Q5(c)**. It has a mass of 27 kg, rolls freely on the horizontal track and carries the 6.5 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 $\theta = 0^{o}$, calculate v when $\theta = 60^{o}$. Neglect the mass of the wheels and any friction. **[10]**