ENGINEERING MECHANICS – III Ref. No.: Ex/ME/5/T/112/2024(S)

B. E. MECHANICAL ENGINEERING (PART TIME) FIRST YEAR FIRST SEMESTER SUPPLEMENTARY EXAM - 2024

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) What will be the expression of Total Strain Energy (U) if a shaft of length L and uniform circular cross section A is subjected to equal and opposite torque of magnitude T at its ends? Assume the modulus of rigidity of the shaft material is G and the polar moment of inertia of the cross section is J.

(b) 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 $\Sigma F = m'\Delta v$, where m' is the steady mass flow rate and $\Delta \boldsymbol{v}$ is the change in velocity vector.

(c) Define slenderness ratio. Discuss classification of columns based on effective slenderness ratio and show them on a plot of test data for axially loaded steel columns.

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

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

(f) Schematically show different types of rigid body plane motion and explain with suitable examples.

2. The compound beam shown in **Fig. Q2** has two segments connected by pin joint at B. (a) Draw the free body diagram and compute all reaction forces at A, B, 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 'I' section. For the given W310x60 'I' section $d = 302\text{mm}$, $I_y = 18.4 \times 10^6\text{mm}^4$ and $I_z = 128 \times 10^6\text{mm}^4$. **[10+10+05]**

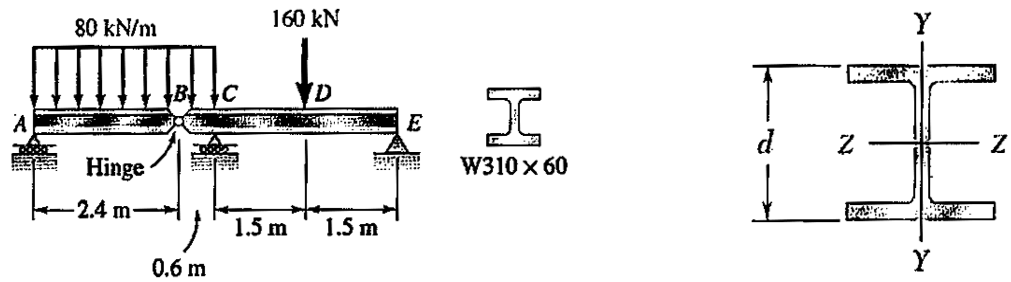

Fig. Q2

3. A cantilever 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 the free end B.

(c) Find the deflection at the free end B. **[15+05+05]**

[Turn over

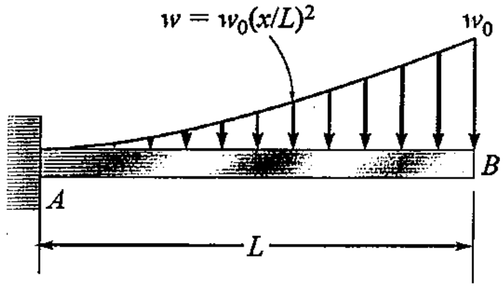

Fig. Q3

4. (a) A statically indeterminate beam of length L is loaded as shown in **Fig. Q4(a)**. Use singularity functions to determine all the support reactions at ends A and D. The modulus of elasticity of the beam material is E and the area moment of inertia of the beam cross section is I. **[15]**

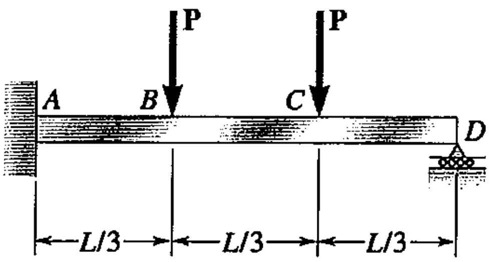

Fig. Q4(a)

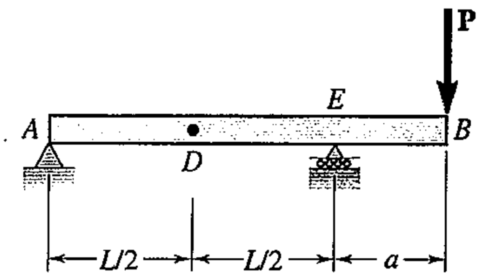

Fig. Q4(b)

(b) Use Castigliano's theorem to determine the slope at D for the beam and loading shown in **Fig. Q4(b)**. The modulus of elasticity of the beam material is E and the area moment of inertia of the beam cross section is I. **[10]**

5. (a) The system of three particles in **Fig. Q5(a)** has the indicated particle masses, velocities, and external forces. Determine $\bar{r}$, $\dot{\bar{r}}$, $\ddot{\bar{r}}$, T, $\bar{H}_O$, $\dot{\bar{H}}_O$, $\bar{H}_G$ and $\dot{\bar{H}}_G$ for this three–dimensional system. All the symbols habe their usual meaning. **[07]**

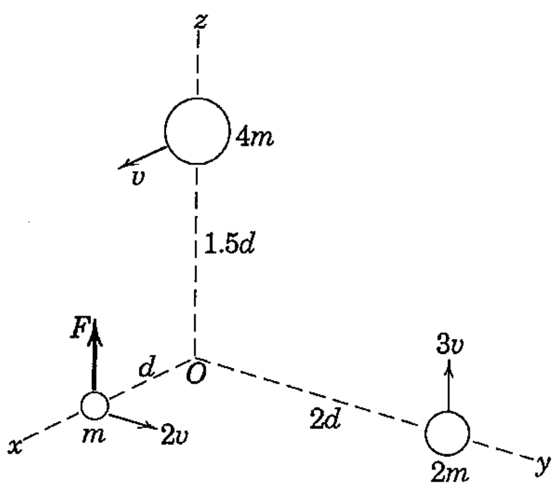

Fig. Q5(a)

(b) A rocket takes the position in its trajectory as shown in **Fig. Q5(b)**. 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. **[08]**

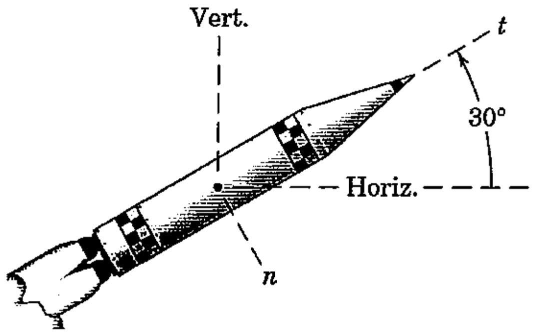

Fig. Q5(b)

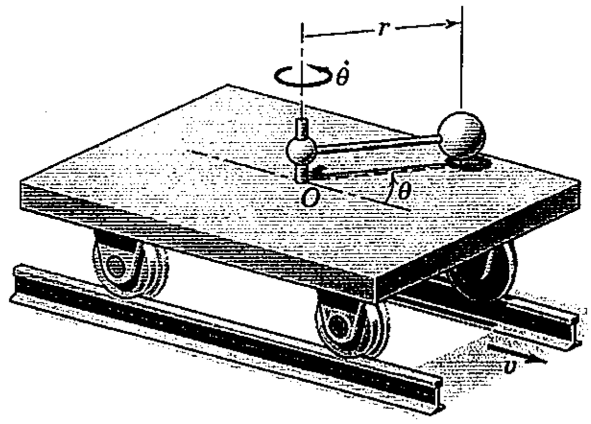

Fig. Q5(c)

(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 $\theta = 0°$, calculate v when $\theta = 60°$. Neglect the mass of the wheels and any friction. **[10]**