B. E. MECHANICAL ENGINEERING (PART TIME) FIRST YEAR FIRST SEMESTER – 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 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) Define (i) strain energy density, (ii) modulus of toughness, (iii) modulus of resilience.

(b) Draw schematic diagrams of a compound beam and a statically indeterminate beam. Show the corresponding free body diagrams.

(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) A group of functions are expressed as $\langle x-b \rangle^n$ for $n = 0, 1, 2....$ Briefly discuss about these functions. Plot the function $\langle x-b \rangle^0$ vs x.

(e) Derive the equation of angular momentum ($\boldsymbol{H}_G$) for a mass system about its mass centre G.

(f) State the Rigid-Body Assumptions. What are the differences between rigid body and deformable body?

2. The compound beam shown in **Fig. Q2** is supported by a roller at A, pin connected at B, and fixed at C. The beam dimensions and loading are also shown. The cross section of the beam is rectangular with 40 mm width and 80 mm height.
(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 the 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]**

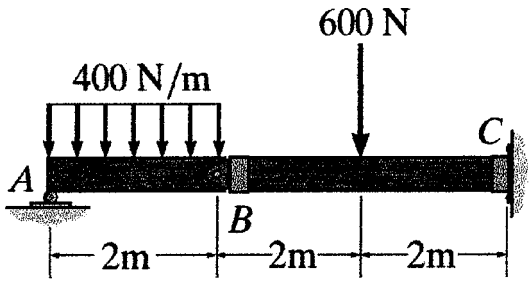

Fig. Q2

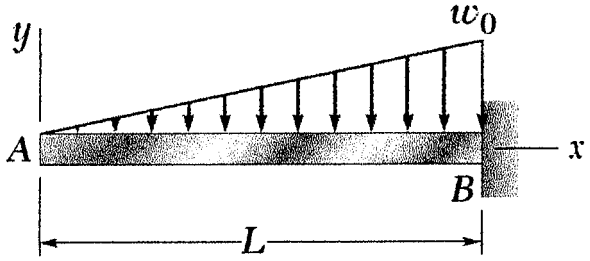

Fig. Q3

3. A cantilever beam AB of length L is subjected to triangularly distributed load with maximum magnitude of w_0 at the fixed end B as shown in **Fig. Q3**.

(a) Starting from the fourth order governing differential equation, determine the equation of the elastic curve of the beam with respect to the given x–y coordinate system.
(b) Compute the slope at the free end A.
(c) Find the deflection at the free end A. **[15+05+05]**

4. (a) Derive the Euler's formula for calculating critical buckling load of a column of length L with both ends pin supported. What is the expression for the critical stress? **[10]**

(b) Use Castigliano's theorem to determine the slope at D for the beam and loading shown in **Fig. Q4(b)**. **[15]**

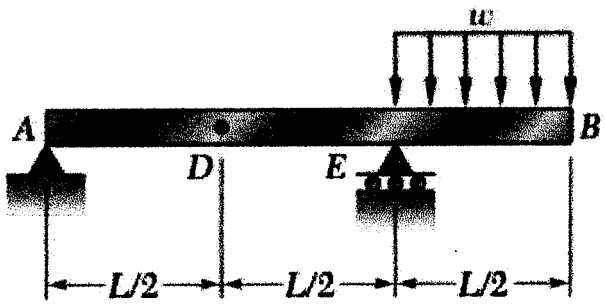

Fig. Q4(b)

5. (a) The system of four 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]**

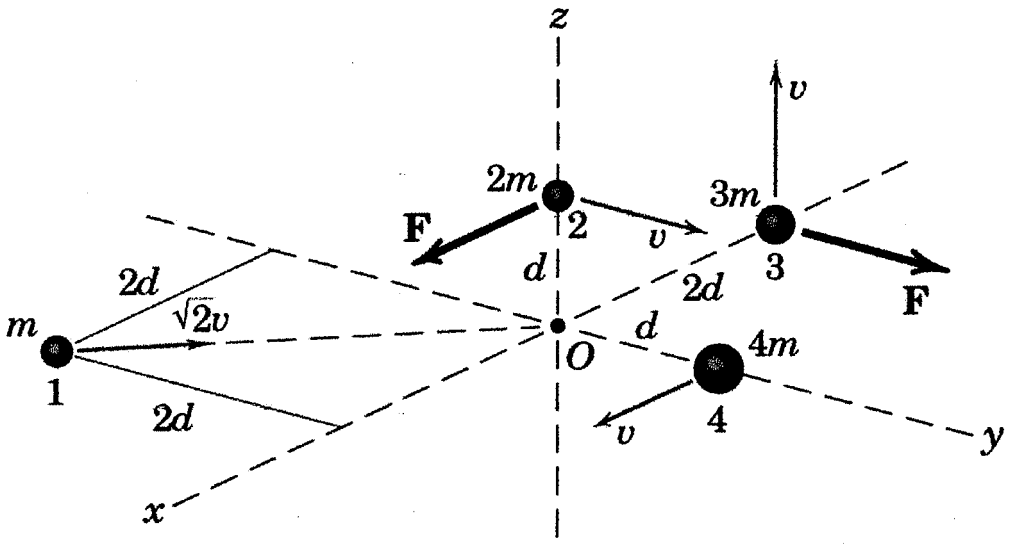

Fig. Q5(a)

(b) The three small spheres shown in **Fig. Q5(b)** are welded to the light rigid frame which is rotating in a horizontal plane about a vertical axis through O with an angular velocity $\dot{\theta} = 25$ rad/s. If a couple $M_O = 40$ Nm is applied to the frame for 8 seconds, compute the new angular velocity. **[08]**

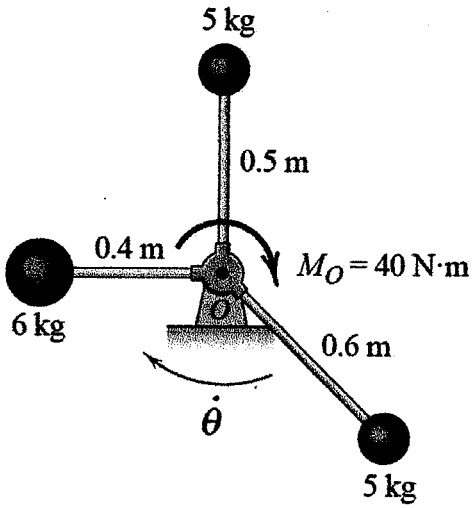

Fig. Q5(b)

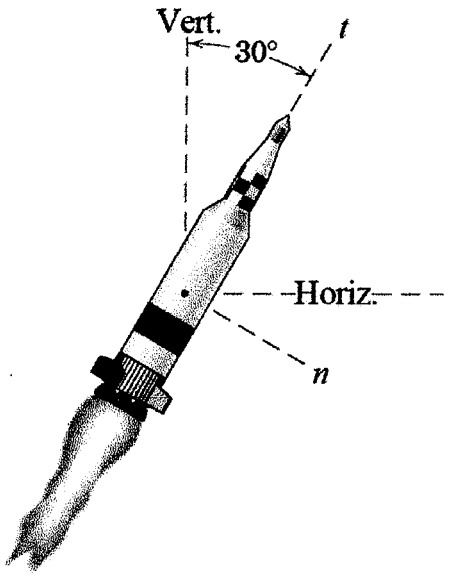

Fig. Q5(c)

(c) The rocket shown in **Fig. Q5(c)** has reached a certain altitude beyond the effective influence of the earth's atmosphere. Its mass has decreased to 2.8 Mg, and its trajectory is 30° from the vertical. Fuel is being consumed at the rate of 120 kg/s with an exhaust velocity of 640 m/s relative to the nozzle. Gravitational acceleration is 9.34 m/s^2 at its altitude. Calculate the n- and t-components of the acceleration of the rocket. **[07]**