

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

044



Study Programme	Bachelor of Science Honours in Engineering
Name of the Examination	Final Examination
Course Code and Title	DMX5201 Advance Engineering Mechanics
Academic Year	2022/23
Date	02 nd February 2023 (Friday)
Time	09.30 - 12.30 hrs
Duration	03 hours

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Four (4)** Pages.
3. Answer **All Six (6)** Questions.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.

QUESTION 1 (16 marks)

The bent rod shown in Figure Q1 has a mass of 3 kg/m. Determine the moment of inertia of the rod about the O-a axis.

$$I_{Oa} = I_{xx}u_x^2 + I_{yy}u_y^2 + I_{zz}u_z^2 - 2I_{xy}u_xu_y - 2I_{yz}u_yu_z - 2I_{zx}u_zu_x$$

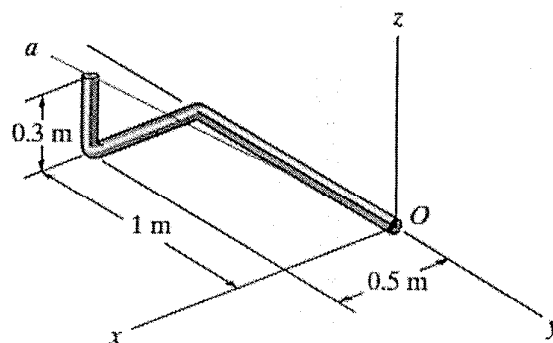


Figure Q1

QUESTION 2 (20 marks)

The slender bar [Figure Q2 (a)] has a mass of 31 kg and a length of 2.6 m. A 50 N force is statically applied to the bar at point B initially and then removed (at $t = 0$). Then the oscillations of point B are monitored, and the acceleration – time graph is shown in Figure Q2 (b). Time scale of the graph is calibrated (given in s) but the acceleration scale is not calibrated (given as units).

- Draw the free body diagram and mark all the forces (External, Linear motion, Angular motion) acting on the bar.
- Find the governing equation for the motion of the bar by taking small displacements at point B as x . Standard form of the governing equation with usual notation is given below.

$$\ddot{x} + 2\xi\omega_n\dot{x} + \omega_n^2x = 0$$

- Find the natural frequency ω_n and damping ratio ξ .
- Compute spring stiffness k and the damping coefficient c for the system.
- Calibrate the acceleration scale.
- Write the equation of motion for this system.

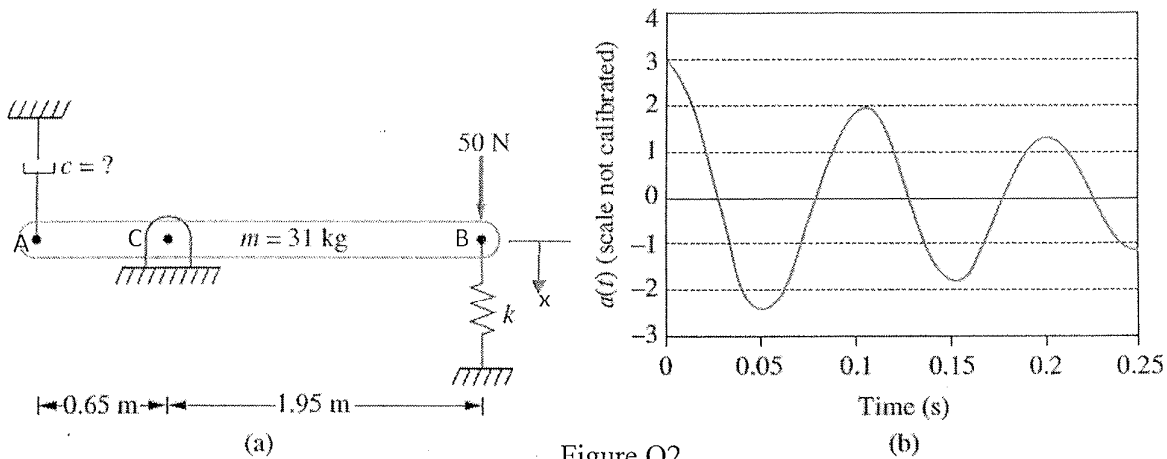


Figure Q2

QUESTION 3 (16 marks)

Figure Q3 shows a vibrating system consisting of two masses m_1 and m_2 . This represents a simple multi degree of freedom vibrating system. It can be assumed that the system is frictionless, and the boundaries are rigid.

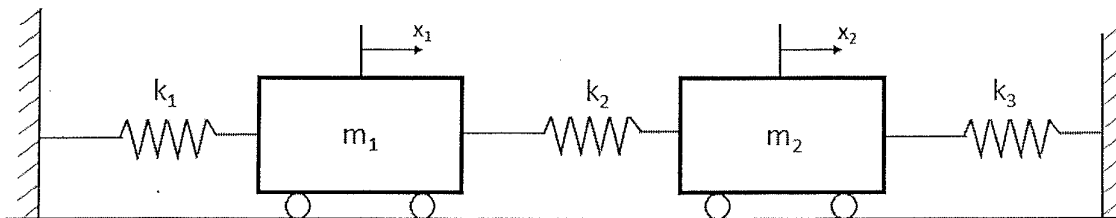


Figure Q3

- Write the governing equations for the motion of mass m_1 and m_2 of the system.
- Write the governing equation of motion for the system in matrix form.

- (c) If $m_1 = 10$ kg, $m_2 = 20$ kg, $k_1 = k_2 = 1 \times 10^5$ N/m and $k_3 = 2 \times 10^5$ N/m find the natural frequencies ω_n and mode shapes of the system.
- (d) When the motion starts (at $t = 0$) $x_1 = 0.001$ m, $x_2 = 0$, $\dot{x}_1 = 0$ and $\dot{x}_2 = 0$. Find the complete solution of this vibrating system. The general solution of such system with usual notations can be written as

$$x(t) = A_1 x_1 \sin(\omega_1 t + \varphi_1) + A_2 x_2 \sin(\omega_2 t + \varphi_2)$$

QUESTION 4 (16 marks)

A torsional vibration system consists of four rotors, 1, 2, 3, and 4, mounted on a steel shaft of diameter 50 mm. Moments of inertia of the rotors and the lengths of the sections of the shaft are given in the Table Q4(a) and Q4(b).

Moments of Inertia of Rotors (kgm ²)	
Rotor 1	0.60
Rotor 2	0.20
Rotor 3	0.10
Rotor 4	0.25

Table Q4(a)

Lengths of Sections of Shafts between Rotors (m)	
Between rotors 1 and 2	0.50
Between rotors 2 and 3	0.25
Between rotors 3 and 4	1.00

Table Q4(b)

To find the natural frequencies and the mode shapes it is decided to use Holzer method and for the first natural frequency of the system is suggested as **62.5** Hz. The modulus of rigidity of the shaft material is given as **80** GN/m²

- (a) Check this approximate value and determine whether it is high or low.
- (b) Sketch the mode of vibration at this frequency and find the position of the node.

QUESTION 5 (16 marks)

- (a) Explain, what a Vibration Exciter is? Name three different types of vibration exciters.
- (b) With the aid of sketches, briefly describe one of the vibration exciters you mentioned above.
- (c) Explain, what is machine condition monitoring stating its advantages and disadvantages?
- (d) Name four different display formats and analysis tools used in vibration signal analysis. Briefly explain one of them.

QUESTION 6 (16 marks)

A motor and attached rod **AB** have the angular motions shown in Figure Q6. A collar **C** on the rod is located **0.25 m** from **A** and is moving downward along the rod with a velocity of **3 m/s** and an acceleration of **2 m/s²**. At the given instance the motor shaft rotates with an angular velocity $\omega_M = 3 \text{ rad/s}$ and angular acceleration of $\dot{\omega}_M = 1 \text{ rad/s}^2$. The circular platform which the motor is attached rotates around its center axis with an angular velocity $\omega_p = 5 \text{ rad/s}$ and angular acceleration of $\dot{\omega}_p = 2 \text{ rad/s}^2$. Determine the velocity and acceleration of the collar **C** relative to the fixed coordinates system at this instant.

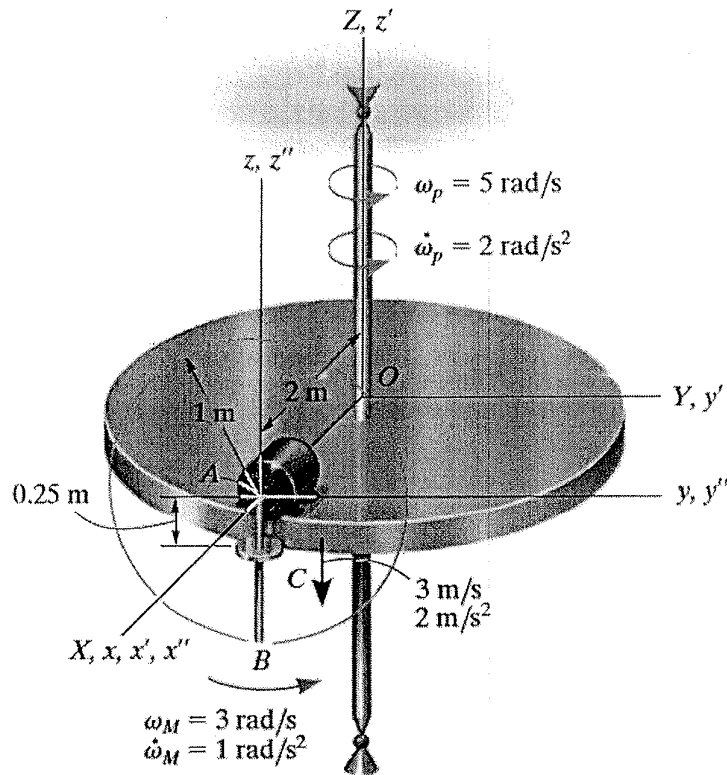


Figure Q6

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