MACHAKOS UNIVERSITY

University Examinations For 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATIONS FOR THE DEGRE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM419: ENGINEERING VIBRATIONS

DATE: TIME: 2 HOURS

INSTRUCTIONS

i) This paper contains FIVE questions
ii) Question ONE is **compulsory** and carries 30 Marks.
iii) The rest of the questions carry 20 Marks each.
iv) **Answer question and any other two.**

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Differentiate between torsional and translational vibrations. **(2 Marks)**

b) The Fig. Q1b) shows a general TDOF vibrating system. Derive the equations of motion and express them in matrix notation. **(5 Marks)**

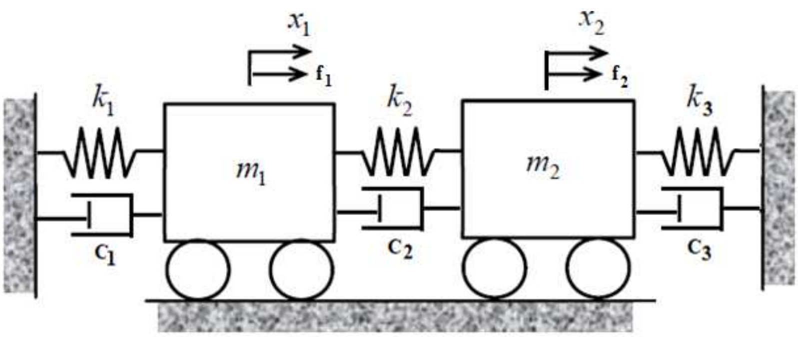


Fig. Q1 b)

c) A shaft 50 mm diameter and 3 m long is simply supported at the ends and carries four loads of 1000 N, 1500 N, 750 N and w = 80 N/m as shown **in Fig. Q1c).** The Young's modulus for shaft material is 200 GN/m^2. Find the cyclic frequency of transverse vibration using Dunkley's method. **(6 Marks)**

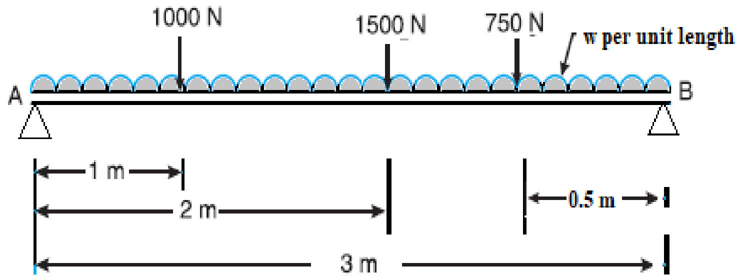


Fig. Q1c)

d) Study the system shown in **Fig. Q1d)** below of a free damped two degree of freedom system.

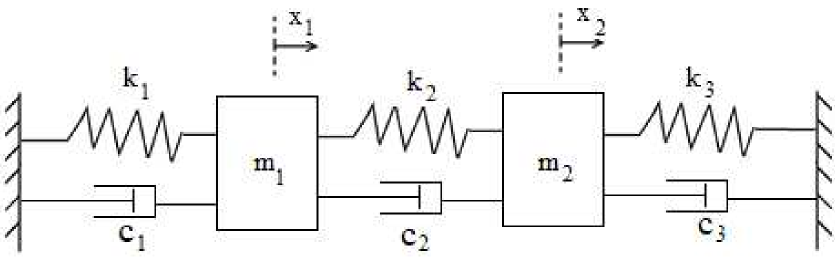


Fig. Q1d)

Derive the state space formulations that can be used in MATLAB to plot the responses of displacements and velocities of the system. **(6 Marks)**

e) A shaft of varying diameters d_1, d_2 and d_3 with lengths l_1, l_2 and l_3 respectively is as shown in **Fig. Q1 e).**

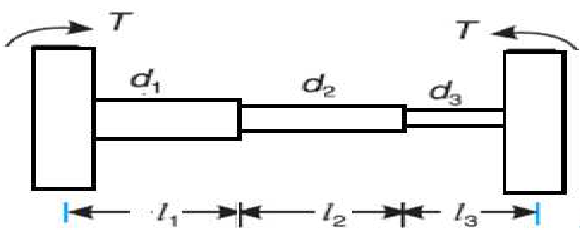


Fig. Q1 e)

Show that such a shaft can be reduced to a torsionally equivalent shaft whose length is given by $l = l_1 + l_2\left(\frac{d_1}{d_2}\right)^4 + l_3\left(\frac{d_1}{d_3}\right)^4$ **(4 Marks)**

f) An electric motor, **Fig. Q1 e),** is to drive a centrifuge, running at four times the motor speed through a spur gear and pinion. The steel shaft from the motor to the gear wheel is 54 mm diameter and L m long; the shaft from the pinion to the centrifuge is 45 mm diameter and 400 mm long. The masses and the radii of gyration of motor and centrifuge are respectively 37.5 kg, 100 mm; 30 kg and 140 mm. Neglecting the inertia effect of the gears, find the value of L if the gears are to be at the node for torsional oscillation of the system and hence determine the frequency of torsional oscillation. Assume modulus of rigidity for the material of shaft as 84 GN/m^2. **(7 Marks)**

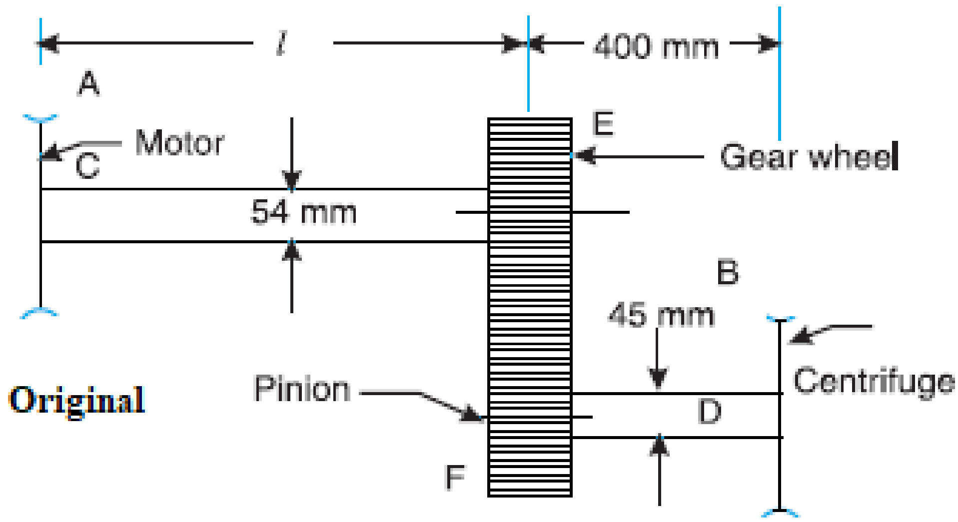


Fig. Q1 e)

QUESTION TWO (20 MARKS)

a) What is a node? State the number of nodes in a 3-rotor system. **(2 Marks)**

b) **Figure Q2 b)**, illustrates a torsional system. Derive the frequency equation. In the particular case where $J_1 = 2J_2 = 2J$ and $K_1 = K_c = K_2 = K$, determine the ratios of amplitudes corresponding to the two natural modes. **(18 Marks)**

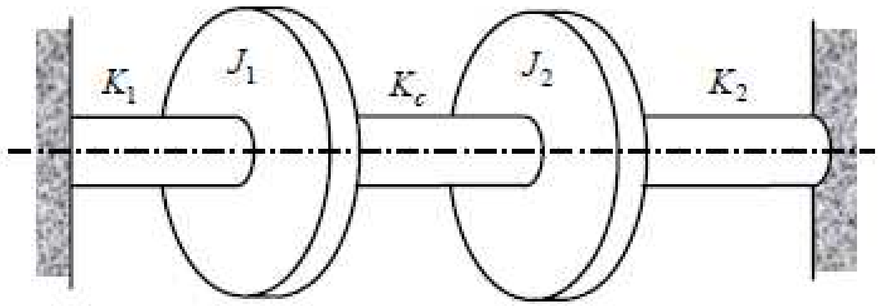


Fig. Q2 b)

QUESTION THREE (20 MARKS)

Consider a MDOF system illustrated in **Fig. Q3** below. Using the flexibility influence coefficients method, set up the system as an eigenvalue problem, derive the frequency equation and hence determine its free vibration natural frequencies given that m = 2 kg and k = 450 N/m.

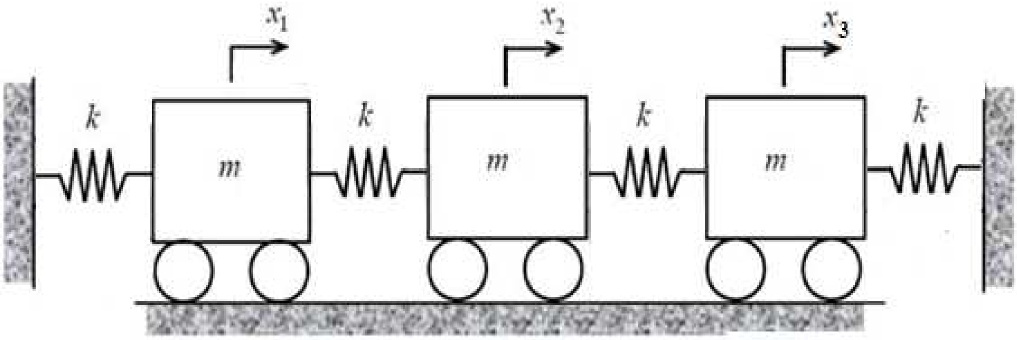


Fig. Q3

QUESTION FOUR (20 MARKS)

a) In **Fig. Q4 a**) a pulley rotates about a fixed centroidal axis and may be considered to be a rigid solid cylinder of homogeneous material. As shown, the mass of the pulley is equal to that of the suspended mass. There can be no sliding between the cord connecting the two springs and the pulley. Determine the natural frequencies of the system for r = 0.5m, m = 1 kg and k = 10 N/m. **(10 Marks)**

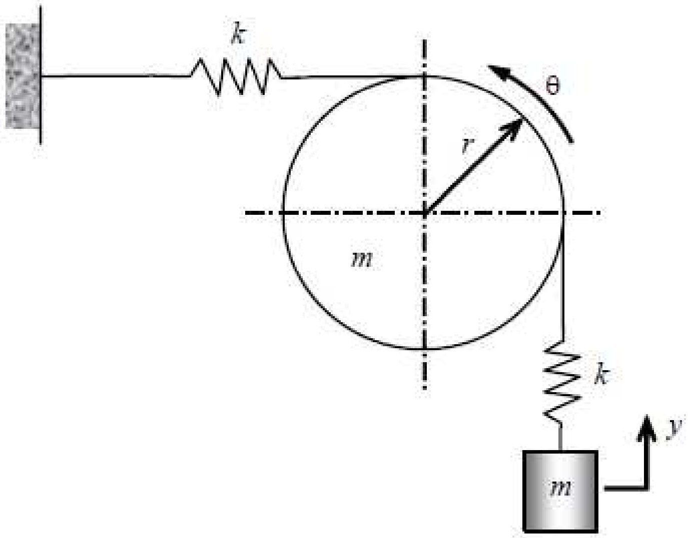


Fig. Q4 a)

b) The response of a sub-critically damped vibrating mass-spring system is given by;

$$y(t) = \frac{\sqrt{(\beta\omega_n x_0)^2 + (v_0 + \zeta\omega_n x_0)^2}}{\beta\omega_n} e^{-\zeta\omega_n t}\cos\left(\beta\omega_n t - tan^{-1}(\frac{v_0 + \zeta\omega_n x_0}{\beta\omega_n x_0}\right)$$

Where the initial displacement and velocity are x_0 and v_0 respectively and the other parameters retain their usual meaning. Given that $x_0 = 0.001$ m, $v_0 = 0.001$ m/s, c = 10 Ns/m, k = 100 N/m and m = 1000 g, write a MATLAB code that can be used to plot the response of the system. Remember to label your axes, provide a title and put grids on.

(10 Marks)

QUESTION FIVE (20 MARKS)

a) Fig. Q5 a), illustrates a model that can applied in the study of car characteristics. The front and rear suspensions are modelled to be purely linear elastic springs. The coordinates are chosen such that vehicle bounce is measured by the vertical motion of the vehicle body's centre of gravity

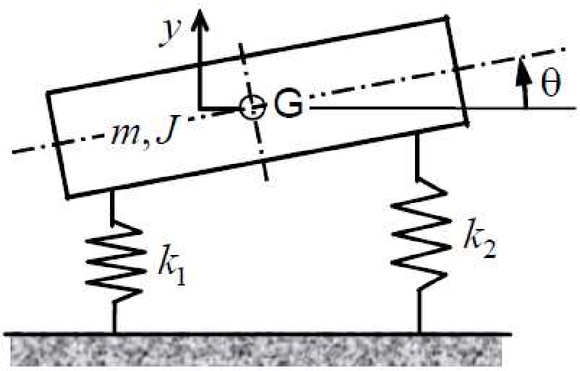


Fig. Q 5 a)

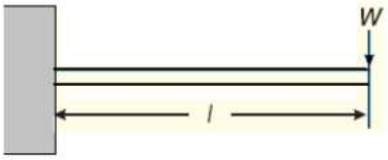
Given that the total mass of the vehicle is 1600 kg, k_1 is 20 kN/m, k_2 is 30 kN/m and the distance between centre of gravity and k_1 and k_2 are 1.35m and 1.70 m respectively, determine the natural circular frequencies of vibration of the system. Take the moment of inertia of the vehicle about the centre of gravity G as 2300 kgm^2 **(12 Marks)**

b) A shaft 60 mm diameter and 3.2 metres long is simply supported at the ends and carries three loads of 1200 N, 2000 N and 800 N at 1 m, 2 m and 2.5 m from the left support. The Young's modulus for shaft material is 110 GN/m^2. Find the cyclic frequency of transverse vibration. **(8 Marks)**

Appendix

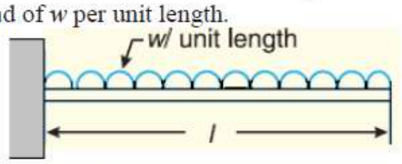
Values of static deflection (δ) for the various types of beams and under various load conditions.

1. Cantilever beam with a point load W at the free end



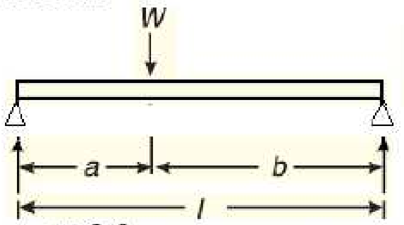
$\delta = \frac{Wl^3}{3IE}$ at the free end

2. Cantilever beam with a uniformly distributed load of w per unit length.



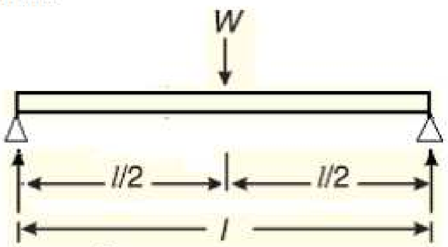
$\delta = \frac{wl^4}{8IE}$ at the free end

3. Simply supported beam with an eccentric point load W.



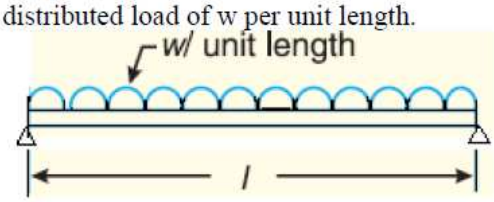
$\delta = \frac{Wa^2b^2}{3IEl}$ at the point load

4. Simply supported beam with a central point load W.



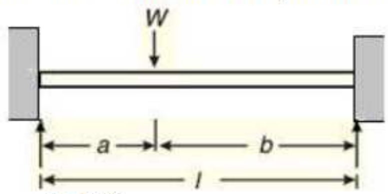
$\delta = \frac{Wl^3}{48IE}$ at the centre

5. Simply supported beam with a uniformly distributed load of w per unit length.



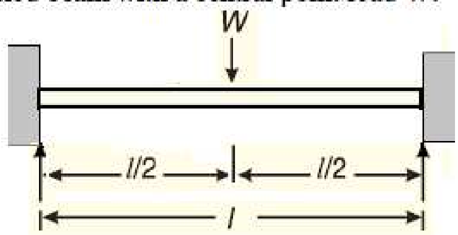
$\delta = \frac{5}{384}\frac{wl^4}{IE}$ at the centre

6. Fixed beam with an eccentric point load W.



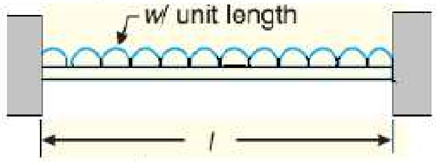
$\delta = \frac{Wa^3b^3}{3IEl^3}$ at the point load

7. Fixed beam with a central point load W.



$\delta = \frac{Wl^3}{192IE}$ at the centre

8. Fixed beam with a uniformly distributed load of w per unit length.



$\delta = \frac{wl^4}{384IE}$ at the centre