MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM311: MECHANICS OF MACHINES II

DATE: 10/12/2021 **TIME: 8:30 – 10:30 AM**

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) Define the following terms

i) Degrees of freedom of a vibrating system (1 mark)

ii) Transmissibility or isolation ratio (1 mark)

b) Distinguish between static and dynamic rotor balancing (2 marks)

c) Fig. Q1 c) shows a vibrating spring-mass system.

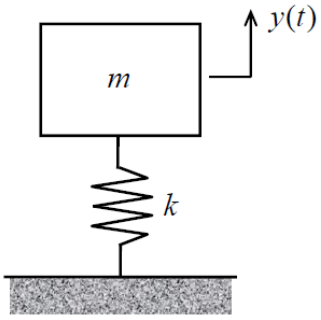


Fig. Q1 c)

If the mass vibrates harmonically with an amplitude of 3 mm and a frequency of 20 Hz, determine;

i) The maximum velocity of the system in m/s (3 marks)

ii) The maximum acceleration m/s^2 (2 marks)

d) An aeroplane settles 10 cm into its landing-gear springs when the airplane is at rest. What are the natural cyclic and circular frequencies for vertical motion of the airplane? (2 marks)

e) The compound pendulum illustrated in Fig. Q1 e) having a mass of 10 kg and mass moment of inertia of 0.3848 kg-m^2 is given an angular displacement of **θ**. By first deriving the equation of motion, determine its natural cyclic frequency when it is left to freely vibrate. Take g = 9.81 m/s^2 and L = 20 cm (5 marks)

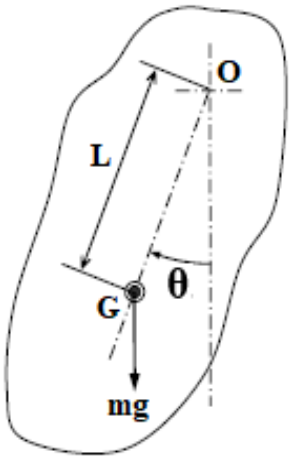


Fig. Q1 e)

f) Using energy method, show that the natural cyclic frequency of longitudinal vibration of a beam of negligible mass carrying a mass of m kg at its free end is given by;

$f_n = \frac{0.4985}{\sqrt{\delta}}$

where δ is the static deflection (5 marks)

g) For torsional vibrations, show that the inertia of a shaft can be accounted for by adding $\frac{I_c}{3}$ to the moment of inertia I of a rotor placed at the end of the shaft. (5 marks)

h) i) Giving an example, explain any two applications of ball thrust bearings (2 marks)

ii) SKF Ball bearings are rated at 1 million revolutions. If you desire a life of 5000 h at 1725 rev/min with a load of 2 kN and a reliability of 90 percent, from which SKF catalogue rating would you search for the bearing? (2 marks)

QUESTION TWO (20 MARKS)

a) Figure Q2 a) shows a model of a single degree of freedom system that was underdamped.

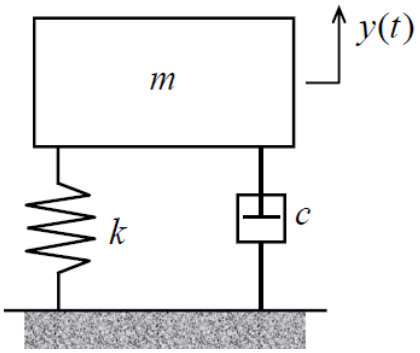


Fig. Q2 a)

Staring from the free body diagram of the system, derive the response equation of the system clearly defining the symbols used. (15 marks)

b) A load of 50 kg is suspended from a spring whose stiffness is 5 kN/m, and its motion is damped by a force proportional to the velocity of magnitude 75 N at 1 m/s. If the load is displaced from its equilibrium position and then released, find the number of complete vibration cycles that it will execute before its amplitude is reduced to less than one tenth of the original displacement. (5 marks)

QUESTION THREE (20 MARKS)

a) Fig. Q3 a) shows a Single Degree of Freedom that is forced to vibrate by a harmonic force.

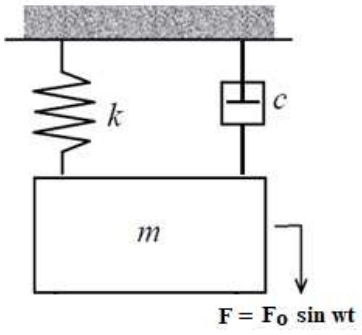


Fig. Q3 a)

Given that its maximum displacement is given by

$x_{max} = \frac{F_0}{\sqrt{(k-m\omega^2)^2+(c\omega)^2}}$

Show that the maximum magnification factor of the system is given by:

$D_{max} = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$ where ζ is the damping ratio. (14 marks)

b) The mass of an electric motor is 120 kg and it runs at 1500 r.p.m. The armature mass is 35 kg and its center of gravity lie 0.5 mm from the axis of rotation. The motor is mounted on five springs of negligible damping so that the force transmitted is one-eleventh of the impressed force. Assume that the mass of the motor is equally distributed among the five springs.

Determine**:**

i) natural cyclic frequency of the system (2 marks)

ii) stiffness of each spring (2 marks)

iii) dynamic force transmitted to the base at the operating speed (2 marks)

QUESTION FOUR (20 MARKS)

a) Establish the effect of inertia of the shaft in transverse vibrations on its natural circular frequency hence proof that; (10 marks)

$\omega_n = \sqrt{\frac{k}{m+\frac{33}{140}m_C}}$ for a shaft fixed at one end and carrying a rotor at the free end

b) A flywheel is mounted on a vertical shaft as shown in Fig Q4 b). Both ends of the shaft are fixed and its diameter is 50 mm. The flywheel has a mass of 500 kg. Find the natural frequency of longitudinal and transverse vibrations. Take E = 200 GN/m^2.

(10 marks)

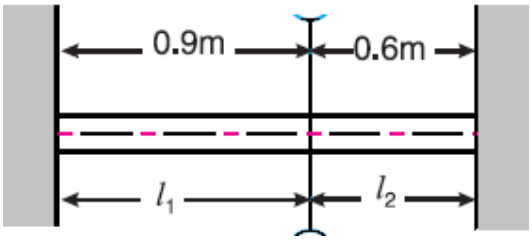


Fig. Q4b)

QUESTION FIVE (20 MARKS)

a) i) What causes unbalance in rotors and what is its effect? (2 marks)

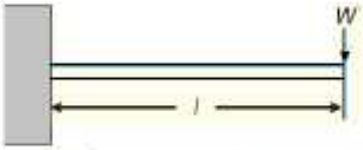
ii) What is rotor balancing? (1 mark)

b) A shaft carries three masses A, B and C. Planes B and C are 60 cm and 120 cm from A. The masses A, B and C are 50 kg, 40 kg and 60 kg respectively at a radius of 2.5 cm. The angular position of mass B and mass C with A are 90^0 and 210^0 respectively. Find the unbalanced force and couple. Also find the position and magnitude of balancing mass required at 10 cm radius in planes L and M midway between A and B, and B and C.

Use analytical method (17 marks)

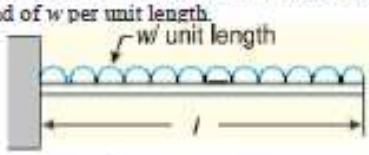
Values of static deflection (δ) for the various types of beams and under various load conditions.

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



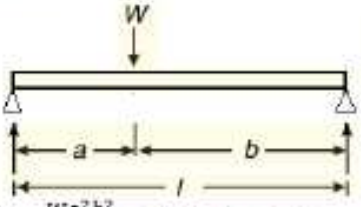
$\delta = \frac{Wl^3}{3IE}$ at the free end

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



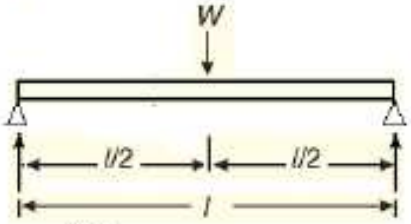
$\delta = \frac{wl^4}{8IE}$ at the free end

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



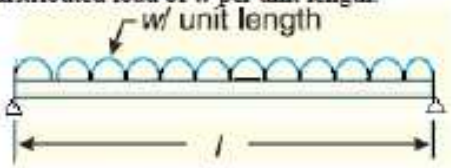
$\delta = \frac{Wa^2b^2}{3IEl}$ at the point load

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



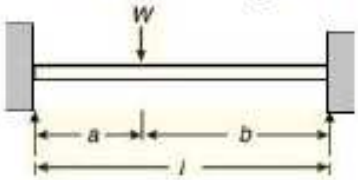
$\delta = \frac{Wl^3}{48IE}$ at the centre

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



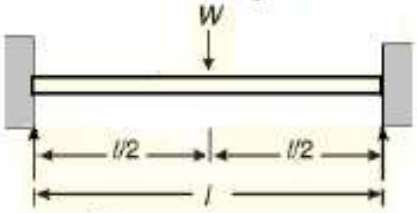
$\delta = \frac{5}{384}\frac{wl^4}{IE}$ at the centre

6. Fixed beam with an eccentric point load W.



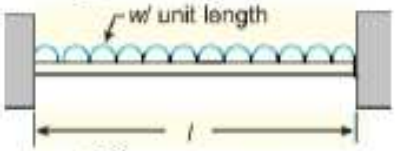
$\delta = \frac{Wa^3b^3}{3IEl^3}$ at the point load

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