بسم الله الرحمن الرحيم

King Abdulaziz University
Engineering College
Department of Production and Mechanical System Design

MENG 470 Mechanical Vibrations

Final Exam
Closed-book Exam
Monday: 19/4/1425 H
Time Allowed: 120 mins

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قال ا تعالى : (تلك الدار الآخرة نجعلها للذين لا يريدون علوا في الأرض ولا فسادا والعاقبة للمتقين)

<u>Instructions</u>

1. This is a closed book and closed notes Opportunity to Shine
2. Show all work for partial credit.

3. Assemble your work for each problem in logical order.
4. Justify your conclusion. I cannot read minds.

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Mechanical Vibrations	Closed Book Exam
MENG 470	Time: 2 Hours
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PART I

Select the most appropriate answer from the multiple choices given:

1. Which one of the following is a valid application for the Principle of Virtual Work?
   a. Solve an eigenvalue problem for a system
   b. Find the static equilibrium of a system
   c. Find the dynamic equilibrium of a system
   d. Determine the stability of a system

2. D'Alembert's Principle can be used directly to derive the differential equations of motion for a dynamic system.
   a. True
   b. False

3. A single-degree-of-freedom system has only one natural frequency.
   a. True
   b. False

4. The real part of the solution to the characteristic equation for a single-degree-of-freedom system is zero. Which one of the following best describes the system?
   a. Underdamped
   b. Unstable
   c. Undamped
   d. Nonperiodic

7. All of the normal modes of a multi-degree-of-freedom system are orthogonal, except for rigid body modes.
   a. True
   b. False

8. If a multi-degree-of-freedom system is positive semi-definite, which one of the following is not true?
   a. The stiffness matrix is positive semi-definite
   b. The eigenvalues of the system cannot be determined
   c. The system has at least one rigid body mode
   d. The system has at least one eigenvalue with a value of zero

9. If the modes, *u*, of a multi-degree-of-freedom system are normalized with respect to the mass matrix, [m], the expression $[u]^T[m][u]$ yields the identity matrix.
   a. True
   b. False

10. Which one of the following is not a characteristic of a continuous dynamic system?
    a. The equations of motion are partial differential equations
    b. The system response cannot be calculated
    c. The system has an infinite number of degrees of freedom
    d. Both boundary conditions and initial conditions must be specified

11. Which one of the following is not required to perform a modal analysis of a continuous system?
    a. Calculate the natural frequencies
    b. Calculate the natural modes
    c. Normalize the natural modes
    d. Calculate Rayleigh's Quotient

12. The flexibility and the stiffness matrices are the inverse of one another.
    a. True
    b. False

13. The element stiffness matrices are always singular unless the boundary conditions are applied.
    a. True
    b. False

14. The finite element method is:
    a. an approximate analytical method
    b. a numerical method
    c. an exact analytical method

15. What cause whirling of rotating shafts?
    a. Mass unbalance
    b. Fluid friction in the bearings
    c. Gyroscopic forces
    d. All above.

16. To measure mechanical vibrations, we use:
    a. Accelerometers and signal analyzer.
    b. Sound level meters.
    c. Exciter and exciter controller.
    d. All above.

17. The fundamental natural frequency of a system is a:
    a. The largest value
    b. The smallest value
    c. Any value.

18. When a two degree of freedom system is subjected to a harmonic force, the system vibrates at the:
    a. Frequency of applied force.
    b. Smaller natural frequency
    c. Larger natural frequency.

19. The response of an undamped system under resonance will be:
    a. Very large.
    b. Infinity.
    c. Zero.

20. Gibbs phenomenon denotes an anomalous behavior is the Fourier series representation of a:
    a. Harmonic function.
    b. Periodic function.
    c. Random function

PART II

Q1. Consider the two-mass system shown in Figure 1. The physical parameters of the system are: m=9 kg, m=1 kg, =24 N/mm, and =3 N/mm.

a) Determine the natural frequencies.
b) Derive modal equations for each natural frequency.
c) Determine the response of the system for the initial conditions $x_1(0)=1$ mm, $x_2(0)=0$ mm, and $\dot{x}_1(0)=\dot{x}_2(0)=0$ mm/s.
d) Decouple the equations of motion using *modal analysis*. Then determine the response of the system for the same initial conditions.
e) If a harmonic force, $\boldsymbol{F(t)=F_2\cos(\omega t)}$ is applied to the second mass . Derive frequency response functions from
   (i) coupled systems.
   (ii) uncoupled systems

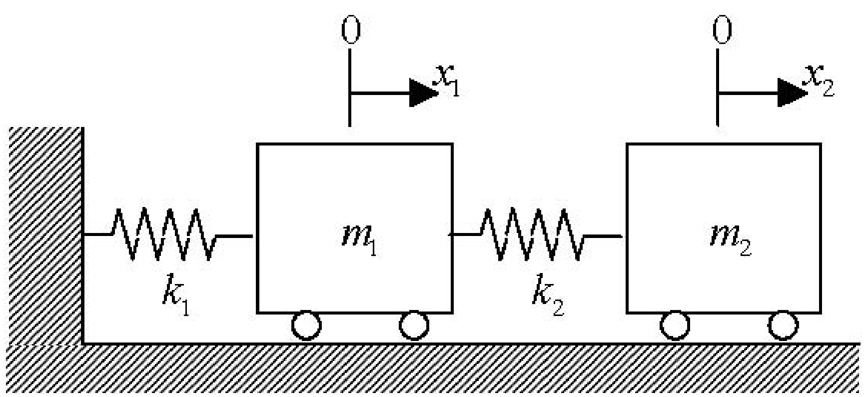

Figure 1

Q2. Engineer Abdulaziz designed one type of horizontal seismograph, a device that records earthquakes in the horizontal direction. It can be modeled as shown in Figure 2. The physical parameters of the seismograph are as following:

$$M = 1\ kg \qquad L = 1\ m$$
$$m = 4\ kg \qquad a = 0.2\ m$$
$$k = 10\ N/m$$

The acceleration of gravity is 9.81 m/s^2, and the angle of oscillation is assumed to be small θ.

(a) Write the dynamic equations in matrix form.
(b) Calculate the natural frequencies and the modal matrix.
(c) As one of the first test cases to verify the appropriateness of the design, the engineer wants to investigate a strong impulse earthquake. When the seismograph was in equilibrium, assume that the ground moved to the right with an initial velocity of $\dot{x}_0$. Decouple the equations and find resultant motions $x(t)$ and $\theta(t)$ each as a function of $\dot{x}_0$ and t.

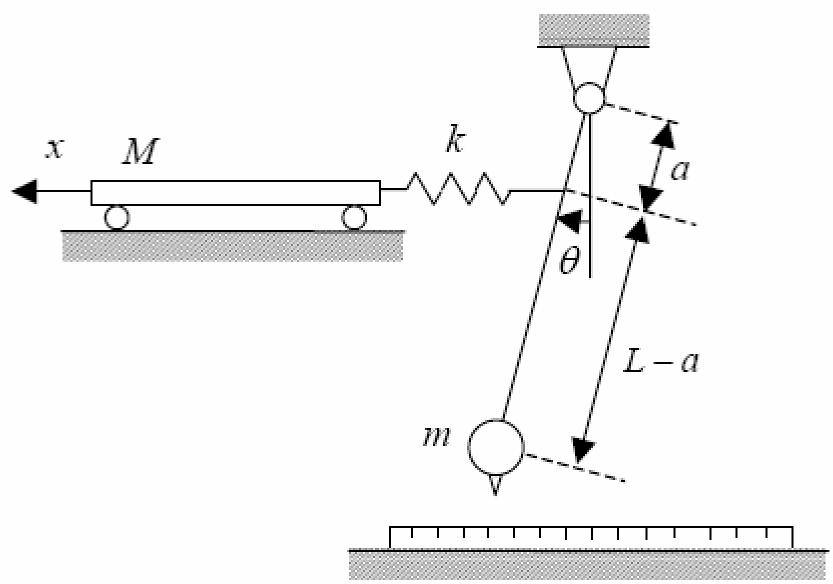

Figure 2

Q3. A beam with constant mass and stiffness properties is fixed at $x = 0$, and is supported by a linear spring at $x = L$ as shown in Figure 3.

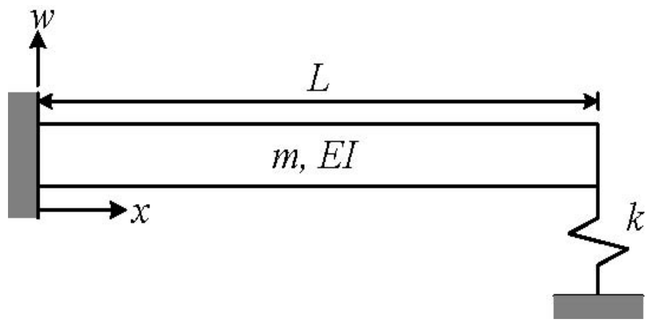

Figure 3

a. Write the boundary conditions for the beam.
b. Derive the characteristic equation for the system, but do not solve it.

Q4. A tapered rod is modeled as two uniform sections, as shown in Figure 4, where $EA_1=2EA_2$ and $m_1=2m_2$.

a) Write the equations of motion in matrix form using FEM.
b) Find the two natural frequencies of the longitudinal vibration
c) Determine the corresponding mode shapes.
d) Draw the mode shapes.

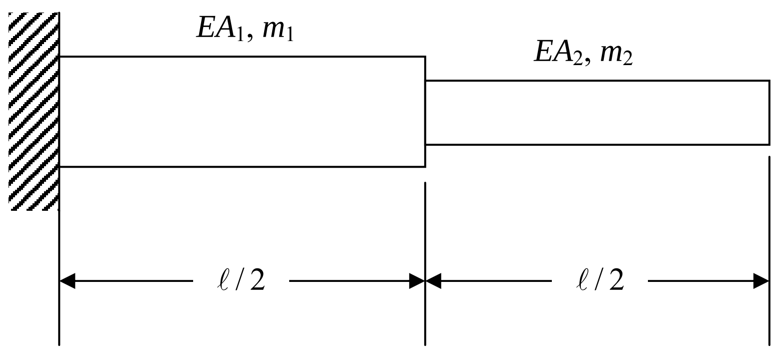

Figure 4

أتمنى لك من أعماق القلب
أداء رائعا فأنت جدير بذلك

د. سعيد بن أحمد عسيري