ME 460/660, Mechanical Vibration Final Exam, Fall 1998

Closed book, closed notes. Use one $8\frac{1}{2} \times 11$ formula sheet, front and back. Test books will be provided. Do all work on the exam pages with the exception of the full length problems.

Multiple choice. Circle the letter of the correct answers. 3 points each. *Read all questions very carefully*

1. What modeling method/s apply for determining the system equations of motion when viscous damping is present in a system?

   a. The Energy Method
   b. Lagrange's Equations
   c. Newton's Law
   d. The Fourier method
   e. (a) and (b)
   f. (b) and (c)

2. What modeling method/s apply for determining the system equations of motion when Coulomb damping is present in a system?

   a. The Energy Method
   b. Lagrange's Equations
   c. Newton's Law
   d. The Fourier method
   e. (a) and (b)
   f. (b) and (c)

3. A cyclic force acts on a system. What is the most appropriate way to approach solving for the system response?

   a. Apply Lagrange's equations
   b. Represent the force by a Fourier series
   c. Represent the response by a Fourier series
   d. Use the convolution integral

4. The suspension system of your car is designed to:

   a. Reduce displacement transmission at low frequencies
   b. Reduce displacement transmission at high frequencies
   c. Amplify displacement transmission at low frequencies

d. Amplify displacement transmission at high frequencies

5. Single degree of freedom models are used to represent:

   a. Ideal masses connected to ideal springs
   b. The low frequency response of continuous systems
   c. The high frequency response of multiple degree of freedom systems
   d. The low frequency response of multiple degree of freedom systems

6. The number of natural frequencies of interest in a model is

   a. The number considered before becoming bored with the model
   b. The number of frequencies for which the wave length (distance between nodes) is less than the distance between the molecules in the object being modelled
   c. The number of frequencies for which the wave length (distance between nodes) is greater than the distance between the molecules in the object being modelled
   d. The number of frequencies for which the modal forces are relatively large
   e. As many natural frequencies as can be obtained from the model, regardless of the accuracy of those natural frequencies

Fill in the blank, 2 points each. (Examples: 0, 1, ∞, any value)

1. In order to provide good displacement isolation in a base excited system, ω should ideally be ____ and ζ should be ____

2. In order to provide good force isolation in a base excited system, ω should ideally be ____ and ζ should be ____

3. In order to maximize harmonic forced response of a system, ω should ideally be ____ and ζ should be ____

4. In order to minimize the response of a system with rotating unbalance, ω should ideally be ____ and ζ should be ____

5. What is the value of the inertance function (amplitude of frequency divided by force amplitude) of a forced spring/mass/damper system as ω_{dr} goes to zero? ____

6. What is the value of the inertance function of a forced spring/mass/damper system as ω_{dr} goes to ∞? ____

Short Answer 4 points each

1. In one sentence, define what is meant by the settling time of a system.

2. What is the 5% settling time of a system defined by $m = 10kg$, $c = 1kg/s$, and $k = 1000$ N/m?

3. Which parameter, m, c, or k, is irrelevant to determining the settling time?

Full Length Problems (20 points each)

1. Derive the equations of motion for the following system using Lagranges equations with x and θ as the generalized coordinates. The block can only move in the vertical direction. Hint: Set the datums (point of zero potential energy with respect to gravity) to be at the unstretched spring length and $\theta = 0$.

2. Find the natural frequencies and mode shapes of the system modeled by:

   $M\ddot{\mathbf{x}} + K\mathbf{x} = \mathbf{0}$ where
   $M = \begin{bmatrix} 4 & 0 \\ 0 & 36 \end{bmatrix}$ and $K = \begin{bmatrix} 3 & -3 \\ -3 & 27 \end{bmatrix}$

3. Undergraduates Only: Find the Fourier series representation of the following function meant to represent the impacts caused by a bad bearing.

$$F(t) = \sum_{a=-\infty}^{\infty} \delta(t - a)$$

   (a is the set of integers between $-\infty$ and ∞)

   This means a unit impulse every second on the second.

   Write the series in the simplest form AND write the first 3 non-zero terms. Recall that the integral of a Dirac delta function times another function is equal to the "another function" evaluated when the argument of the argument of the Dirac delta function is zero.

4. Graduate Students Only: Solve the following equation for $w(x, t)$ subject to $w(0, t) = w(l, t) = 0$ where $c = \sqrt{\tau/\rho}$.

$$w_{tt}(x, t) - c^2 w_{xx}(x, t) = 100 \sin(3t)\delta(x - l/2)$$