ME563 – Fall 2014
Purdue University
West Lafayette, IN

Final Examination

- You have two hours (120 minutes) to complete the exam.
- You are allowed to use your ME 563 lecture book during the exam. No other materials may be accessed during the exam.
- Calculators may be used during the exam. However, no cell phones, tablets or computers may be used.
- Please do NOT write on the back of the exam papers.

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Problem 1 (25 pts)	________________
Problem 2 (15 pts)	________________
Problem 3 (15 pts)	________________
Problem 4 (15 pts)	________________
Problem 5 (15 pts)	________________
Problem 6 (15 pts)	________________
TOTAL	________________

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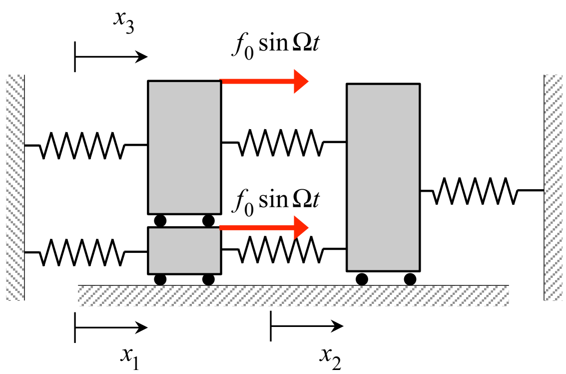
Problem 1 – 25 pts



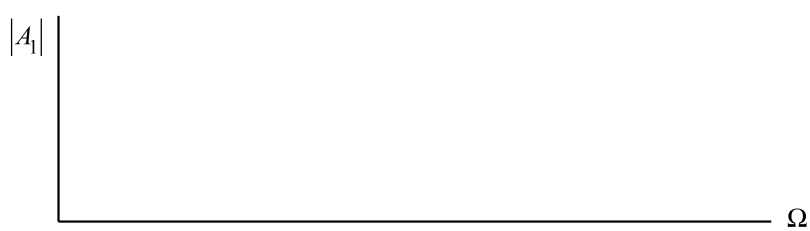
The three-DOF system shown above has the following natural frequencies and mass-normalized modal vectors:

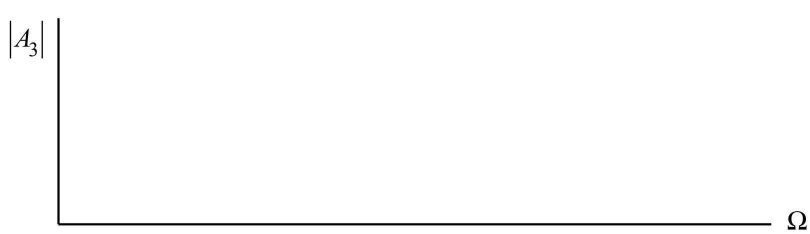
$$\omega_{1,2,3} = 1, 2, 5 \; rad/\sec$$

$$\hat{\vec{X}}^{(1)} = \begin{Bmatrix} 1 \\ 2 \\ 4 \end{Bmatrix} \qquad \hat{\vec{X}}^{(2)} = \begin{Bmatrix} 1 \\ 0 \\ -1 \end{Bmatrix} \qquad \hat{\vec{X}}^{(3)} = \begin{Bmatrix} 1 \\ -1 \\ 2 \end{Bmatrix}$$

a) If the particular solution of the EOMs for this system is written as $\vec{x}_P(t) = \vec{A} \sin \Omega t$, determine $\vec{A}$ as a function of Ω.

b) Make sketches of $|A_j|$ vs. Ω on the plot axes provided below. Clearly indicate all resonances and anti-resonances in your sketches.





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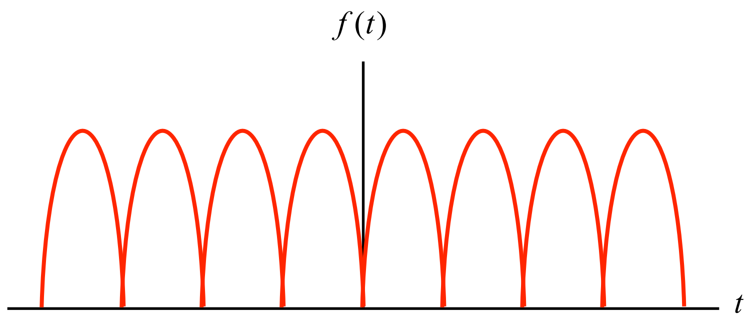
Problem 2 – 15 pts

Consider the function $f(t) = 3\left|\sin 4t\right|$ shown below. Suppose that the Fourier series for this function is written as: $f(t) = f_0 + \sum_{k=1}^{\infty}\left[f_{ck}\cos k\Omega t + f_{sk}\sin k\Omega t\right]$.



a) Determine the fundamental frequency Ω for this periodic function.

b) Set up the integral expressions for the Fourier coefficients f_0, f_{ck} and f_{sk}. Do NOT evaluate these integrals.

c) Which, if any, of the Fourier coefficients written down above in b) are zero?

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Problem 3 – 15 pts

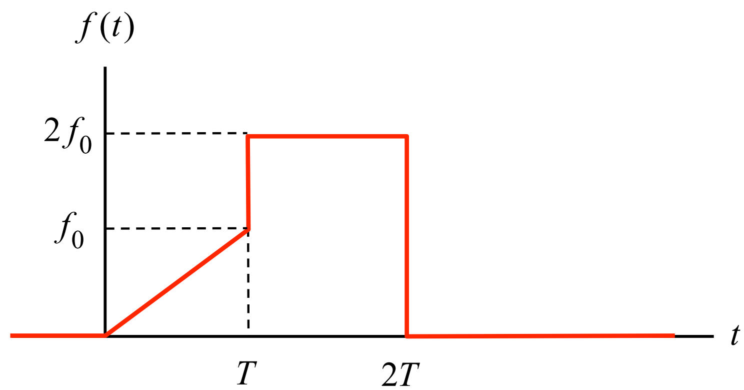
An undamped single-DOF system governed by the following EOM:

$$m\ddot{x} + kx = f(t)$$

has an excitation of $f(t)$ shown below. The system is given the initial conditions of: $x(0) = \dot{x}(0) = 0$. Set up the convolution integral solution for the response of this system. Clearly indicate the solutions that are valid for the time ranges of:

- $0 \le t \le T$
- $T \le t \le 2T$
- $t \ge 2T$

Do NOT evaluate the integrals above.



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Problem 3 (cont.)

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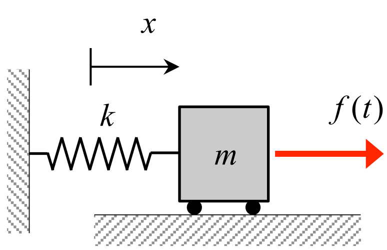
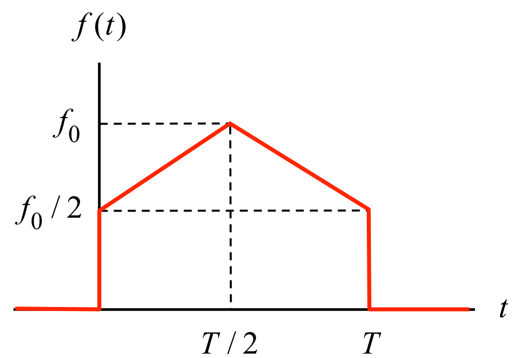
Problem 4 – 15 pts

Forcing f(t) acts on an undamped single-DOF system, with f(t) as shown below. Use the following parameters: $m = 100kg$, $k = 10{,}000N$, $f_0 = 120N$ and $T = 0.2\,\text{sec}$.

a) Treating f(t) as a SHOCK loading, determine upper AND lower bounds on the value of x_{max}.
b) Treating f(t) as an IMPACT loading, determine an upper bound on the value of x_{max}.
c) Does the system serve as an effective shock isolator?





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Problem 5 – 15 pts

A five-DOF system has the following mass and flexibility matrices:

$$[M]=\begin{bmatrix} 10 & & & & \\ & 10 & & & \\ & & 10 & & \\ & & & 10 & \\ & & & & 10 \end{bmatrix} kg \qquad [A]=\begin{bmatrix} 2 & 2 & 2 & 2 & 2 \\ 2 & 4 & 4 & 4 & 4 \\ 2 & 4 & 6 & 6 & 6 \\ 2 & 4 & 6 & 8 & 8 \\ 2 & 4 & 6 & 8 & 9 \end{bmatrix} \times 10^{-4} \frac{m}{N}$$

Determine an upper bound and a lower bound on the lowest natural frequency for the system. Do NOT perform any matrix inversions in your analysis.

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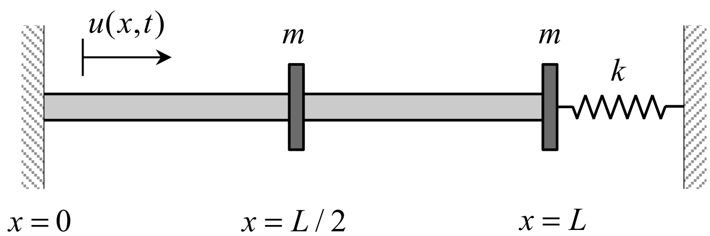
Problem 6 – 15 pts

A rod of length L, Young's modulus E, cross-sectional area A and mass density ρ is attached to a fixed wall at its left end (x = 0). A rigid block of mass m and a spring of stiffness k are attached at the right end (x = L). A second rigid block, also of mass m, is attached to the rod at midlength (x = L/2). Use $m = \rho AL$ and $kL / EA = 1$.

a) Write down the Rayleigh quotient for this rod system.

b) Choose an admissible trial function v(x) and calculate an upper bound for the lowest natural frequency for the rod system. Feel free to use any integration results from lecture examples in your work here.



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