Vibrations II: 20-263-662 ***Name: ________________________***

Take-Home Test Number 3: March 7, 2002 (Final Exam)

GENERAL INSTRUCTIONS:

This is a take-home test. You are on your honor to do your own work. If you have questions, see Dr. Allemang.

The test is due on Thursday, March 14, 2002 at 3:00 PM in Dr. Allemang's office (593 Rhodes Hall). Points will be deducted for late work.

Make sure your name or initials are on every sheet that you turn in. Be sure to write down any pertinent aspect of the problem which might help in the grading of your work. For any of the MATLAB related work, turn in your script as well as the results.

Do your own work...

PROBLEM NUMBER ONE (5%)

- ***Part A: How many frequency response functions must be measured to determine the modal vectors of a system? Explain.***
- ***Part B: How many frequency response functions must be measured to determine the poles, or modal frequencies, (frequencies and damping factors) of a system? Explain.***

PROBLEM NUMBER TWO (5%)

The vibration and modal analysis theory that has been covered so far in this course is based upon several assumptions. What are these assumptions?

PROBLEM NUMBER THREE (5%)

Rework Problem Number 3 (Lagrange Problem) from the second test using the Lagrange method. If you worked the problem correctly, just turn it in.

PROBLEM NUMBER FOUR (5%)

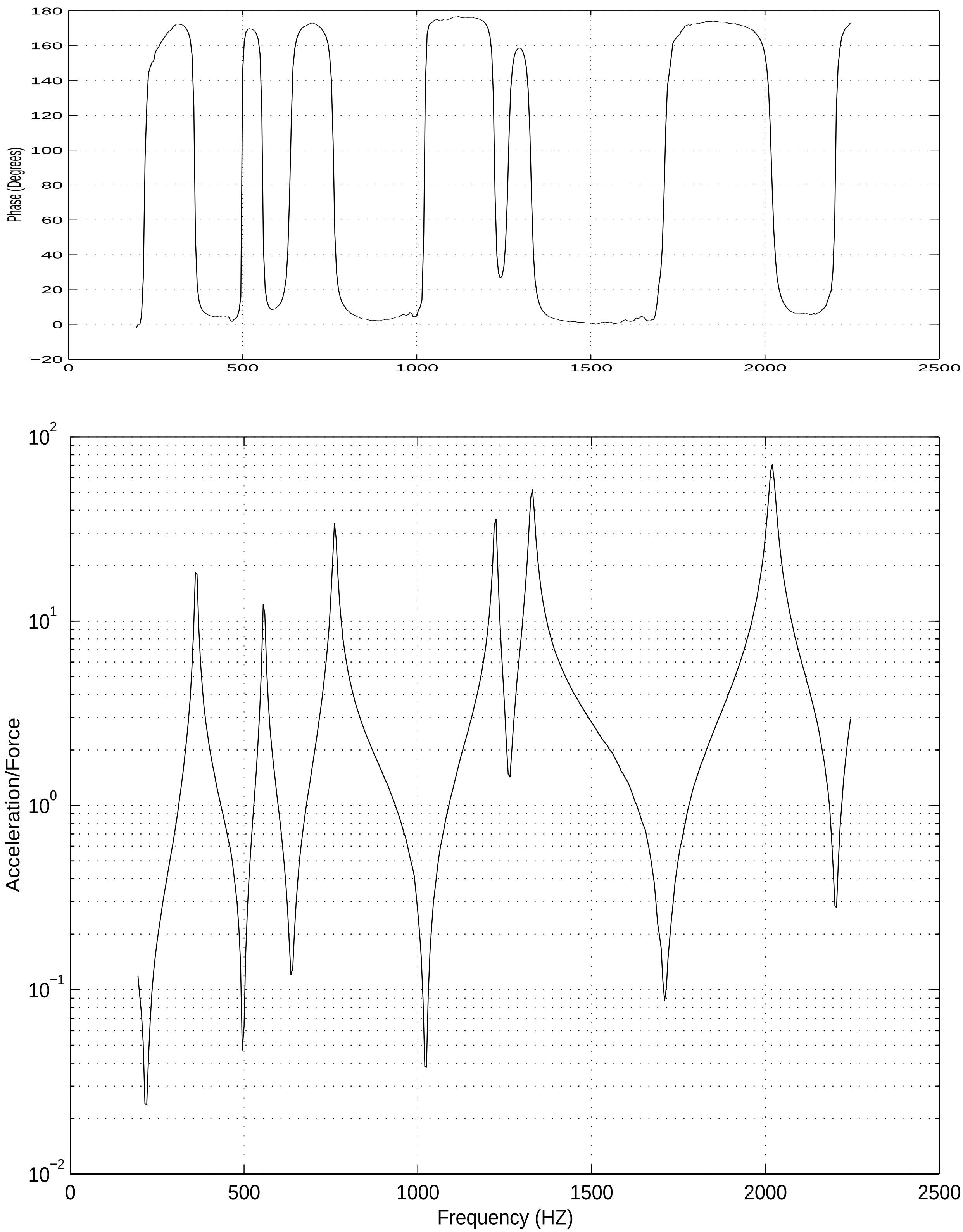
Work the above problem, Problem Number Three (Problem Number 3 from the second test), using the Newton method. You are only required to obtain one (the same) equation of motion as in the original problem.

Show that the exact equation of motion for Body 4 is the same using both methods.

PROBLEM NUMBER FIVE (15%)

Using the measurement H_{pp} ***shown on the next page, assume that the numerical values shown are valid and the measurement is acceleration divided by force in units of G's per pound (force). State any other pertinent assumptions.***

- ***Part A: Develop a partial fraction model for this frequency response function, from 200 Hertz to 2200 Hertz, using*** *estimates* ***of the modal parameters (damping factors,*** σ_r***, damped natural frequencies,*** ω_r***, and residues,*** A_{ppr}***, for the modes shown) taken from the measurement. Do not worry about repeated root situations and use only SDOF methods to get your estimates.***
- ***Part B: Use MATLAB to synthesize the frequency response function*** H_{pp} ***based upon your partial fraction model.***
- ***Part C: For each mode of vibration, estimate the modal mass, scaling the modal coefficient for each mode at measurement degree of freedom p equal to unity (***$\psi_{pr} = 1.0$***).***



Phase (Degrees)
180
160
140
120
100
80
60
40
20
0
−20
0
500
1000
1500
2000
2500
Acceleration/Force
10^2
10^1
10^0
10^{-1}
10^{-2}
Frequency (HZ)

PROBLEM NUMBER SIX (20%)

- ***Part A: For the following three degree of freedom system, design a spring-mass-damper system to be added to mass 3 as shown*** *to reduce the response of the second mode of vibration.* ***Note that the masses can only move vertically in the plane of the paper. Use the following design criteria to choose the values for the system (*** M_4, K_4, C_4 ***). 1) Choose the mass*** M_4 ***to be no more than 10% of the modal mass of mode 2. Be sure to compute the modal mass of mode 2 on a physical basis. 2) Limit the damping such that the attached SDOF system is no greater than 3 percent of critical damping.***

- ***Part B: Use MATLAB to compare the performance of the original system (three degree of freedom) and the new system (four degree of freedom) by comparing the driving point frequency response function at mass 3 (*** H_{33} ***) for the two systems.***

  Synthesize the frequency response function H_{33} ***for the comparison in the following way:***

  - ***Inversion of the original three (3) degree of freedom [M], [C], [K] system matrix.***
  - ***Inversion of the four (4) degree of freedom [M], [C], [K] system matrix.***

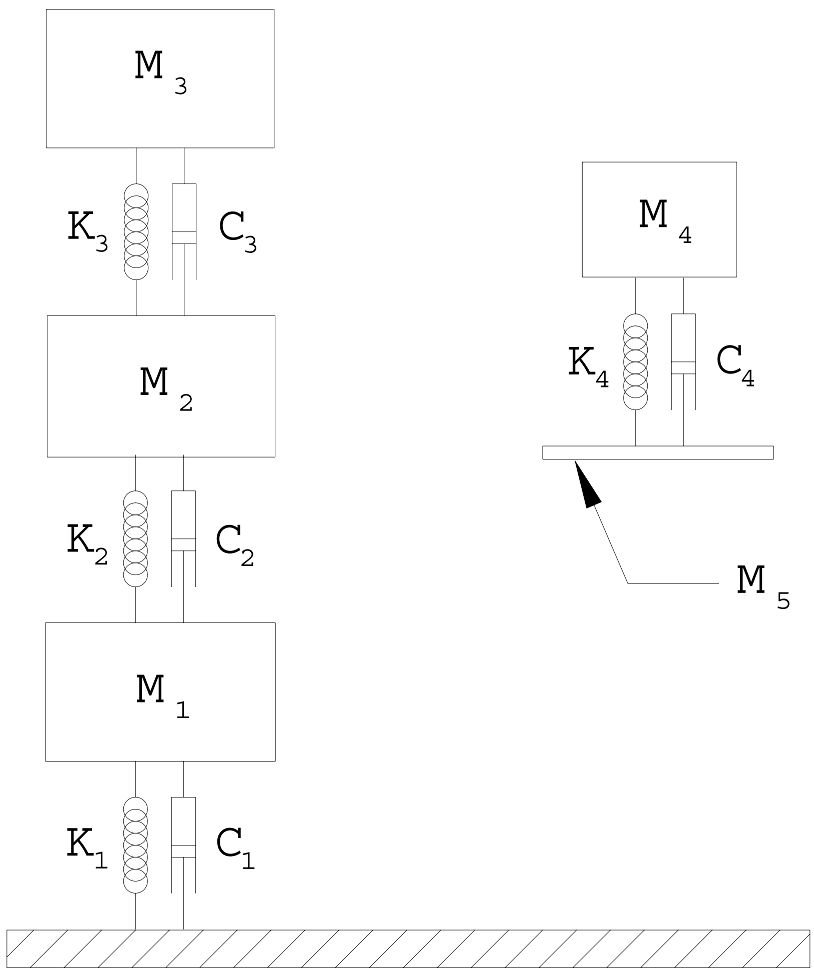
- ***Part C: Once you have decided upon the spring-mass-damper system to be added (*** M_4, K_4, C_4 ***), perturb each parameter (*** M_4, K_4, C_4 ***), one at a time, by plus and minus 10 percent of the chosen value to empirically study the effect on the frequency response function (*** H_{33} ***).***

Plot all frequency response functions in a semi-log magnitude/phase format.

$M_1 = 8 \;\; Kilogram$
$M_2 = 12 \;\; Kilogram$
$M_3 = 10 \;\; Kilogram$

$K_1 = 140,000 \;\; Newton/meter$
$K_2 = 120,000 \;\; Newton/meter$
$K_3 = 100,000 \;\; Newton/meter$

$C_1 = 7 \;\; Newton-sec/meter$
$C_2 = 6 \;\; Newton-sec/meter$
$C_3 = 5 \;\; Newton-sec/meter$



PROBLEM NUMBER SEVEN (15%)

Using Problem Number Six as a starting point:

- ***Formulate and plot the driving point FRF of the original system (3 DOF) at the point that the SDOF MCK system will be added (*** H_{33}^{3DOF} ***). This is already done from Part B of Problem Seven.***

- ***Formulate and plot the driving point FRF of the SDOF MCK system at the base (attachment point) of the SDOF system (*** H_{55} ***). DOF 5 is the base motion of the SDOF MCK system. This is the hard part. Hint: Draw the free body diagram of this SDOF system, giving the mass motion (*** X_4, F_4 ***) and the base motion (*** X_5, F_5 ***).***

- ***Formulate and plot the driving point FRF of the final system (4 DOF), at the point that the SDOF MCK system was added, from the following equation at each frequency (Impedance Method):***

$$H_{33}^{4DOF} = \frac{H_{33}^{3DOF}\ H_{55}}{H_{33}^{3DOF} + H_{55}}$$

- ***This should be the same FRF you determined from the analytical solution for the 4 DOF system. Is it? Plot the two FRFs using MatLab for comparison. This should demonstrate that the spring-mass-damper can be designed and simulated directly from experimental data (the original M, C, K formulation is not needed).***

Plot all frequency response functions in a semi-log magnitude/phase format.

PROBLEM NUMBER EIGHT (5%)

Based upon Part C of Problem Six:

- ***What MKC configuration of the added damper gives the greatest attenuation?***
- ***What MKC configuration gives significant attenuation over the widest frequency range?***

PROBLEM NUMBER NINE (5%)

- ***Part A: How is modal, or generalized, mass and modal A computed from an analytical point of view?***
- ***Part B: How is modal, or generalized, mass and modal A computed from an experimental point of view?***
- ***Part C: What is the importance (function, use) of modal mass and modal A?***

PROBLEM NUMBER TEN (20%)

Turn in Homework Problems 9, 10, 11 and 12.