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Examination, December 1, 1998

1.561 Motion-Based Design – (OPEN BOOK)

PROBLEM #1 (30%)

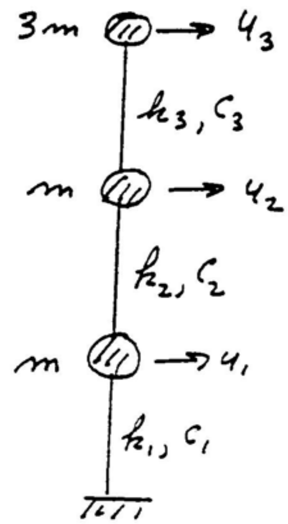
Suppose the response of a structural system is periodic, with amplitude 0.1m and frequency, 1Hz. As a structural engineering consultant, you are requested to design an energy transformation device which extracts 10^4N.m of energy per cycle from the system. Recommend solutions for the following damping mechanisms:

1. viscous
2. Coulomb friction
3. Hysteretic
   Consider the material to have σ_y = 200 Mpa and E = 210,000 Mpa. Also take the length of the device to be 2m.
4. Viscoelastic
   Consider the material to be ISD110, the temperature to be 20°C, and the allowable shear strain for the material to be 100% ← $\gamma = 1$

PROBLEM #2 (20%)

Consider a SDOF system having a spring and viscoelastic damper. Suppose m = 1000 kg and the desired free vibration frequency is 1 Hz. Determine the spring and damper properties such that the desired frequency is obtained, and the damping ratio is 0.05. State clearly all the assumptions you introduce.

PROBLEM #3 (30%)



$m = 1000$ kg

Consider the 3 DOF system shown above.

1. Determine the stiffness distribution such that the first mode has the form $\phi = \{\frac{1}{3}, \frac{2}{3}, 1\}$
   Calibrate the stiffness for seismic excitation, taking $S_v = 1$ m/s and $q_{max.} = 0.05$m
2. Determine the viscous damping coefficients such that the damping ratio for the first mode is 0.15. Consider both stiffness proportional damping and uniform damping.

PROBLEM #4 (20%)

1. Discuss the effectiveness of viscous and hysteretic damping at low levels of excitation.
2. Identify what you feel are the advantages and disadvantages of viscoelastic dampers.
3. Describe how you would locate dampers to control the response of a particular mode in an "optimal" manner. Clearly state what you adopt as the meaning of "optimal".

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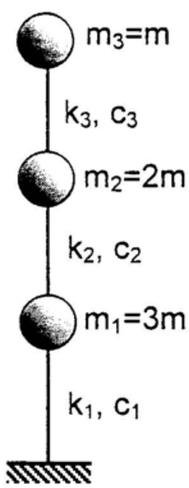
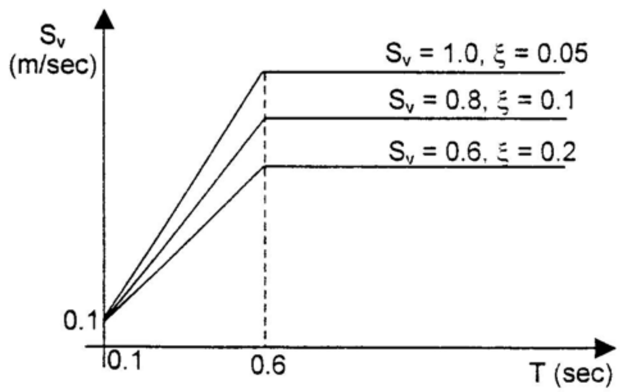
1.561 Motion-Based Design

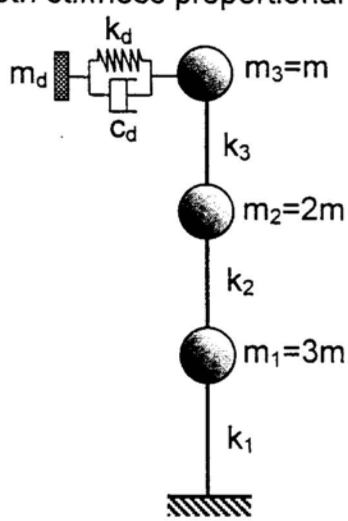
PROBLEM #1 (60%)





Consider the 3 DOF system shown above. Take m=1000kg.

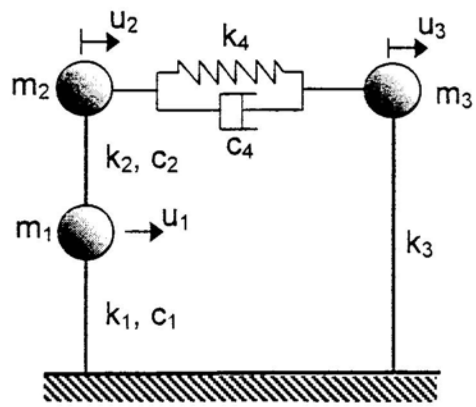
1. Determine the stiffness distribution such that the first mode shape is $\Phi = \{1/3, 2/3, 1\}$
2. Calibrate the stiffness for seismic excitation. Take the modal damping ratio to be 0.1, and the modal amplitude is q_{max}=0.05m
3. Determine the viscous damping coefficients such that the damping ratio for the first mode is 0.1. Consider both stiffness proportional damping and uniform damping.



4. Consider a tuned mass damper to be attached to the 3rd floor. Determine the properties of the tuned mass damper such that the structure will have an equivalent damping of 0.1 for the first mode. Assume that there is no viscous damping ratio in the structure.

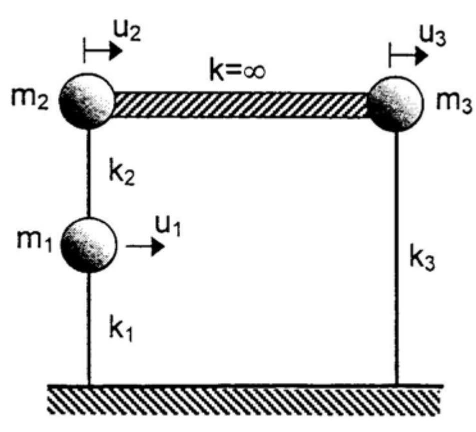
PROBLEM #2 (40%)

a) Consider 2 structures connected as shown in the sketch. Formulate the governing equations and express them in the form $M\ddot{U} + C\dot{U} + KU = P$, where $U = \{u_1, u_2, u_3\}$



b) Consider the structures to be connected with a rigid link, as shown below. Take m_1=2000kg, m_2=1000kg, and m_3=3000kg. Determine the stiffness properties, k_1 and k_2, such that the fundamental mode shape for the first structure is Φ = {0.5, 1.0} and the fundamental frequency is $\omega=\pi$ rad/sec. Consider 2 values for k_3:

a) k_3=20,000 N/m
b) k_3=40,000 N/m



Massachusetts Institute of Technology

1.561 Exam II (Open Book)
December 7, 2000
11:00 am - 12:30 pm

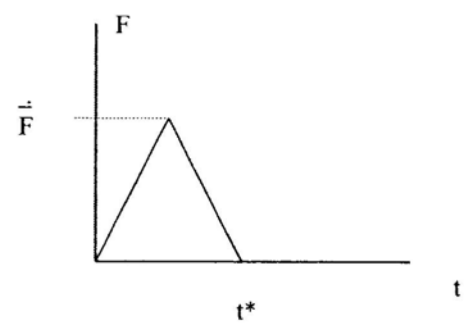
PROBLEM #1 (20%)

Consider a SDOF system having a linear spring and a linear viscous damper. Consider the system to be at rest at t=0.

Suppose the system is subjected to an external forcing and the design objective is to limit the maximum displacement to be less than a prescribed value, u*. Describe how you would establish values for the stiffness and damping parameters for the following loadings. Assume the mass is fixed.

The external loading conditions are:

a) An impulsive load. Consider t* to be very small with respect to 1.



b) A periodic loading

$$F = \overline{F}\sin(\Omega t)$$

PROBLEM #2 (15%)

Compare the effectiveness of viscous, visco-elastic and hysteretic dampers at low levels of excitation.

PROBLEM #3 (15%)

a) Discuss the effectiveness of tuned mass dampers for the following external forcings:

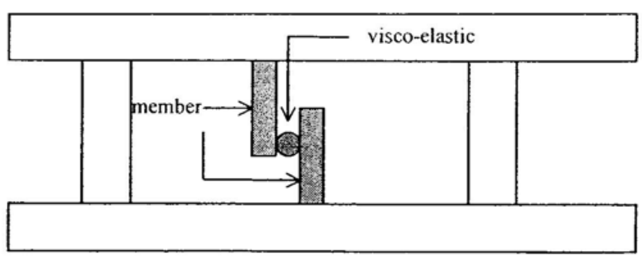
   i. Impulsive
   ii. Periodic
   iii. Seismic

b) How would you determine the 'optimal' location of a tuned mass damper for a multi-degree of freedom system ?

PROBLEM #4 (20%)

Consider the damper scheme described by Prof. Wada.

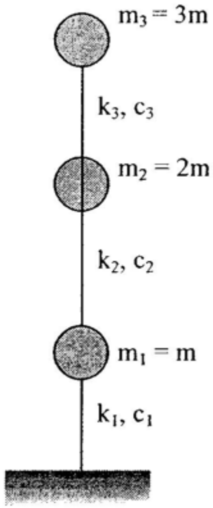
Structural dampers are rigidly attached to adjacent floor beams, and a block of visco-elastic material is inserted between the members.

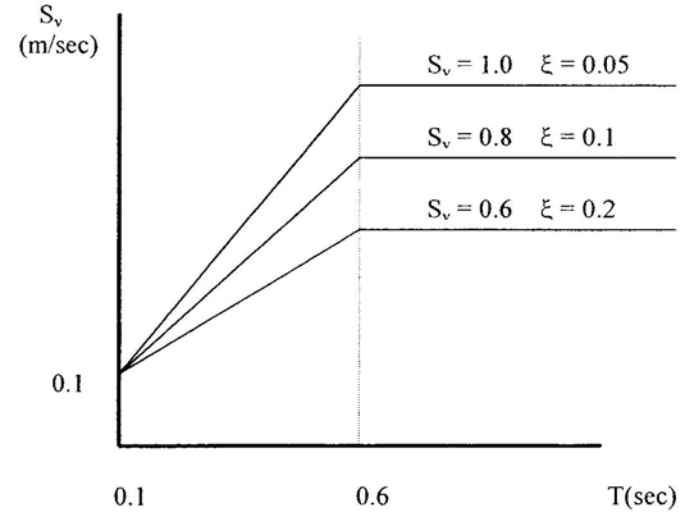


a) Discuss how this system performs.

b) As a structural engineer, what issues should you address?

PROBLEM #5 (30%)





Consider the 3 DOF shown above. Take m = 1000Kg.

a) Determine the stiffness distribution such that the first mode shape is:

$$\Phi = \left\{ \tfrac{1}{3} , \tfrac{2}{3} , 1 \right\}$$

b) Calibrate the stiffness for seismic excitation. Take the modal damping ratio to be 0.05 and the modal amplitude as $q_{max} = 0.075$ m

c) Suppose a pendulum type mass damper is to be attached to the 3rd floor. Determine the properties of the tuned mass damper such that the structure will have an equivalent damping of 0.1 for the first mode.