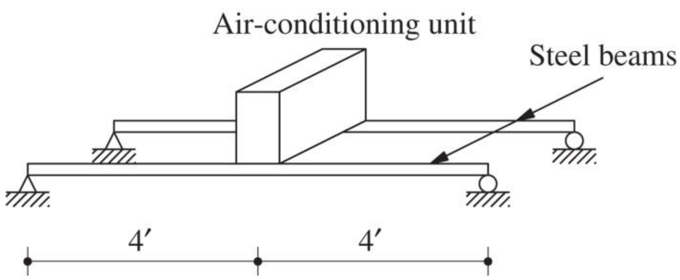
**UNIVERSITY OF CALIFORNIA, BERKELEY** **Dept. of Civil and Environmental Engineering**
**Spring Semester 2018** **Structural Engineering, Mechanics and Materials**

## M.S. Comprehensive Examination: Dynamics

Name: ________________________________

**QUESTION 1 [40%]:**
An air-conditioning unit weighing 1200 lb is bolted at the middle of two parallel simply supported steel beams ($E$ = 30,000 ksi) as shown below. The clear span of the beams is $L$ = 8 ft. The second moment of cross-sectional area of each beam is $I$ = 10 in$^4$. The motor in the unit runs at 300 rpm and produces an unbalanced vertical force of 60 lb at this speed. Neglect the weight of the beams and assume $\zeta$ = 1% viscous damping in the system. Determine the amplitudes of:

1) steady-state deflection, and 2) steady-state acceleration (in g's) of the beams at their midpoints which result from the unbalanced force.




**Hints:**

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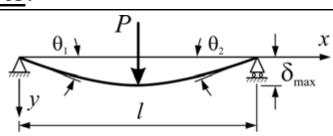
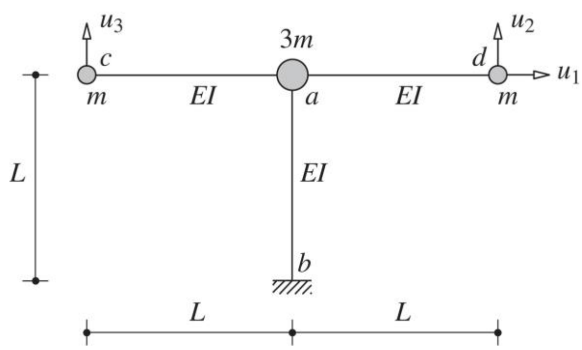
|---|---|---|
|  $\delta_{max} = \dfrac{Pl^3}{48EI}$ | Deformation response factor: $R_d = \dfrac{1}{\sqrt{\left[1 - (\omega/\omega_n)^2\right]^2 + \left[2\zeta\omega/\omega_n\right]^2}}$ | g = 386 in/sec$^2$ |

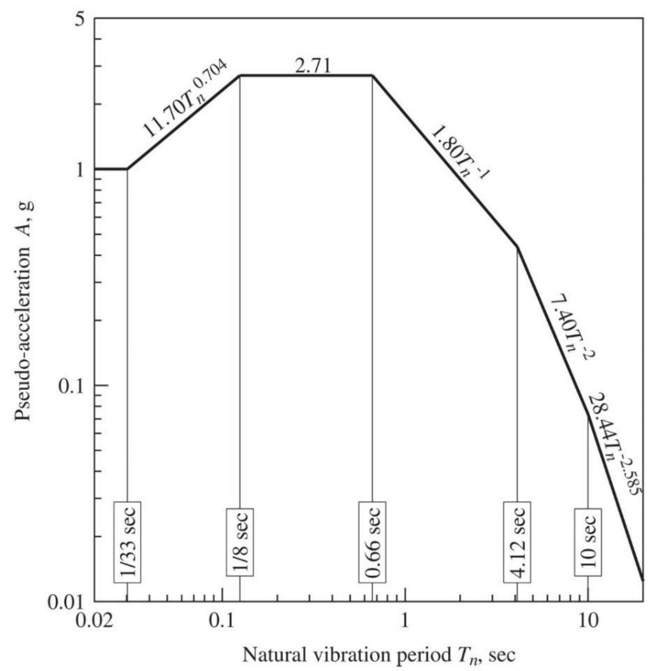
**QUESTION 2 [60%]:**

The umbrella structure shown below has 3 DOF with the listed eigen solution. It is made of standard steel pipe and has the following properties: $I$ = 28.1 in$^4$, $E$ = 29,000 ksi, weight = 18.97 lb/ft, $m$ = 1.5 kips/g, and $L$ = 10 ft. It is required to determine the peak response of this structure to horizontal ground motion characterized by the design spectrum shown below (for 5% damping) scaled to 0.20g peak ground acceleration and using the SRSS modal combination rule. It is required to perform the following: 1) Check that the distributed weight of the umbrella structure can be neglected (i.e. less than 10%) compared to the lumped weights and find the corresponding mass matrix, and 2) Compute the displacements $u_1$, $u_2$, and $u_3$.




$$\omega_1 = 0.5259\sqrt{\frac{EI}{mL^3}} \quad \omega_2 = 1.6135\sqrt{\frac{EI}{mL^3}} \quad \omega_3 = 1.7321\sqrt{\frac{EI}{mL^3}}$$

$$\phi_1 = \begin{Bmatrix} 1 \\ -1.9492 \\ 1.9492 \end{Bmatrix} \quad \phi_2 = \begin{Bmatrix} 1 \\ 1.2826 \\ -1.2826 \end{Bmatrix} \quad \phi_3 = \begin{Bmatrix} 0 \\ 1 \\ 1 \end{Bmatrix}$$




Elastic pseudo-acceleration design spectrum for ground motion: $\ddot{u}_{go}$ = 1g (g = 386 in/sec$^2$) and $\zeta$ = 5%.

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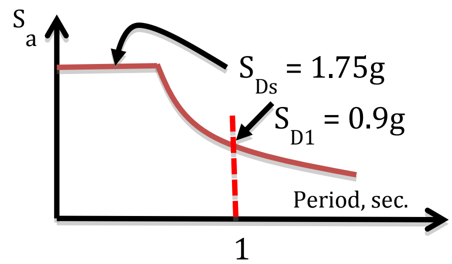
# Comprehensive Examination in Dynamics

When needed, consider the pseudo-acceleration response spectrum shown to the right in your solutions to the following problems. Provide a brief narrative discussion of the procedures and assumptions you use.




1. Provide an estimate of the peak earthquake ground acceleration that would be needed to produce this spectrum.

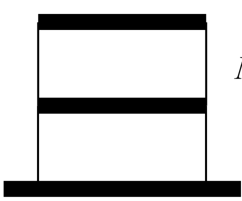
2. Consider the small 2 DOF system shown below. The numbering convention is such that DOF 1 is at the roof. The system is mounted rigidly on the ground, and is subjected to an earthquake excitation represented by the pseudo-acceleration response spectrum provided above. Viscous damping may be neglected.

   a. What modal combination rule will you use to estimate the peak responses of the structure, and briefly, why?

   b. Considering two modes of response, what is the expected peak base shear?

   c. What percentage of the total base shear is contributed by the first mode? That is, what is the shear computed for the first mode alone divided by the total peak base shear computed considering the modal combination method you used.

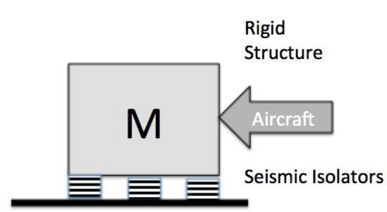
   d. Similarly, what percentage of the top story drift is contributed by the first mode?

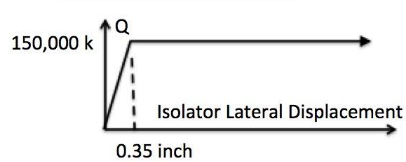


$$M = 0.0836\ k\text{-}s^2/in \begin{pmatrix} 1/2 & 0 \\ 0 & 1 \end{pmatrix} \quad f_1 = \begin{Bmatrix} 1 \\ 0.33 \end{Bmatrix} \quad f_2 = \begin{Bmatrix} 1 \\ -0.53 \end{Bmatrix} \quad T = \begin{Bmatrix} 0.63 \\ 0.12 \end{Bmatrix} \text{sec}$$

3. Consider the seismically isolated structure to the right. Using engineering fundamentals, estimate the maximum lateral displacement of the isolators, if an aircraft strikes the structure.

   The structure above the isolators weighs 500,000 kips and can be considered completely rigid. The isolators have elastic-perfectly plastic properties in the lateral direction as shown to the right. Vertically, the isolators are inextensible. The aircraft weighs 300 kips and is traveling horizontally at 800 ft/sec at the time of impact. The aircraft "sticks" to the structure during/following the impact. The duration of the impact loading is 0.1 sec, which may be considered significantly shorter than the natural period of the structure. Energy dissipation of the structure, other than in the isolators, should be considered minimal (zero).



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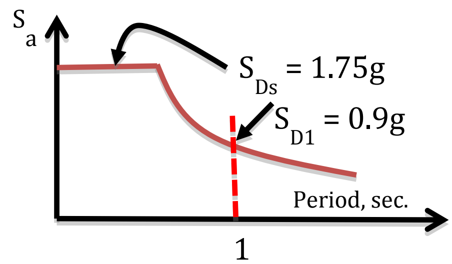
University of California at Berkeley
Civil and Environmental Engineering

Structural Engineering, Mechanics & Materials
Spring Semester 2016

# Comprehensive Examination in Dynamics

When needed, consider the pseudo-acceleration response spectrum shown to the right in your solutions to the following problems.




1. For an elastic single degree-of-freedom (DOF) system, weighing 1000 kips, what is the minimum lateral stiffness of the system required such that it does not displace laterally more than 4.5 inches when subject to the spectrum shown?

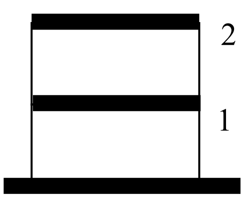
2. Consider the 2 DOF shown below. The numbering convention is such that DOF 1 is at the roof. The structure is subjected to an earthquake excitation represented by the pseudo-acceleration response spectrum provided above.

   a. Considering only the first mode response, what is the expected base shear?

   b. What percentage of the total base shear is contributed by the first mode?

   c. Is the percentage of story shear contributed by the first mode to the story shear in the top story more, less or the same as for the bottom story? Briefly explain. You do not need to compute the second story or second mode shear!

   d. What maximum lateral story drift do you expect in the top story of the building due to the first mode response?




$$M = \frac{1000 kips}{g}\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad f_1 = \begin{Bmatrix} 1 \\ 0.5 \end{Bmatrix} \quad f_2 = \begin{Bmatrix} 1 \\ -2 \end{Bmatrix} \quad T = \begin{Bmatrix} 1.0\,\text{sec.} \\ 0.25\,\text{sec.} \end{Bmatrix}$$

3. The floors in a one-story seismically isolated structure each weigh 1000 kips. The first mode shape is give as $< 1, 1 >^T$, where the first value corresponds to the roof and the second value correspond to the floor just above the isolation plane. The second mode shape is $< 1, ? >^T$.

   a. What is the value of the missing term?

   b. How much does the second mode contribute to the base shear of this structure?

4. When might one use an explicit numerical integration method (such as the Central Difference Method) rather than an implicit method (such as the "constant average acceleration method")?

5. When would the pseudo-acceleration differ significantly from the actual acceleration of a SDOF structure subjected to earthquake motions? Provide a sketch to illustrate your answer.

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6. Modal responses are often combined in modal analysis methods using the square root of the sum of the squares method.
   a. List two cases where this method might not be an adequate approximation?
   b. What other method might be used instead?