

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF OCEAN ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

13.013J/1.053J Dynamics and Vibration

Fall 2002

Problem Set 12

Issued: **Day 31**

Due: **Day 34**

Presentations:

1. (Problem 1)
2. (Problem 2)
3. (Problem 3)
4. (Problem 4)
5. (Problem 5)
6. Self Evaluation in another sheet as per the instructions in the first class.

- Think about these problems before class and come prepared to ask me about what you don't understand. However, read through the notes I handed out first.
- I am expecting well-prepared presentations. For the problem you are responsible for, I expect you to have really worked to get it right, including coming in to talk if you don't understand something.
- Each problem I assign is intended to reinforce your understanding of an important concept and to give you some practice at applying the concept in a practical way. In most cases I will try to tell you what the learning objective is.

1. The TLP in surge has an equation of motion and natural frequency as found in P.S. 11,
 - a. How much horizontal force is required to cause a static surge displacement of 1 foot?
 - b. Assume you have a periodic horizontal wind force ten times the amount found in a. It acts at the natural period in surge. Also assume you have a surge damping ratio of 5% of critical. What is the approximate surge response amplitude and phase angle with respect to the wind force? Identify the quantities: static response and dynamic amplification.
 - c. Objective: The purpose of this problem is to evaluate response for a single degree of freedom system in a steady state resonance condition. This is one of the fundamental bits of knowledge in basic vibration know-how.

2. Consider a spar buoy. It looks like a telephone pole floating vertically in the water. It has a draft, $D = 21.0$ feet, and a length of $L=28$ feet. The diameter is constant and given by $d=1.0$ feet. The added mass is small, because it is approximately a hemisphere of water with a 1-foot diameter, which is accelerated by the flat bottom of the pole.
 - a. What is the mass of the buoy and the added mass.
 - b. Write down an equation of motion including a vertical wave force $F(t)$.
 - c. What is the natural frequency in heave? Ignore the added mass in order to allow us to use the simplest form.
 - d. Now for a little ocean engineering. For wave lengths much greater than a diameter, the vertical wave force is approximately given by:

$$F(t) = \frac{H}{2} \cos(\omega t) \rho_w g A_{wl} e^{-\frac{2\pi D}{\lambda}} \quad \text{valid for } \lambda \gg d$$

For deepwater waves the relationship between wavelength and frequency is given by:

$$\frac{2\pi}{\lambda} = \frac{\omega^2}{g}$$

ρ_w is the density of water and A_{wl} is the area of the waterline.

The vertical exciting force is due to the pressure exerted on the flat bottom of the spar due to the passage of the wave.

- e. Assume that the wave frequency is at the natural frequency of the spar and find a quite remarkable expression for the wave force exerted on the spar. Hint, express λ in terms of frequency and then eliminate frequency from the wave force equation, by using what you know about the natural frequency.

Problems 3 & 4 are pure applied ocean engineering with some useful o.e. knowledge mixed in.

3. Assume that a sinusoidal wave passes the buoy with a wave height of 1.0 foot. Estimate the response amplitude and phase angle for the cases that the wave frequency is at 0.1, 1.0 and 3.0 times the natural frequency. Assume 2.5% damping. This problem is to give you some practice evaluating the steady state transfer function. I suggest that you do it in Matlab or Excel. You could plot the result over a range of values of f/f_n . Check the assumption that the wavelength is much larger than the diameter. You might set it up so that it is simple to vary the value of damping ratio.
4. Do a modified version of problem 6-64. This is very similar to the pendulum in a grandfather clock. Let $m_1 = 2m = 3.0$ kg. Let $r = 0.1$ meters. Find the length, l , such that the natural period of the pendulum equals 2.0 seconds. Much of the damping in the clock comes from the work done to move the clock mechanism. Let's assume that the damping is 0.5% of critical. It is also specified that we want the pendulum to swing with peak steady state amplitude of 10 degrees.
 - a. What is the amplitude of the sinusoidal torque that must be applied on the pendulum at its natural frequency in order to sustain the amplitude of response at 10 degrees?
 - b. Optional: Where does this torque come from in a real grandfather clock.
5. Your room has a serious vertical floor vibration problem at 20 Hz, caused by a large air conditioner unit on the roof nearby. It is disturbing the fish in your aquarium. You decide to place the aquarium on a flexible pad, which may be modelled by a spring and a dashpot.
 - a. If you wish to reduce the vertical amplitude of vibration by at least a factor of 5.0, what is the highest allowable natural frequency for the aquarium sitting on the pad?
 - b. At that frequency, what is the static deflection of the pad with the aquarium sitting on it?

Vibration mitigation is one of the most important applications of vibration analysis.
6. This is a problem for group discussion. You must think about it in advance. Provide an equation of motion for pitch or roll motion of the TLP. I believe that you will have to guess at one or more things. Come to class prepared to discuss what additional information you will need to solve the problem correctly. You will in the following week be expected to apply what we come up with in discussion to complete the problem. By the time we finish this problem we will have done a first pass at the dynamic analysis of a TLP for most of its important possible motions.