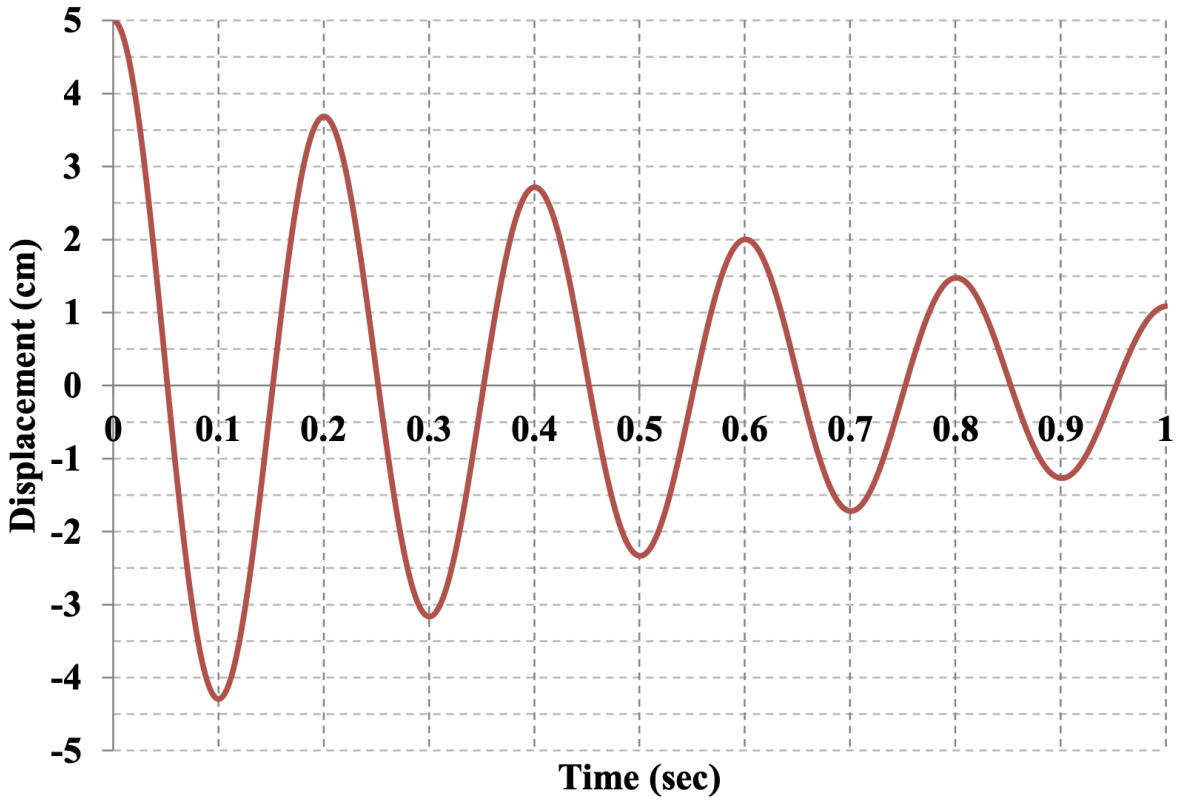
MEC E 451 Winter 2024 Assignment #2 Due: Feb 9, 11:59 PM

Instructions:

- Submit your assignment as a single PDF file through eClass.
- Show all your steps and solution procedures including clear and well labelled FBD/MAD diagrams when needed.
- Make sure that your solution is well organised and that you are using appropriate headers for each question and sub-question.
- Scanned photos of your handwritten solution are acceptable as long as they are **legible**

Question 1 (10 pts)

The free vibration of a viscously damped SDOF system due to a non-zero initial displacement (zero initial velocity) is given in the graph shown below. Determine the following questions using this graph. Clearly indicate the values you obtain from the graph.

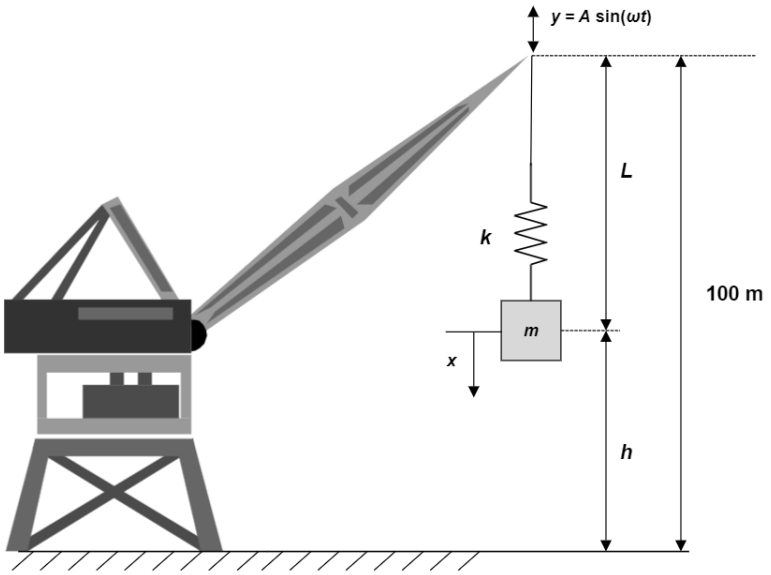


a) **(5 pts)** Write a differential equation that governs the equation of motion of this system.

b) **(5 pts)** If the same system was subjected only to a non-zero initial velocity of 100cm/sec (zero initial displacement), what would be the displacement response at t = 0.25 sec.

Question 2 (10 pts)

A crane 100 m tall is loading a container full of feathers and delicate glass figurines weighing 5 metric tons onto a cargo ship. While the container is in the air, there is an emergency shutdown of the crane and the case is left hanging for a short time. During this time, winds cause the arm of the crane to vibrate **vertically** at a frequency of 4 Hz with an amplitude of 5 cm. The supporting cable has an effective stiffness of $k = \frac{100}{L}$ MN/m, where L is the length of exposed cable in metres (neglect changes in L due to vibration).



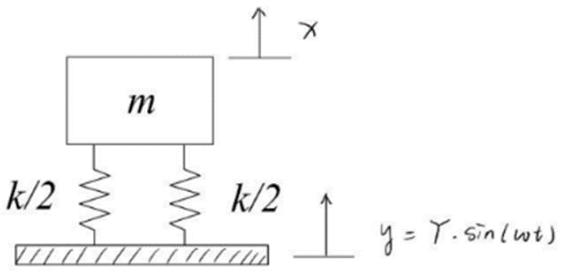
a) **(2 pts)** Determine the cable length L at which the transmissibility would be exactly 1.

b) **(5 pts)** Assuming **steady state vibration,** determine all possible heights h at which the crate would hit the ground.

c) **(3 pts)** After the emergency is dealt with, operations resume as the wind continues to excite the crane arm. The crane needs to lift shipments 80 m high to place it onto the cargo ships. What is the smallest mass of cargo that can be lifted in these conditions without shaking with an amplitude greater than 4 cm? Assume $\omega > p$.

Question 3 (10 pts)

National Institute of Nanotechnology (NINT) is a first generation Nano-research facility and the first of its kind in Canada. The facility is a six-storey building located on the University of Alberta Campus. Along with research offices, wet laboratories and clean nano-fab space, the facility features several ultra sensitive electron microscopes. In order for these microscopes to operate in the nanoscale, they must be provided with an extremely stable environment that is free from movement and vibration. One model of isolation setup for the electron microscopes is shown as (1) where an excitation displacement is applied to the base in response of floor vibration. The floor vibration is assumed to have a frequency of 50 Hz. The natural frequency of these whole setup is measured as 10 Hz.



(1)

a) **(4 pts)** Estimate the amplitude of vibration of electron microscope by comparing it to the amplitude of the floor for the setup as (1).

b) **(5 pts)** The quality of the image from electron microscope is not satisfying since the amplitude is still too large. A dampler was added between the electron microscope and floor. What damping ratio should be chosen to make the amplitude of the vibration of electron microscope ~~reduced to 10% of (1)~~?

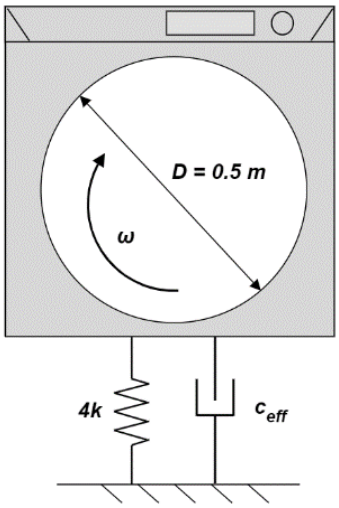
two times the amplitude in part (a)?

c) **(1 pts)** If the damping ratio of the damper needs to be adjusted to increase the amplitude of vibration of electron microscope, should the laboratory staff adjust the damping factor up or down?

Question 4 (10 pts)

A washing machine produces disruptive noise during its spin cycle due to an uneven distribution of clothes around its circumference. To reduce the noise, an engineering consulting firm has proposed that the machine be mounted on spring isolators at each corner (four in total).

The machine has a capacity of 10 kg of laundry, an **unloaded** mass of 450 kg, a drum diameter of 0.50 m, and spin cycle speed of 955 rpm. To address the noise levels, the transmitted force should be reduced by 75%. Assume vertical vibrations only and that c_{eff} is inherent to the system (damping from the spring isolators are negligible).



a) **(5 pts)** Determine the isolator spring constant needed to resolve the noise issue. Assume that the system is 25% damped **at full capacity** ($\zeta = 0.25$)

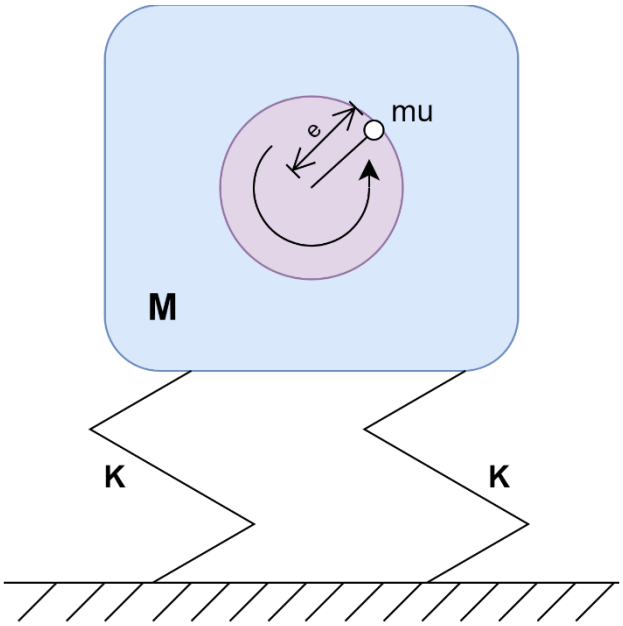
b) After installing an appropriate set of spring isolators, it was found that a 0.3 kg wet hoodie was spinning out of balance.

   i. **(2.5 pts)** Using the stiffness from part a), find the response amplitude due to this imbalance during the spin cycle for the washing machine when it is fully loaded.

   ii. **(2.5 pts)** After **removing the hoodie and resuming the same wash**, a wet towel with a mass of 0.5 kg began to spin out of balance. Determine the spring constants needed to maintain the same amplitude as part i).

Question 5 (10 pts)

A motor with the mass 40 kg is supported with 4 springs, each of stiffness 250 N/m as it is illustrated in following figure. The rotor is unbalanced such that the unbalanced effect is equivalent mass of 5 kg located 50 mm from the axis of rotation. (Note: There is no damping in the system.)



a) **(5 pts)** Find the amplitude of vibration and the force transmitted to the foundation when the speed of motor is 1000 rpm.

b) **(5 pts.)** Compare the amplitude of vibration and the transmitted force calculated in part (a) with the case that the motor is running at speed of 60 rpm.