Question	Score
1	
2	
3	
4	
Total	

UNIVERSITY OF MICHIGAN
Official Examination Booklet

Name of Student: ______________________________

Date of Examination: ______________________________

Course: ______________________________

The University of Michigan Honor Code

The Honor Code outlines standards for ethical conduct for graduate and undergraduate students, faculty members, and administrators of the College of Engineering at the University of Michigan.

Policies

When Taking Exam

- The instructor need not monitor the exam
- The instructor will announce the time of the exam and the instructor's whereabouts will be communicated to the class
- Students will allow at least one empty seat between themselves and their neighbor
- The instructor will inform the class prior to the exam if aids are allowed during the exam
- Students must write and sign the Honor Pledge on their exams

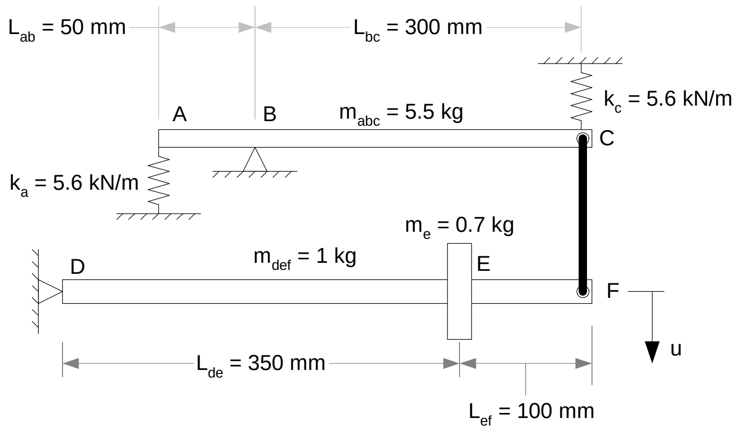
The Honor Pledge is:

I acknowledge that I have neither given nor received aid on this examination nor have I concealed any violation of the Honor Code.

(Signed) ______________________________

QUESTION #1 (30 POINTS) – DYNAMIC EQUILIBRIUM (3 parts)

A small “balancing” frame is designed by a local artist for display on the U of M campus as an interactive sculpture. With people moving the balanced structure, the university is concerned of the system behavior. As the structural engineer for the university, you are asked to analyze the dynamic behavior of the system. The frame is as shown:



Lever ABC is a non-uniform section with a mass of 5.5 kg and has a rotational inertial about the mass center point “B” of I_o = 0.0309 kg-m^2. Lever DF is a uniform section with a mass of 1 kg. A mass of 0.7 kg has been attached by the artist on the lever DF at point “E”. The mass of the connecting bar CF can be ignored in the analysis. The springs at points “A” and “C” both have the same stiffness of 5.6 kN/m.

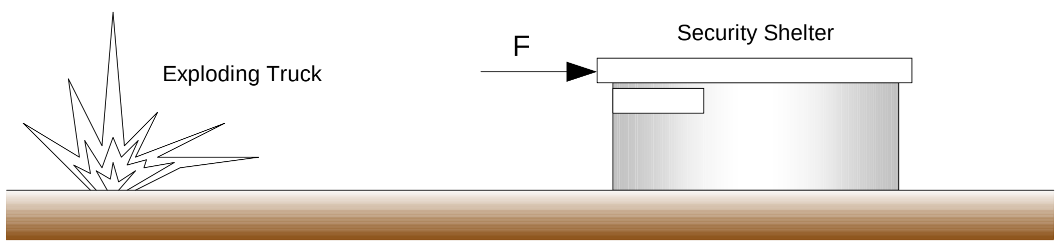
1) Obtain the equation of motion of the system for small vibrations of the frame about the position of static equilibrium (for a degree of freedom, please choose the vertical displacement of point F as noted):

2) What is the natural period, T_n, of the frame structure?

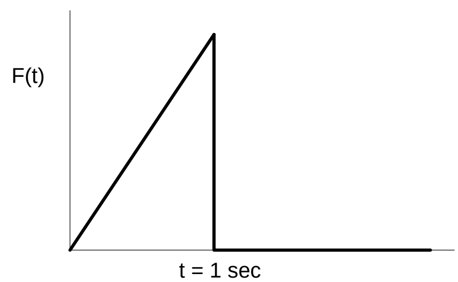
3) A primary concern of the university is that bystanders will grab the structure at point F and force the structure to displace under the person's self weight. After the structure has come to a steady state displacement, u_{st}, under the person's weight, the person lets go thereby exciting the sculpture. Assuming a person with a mass of 100 kg causes the structure to displace under their self-weight, after the person lets go, write an expression for the response of the structure:

QUESTION #2 (30 POINTS) – BLAST LOADS ON STRUCTURES

As a specialist in hardening structures against blast loads, you have been hired to analyze the vulnerability of a security shelter outside the Pentagon to exploding trucks. Given the structure's short and stocky form, it behaves primarily as a single degree of freedom system. If the effective enacted structural mass is 9000 kg and the structural stiffness is estimated to be 4500 kN/m, what is the response of the structure for 3 seconds after the start of the explosion?

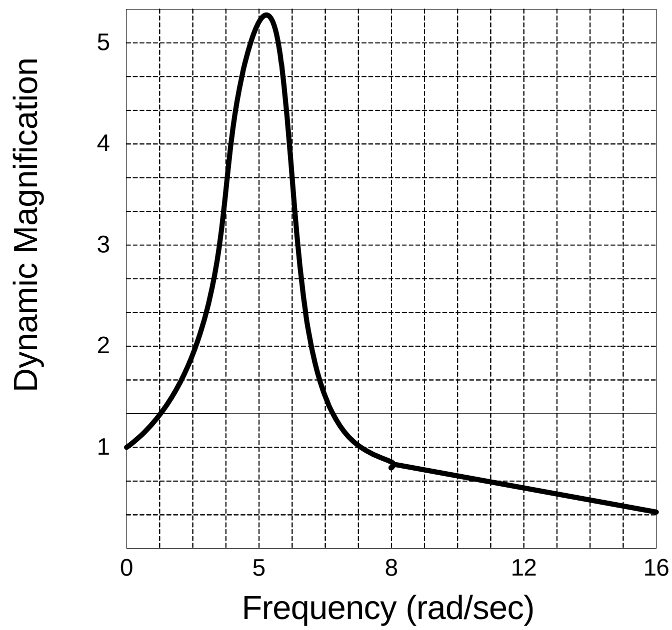


The blast load produces an equivalent dynamic force, $F(t) = 100t$ (in units of N) on the shelter only for 1 second. After 1 second, the load dissipates to zero. Assume the structure is undamped:



QUESTION #3 (25 POINTS) – SYSTEM I.D. AND PREDICTED RESPONSES

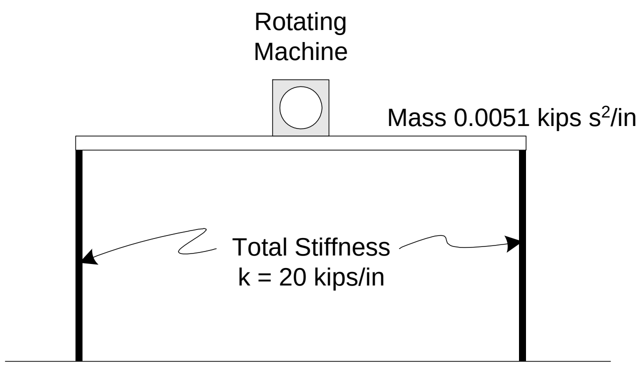
The Lurie Tower is instrumented with a variable shaker to excite the tower at different harmonic frequencies. Based upon the steady state response of the Lurie Tower to the harmonic excitations, you are able to determine the following results:



Let us now assume the Lurie Tower can be given an initial displacement, say 4 cm. Once achieving this displacement, the structure is let go and free to vibrate. Please plot a graph showing the resulting vibration time-history of the tower if we assume the structure to behave as a single degree-of-freedom system. On that graph, please note any "key" points, such as zero crossing (times at which they occur); also, if the response exhibits a harmonic like response, please calculate the first four peaks (response magnitude).

QUESTION #4 (15 POINTS) – NUMERICAL MODELING (5 parts)

You have been asked by your design firm to code a numerical program that could solve the response of a single degree of freedom system to an external load, $p(t)$. After writing your numerical solver using the central difference method, you test it on the following test structure:



where $p(t) = 0.0051\ sin(\omega t)$ (in units of kips). Also, you assume the structure has 5% of critical damping associated with it.

a) Write the equation of motion of the system:

b) Write the difference equation associated with the central difference method for the system shown. In other words, use the known parameters of the system when writing the difference equation.

c) You decide to conduct your analysis at a time step of Δt = 0.01 s. Is this a good time step to use? Please explain why.

d) You decide to carry out the analysis of the structure for the first three time steps (*i.e.*, t = 0.01, 0.02 and 0.03 s) assuming the structure is initially at rest. Please report the calculated displacement of the SDOF structure for these first three steps (i.e., $u(0.01)$, $u(0.02)$ and $u(0.03)$).

e) Please compare these three numerically determined displacement values to the true, theoretical displacement of the structure. Please comment on how one could make the central difference numerical solver even more accurate.