University of British Columbia
Department of Mechanical Engineering

MECH 463. Midterm 2, November 2, 2020

Allowed Time: 50 min

Materials admitted: Pen, pencil, eraser, straightedge, simple scientific calculator without programming or communication capabilities, Matlab for Q2, personal hand-written notes within one letter-size sheet of paper (one side), timer and document copier apps on your phone (all other phone functionalities are **not** allowed).

There are 2 questions in this exam. You are asked to answer all questions.

The purpose of this test is to evaluate your knowledge of the course material. Orderly presentation demonstrates your knowledge most clearly. Marks are assigned accordingly. A bonus of up to 2 marks will be given for exemplary presentation.

Honour Code: You are asked to behave honourably during this exam and to obey all instructions carefully. Please write and sign the following promise in the space below: "I promise to work honestly on this exam, to obey all instructions carefully, and not to have any unfair advantage over any other students."

Promise:

Signed: Name:

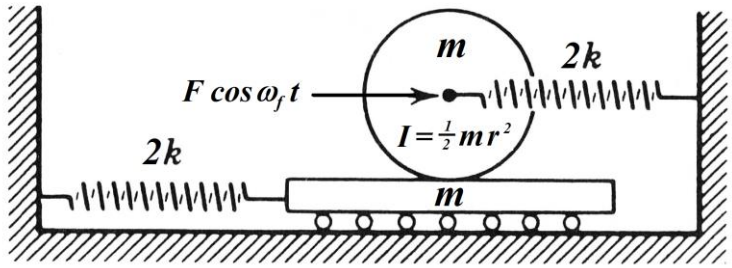
	Mark Received	**Maximum Mark**
1		13
2		12
Presentation		2 bonus
Total		25+2

Start Time running

Finish Time running

Name: ____

1. A mechanism within a machine consists of a plate of mass m that moves horizontally on rollers. It is attached to the machine housing by a spring of stiffness k. A cylindrical roller of mass m, radius r and moment of inertia I = ½ m r^2 rolls without slipping on the plate, and is also attached to the machine housing by a spring of stiffness k. A harmonic force F cos ω_ft acts on the roller, as shown in the diagram. Work this question by hand, do not use Matlab.



(a) Draw labeled free-body diagrams of the parts of the vibrating system. *(Hint: remember to include the horizontal force between the two masses.)*

(b) Use your free-body diagrams to formulate the equations of motion and express them in matrix form.

(c) Derive a formula for the steady state response of the cylinder in terms of magnification factor. Show the needed steps in detail. At what excitation frequency will there be zero response?

(d) Draw a magnification factor vs. excitation frequency plot for the cylinder and label the key points.

(e) *(Bonus)* Find the natural frequencies of the vibrating system.

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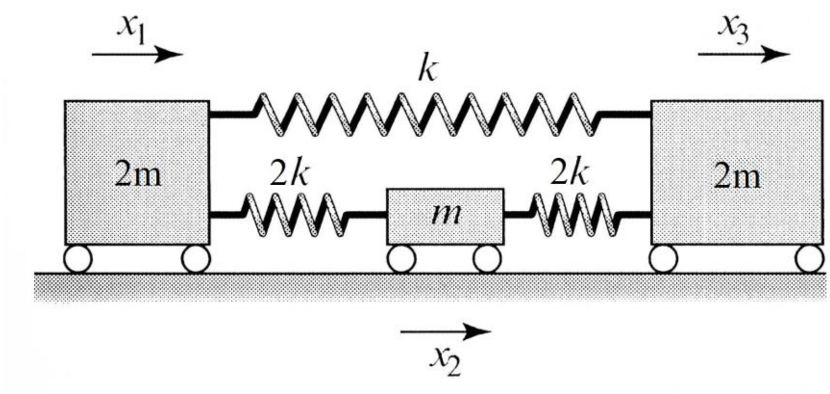
2. A mechanism within a machine consists of three masses connected together by springs as shown in the diagram.



(a) Draw fully labeled free-body diagrams for the various parts of the vibrating systems and use them to derive a matrix equation of motion.

(b) Adapt the following fragment of Matlab code used for the Capstone Laboratory exercise to solve for the natural frequencies and mode shapes of the vibrating system. Take a screenshot of your completed coding and computed results and include it in your exam paper submission.

```
m = 1;
k = 1;
M = [[m 0]' [0 m*R^2/D^2]'];
K = m*g*a1*a2/L1/L2 * [[L1/a2+L2/a1 L1-L2]' ...
[L1-L2 a2*L1+a1*L2]'];
[V,w2] = eig(K,M,'vector');
V(:,:) = V(:,:) ./ V(1,:);
V
w2
```

(c) Explain in detail why the Matlab function “eig” is useful for finding the natural frequencies and mode shapes.

(d) Give a physical explanation for each mode shape and corresponding natural frequency. Use the approach that we discussed in class.

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