University of British Columbia
Department of Mechanical Engineering

MECH366 Modeling of Mechatronic Systems
Midterm exam

Examiner: Dr. Ryozo Nagamune
October 12 (Friday), 2018, 3pm-3:50pm

Last name, First name

Name: Student #:

Signature:

Exam policies

- Allowed: One-page letter-size hand-written cheat-sheet (both sides).
- Not-allowed: PC, calculators.
- Write all your answers on this booklet. No extra sheet will be provided.
- Motivate your answers properly. (No chance to defend your answers orally.)
- 20 points in total.

Before you start ...

- Use washroom before the exam.
- Turn off your mobile phone.
- No eating.
- Questions are NOT allowed.

If you finish early ...

- Please stay at your seat until the end of exam, i.e., 3:50pm. (You are not allowed to leave the room before the end of exam, except going to washroom.)

To be filled in by the instructor/marker

Problem #	Mark	Full mark
1		5
2		5
3		10
Total		20

1. Answer the following questions **concisely (if possible, by a few sentences or even by one-word or two-words if appropriate)**.

   (a) Give **only one** reason why a linear model is preferred to a nonlinear model? (1pt)

   Write your answer here.

   (b) What is the difference between **the static system** and **the dynamic system**? (1pt)

   Write your answer here.

   (c) Is a system represented by $y = 2u + 1$ linear? Here, u is the input and y is the output of the system. **Motivate your answer properly**, rather than just answering 'Yes' or 'No'. (1pt)

   Write your answer here.

(d) In **electrical** systems, write the constitutive equation for the **T-type** element. (1pt)

<u>**Write your answer here.**</u>

(e) **Using the relation between the energy and the power**, derive the **energy formula** for the mechanical **mass** element. (1pt)

<u>**Write your answer here.**</u>

2. Consider the following normalized equation of motion for a pendulum system:

$$\ddot{\theta} = \tau - b(\dot{\theta}) - \sin\theta.$$

Here, the input is the torque τ and the outputs are the angle θ and the angular acceleration $\ddot{\theta}$, and the term $b(\dot{\theta})$ is a differentiable nonlinear function and $b(0) \neq 0$.

(a) Obtain the nonlinear state-space model. (1pt)

(b) Linearize the nonlinear state-space model (i.e., both state equation and output equation) around an equilibrium **point** (θ_0, τ_0). (2pt)

(c) For the equilibrium **point** $\theta_0 = \pi/6$, obtain the corresponding torque input τ_0. (Note: $\sin(\pi/6) = 1/2$.) (1pt)

(d) For the equilibrium **trajectory** $\theta_0(t) = \sin(2t)$, obtain the corresponding torque input trajectory $\tau_0(t)$. (1pt)

Write your answer here.

Write your answer here.

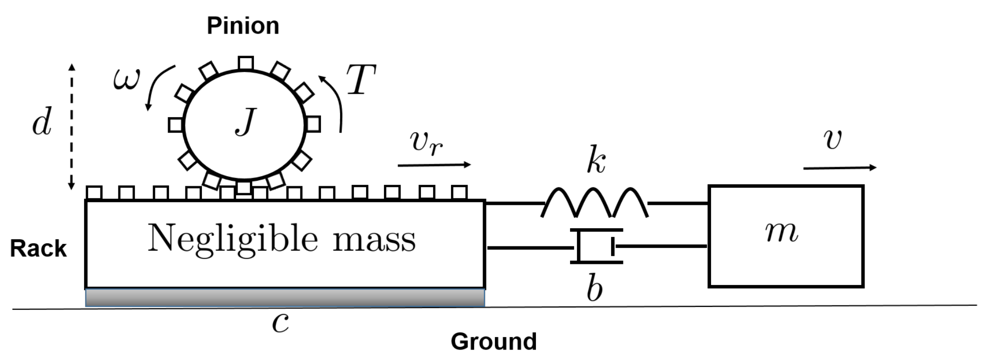
3. Consider a lumped model of a system in the figure below. The notations are indicated in the figure, and given as follows.

Notation	Meaning
T	Torque applied to the pinion (**Input**)
J & ω	Moment of inertia & angular velocity of the pinion
v_r	velocity of the rack
m & v	Mass & velocity (shown in the figure)
k & b	Linear spring & damping constants (shown in the figure)
c	Linear viscous friction constant between the rack and the ground
d	Diameter of the pinion

Note: In this question, it is not necessary to specify the output of the system.

Note: It is assumed that the friction between mass m and ground is negligible.

Note: It is assumed that the mass of the rack is negligible.



(a) The two velocities ω and v_r are related as $v_r = r\omega$. Obtain the positive constant r. (1pt)

Write your answer here.

Below, you can **use the notation** r, introduced in Question (a).

(b) Draw a linear graph, by introducing notations appropriately. (3pt)

(c) Select the state variables. (1pt)

(d) Write the constitutive equations for the passive elements and the transformer in the linear graph. (2pt)

(e) Write loop equations and node equations for the linear graph. (2pt)

(f) Using the linear graph, obtain the state equation. (1pt)

——— (End of Midterm Exam) ———

<u>Write your answer here.</u>

Extra page. Write the problem number before writing your answer.

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