MECH 3140 SYSTEM DYNAMICS AND CONTROLS

EXAM NO. 2

November 2, 2022

1 hour and 15 minutes

General Instructions

This exam is closed book and closed notes (and no calculators). You may only use the sheet of notes provided for the exam.

NOTE: If a system is non-linear you must provide the full non-linear equations of motion to receive full credit.

Solve each problem fully showing your work. Clearly indicate your answer(s) to each problem. State all assumptions used in your analyses. Since you are not allowed a calculator, you may make reasonable assumptions about constants such as $\pi \approx 3$, $\sqrt{2} \approx 1.4$, etc. Clearly state these assumptions if you use them!

Unless otherwise noted, assume all springs and dampers are ideal (i.e. massless and linear).

Total credit is 110 points.

Name:________________________________ Instructor: ______________________________

Exam Time (5:30 or 7:00):__________________________________

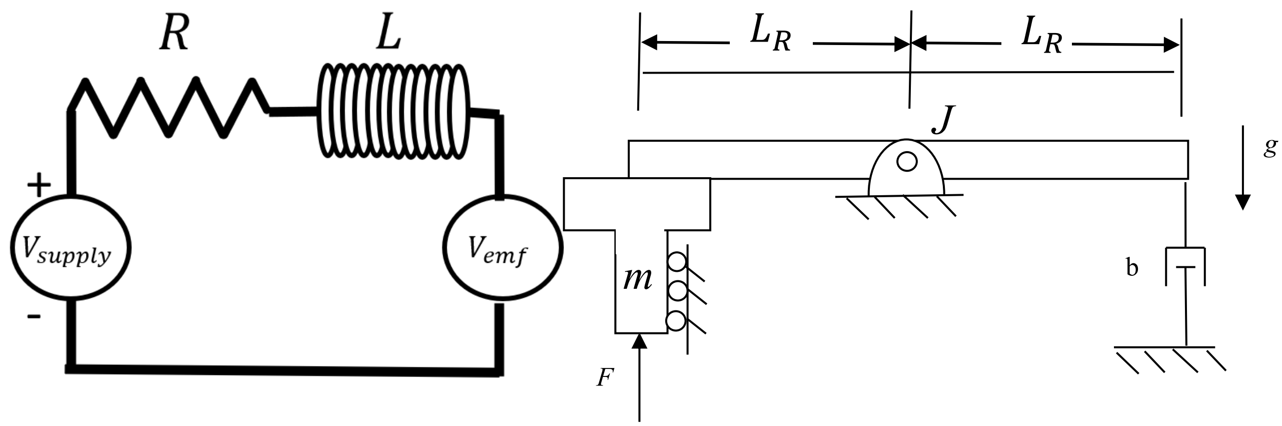
I certify that I have performed this exam according to the Auburn University honor code and have not given or received any external information during this exam.

Signature:_____________________________

1. (35 points) A solenoid (with non-neglible inductance) is used to actuate a rocker system using a voltage source as shown below. Note that a solenoid is the ***translational*** version of a (rotational) DC motor, governed by the same circuit and relationships, except the back EMF V_{emf} is proportional to a back EMF constant (K_b) times ***translational*** velocity, instead of angular velocity. Similarly, the solenoid's force (F) can be modeled as proportional to current times a force constant (K_f). The solenoid's mass (m) is ***rigidly connected*** to the rocker system as shown. The rocker has inertia J about the perfect pivot (i.e. no damping at bearing). The force of the solenoid and the damping force act ***vertically***. Assume the center of gravity of the rocker is at the pin.

   a) Derive the equation(s) of motion

   b) Derive an expression (differential equation or transfer function) to describe the dynamics of the angular position of the rocker with V_{supply} as the input.



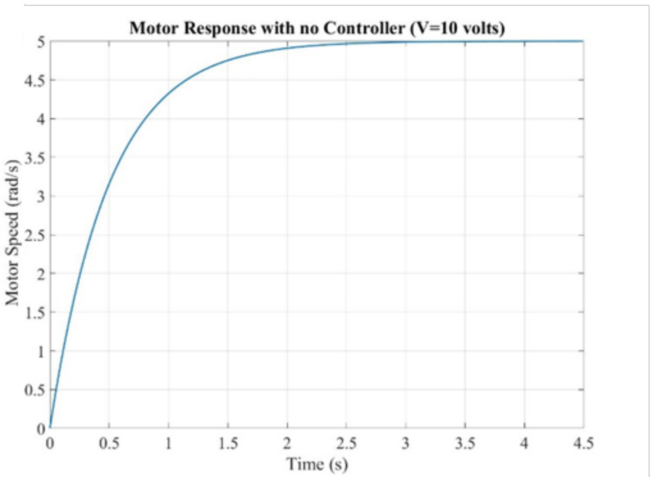
2. (25 points) Engineers are evaluating a sensor on a rate table and notice that the sensor output amplitude and phase is different from the rate table input (which was $\sin(\omega_{in} t)$ for all the tests performed. The sensor's measured amplitude and phase difference from the rate table input for each frequency test are given below.

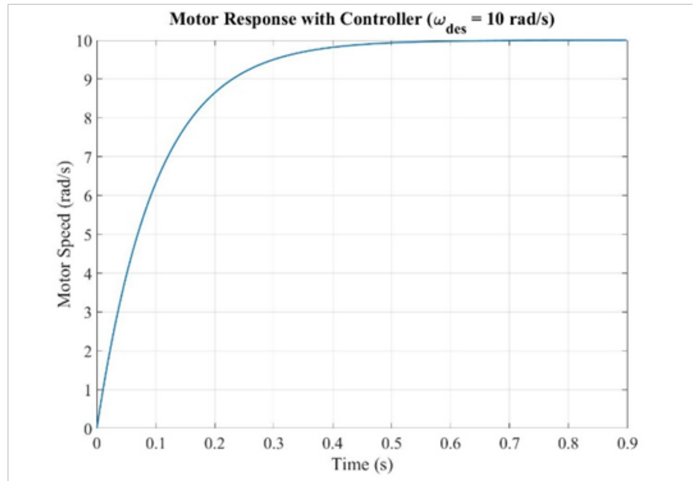
Input Frequency (rad/s)	0.01	0.1	1	10	100
Amplitude	10.0	10.1	50.0	0.1	0.001
Phase Difference (deg)	-0.1	-1	-90	-170	-179.9

a) Estimate (or predict) the ***approximate*** amplitude and phase difference for a test performed at 20 rad/s.
b) Calculate the ***actual*** amplitude and phase difference for a test performed at 2 rad/s.

3. (25 points). Engineers are trying to reverse engineer a controller used to control the speed of a DC motor. First, they apply a constant input voltage to the motor and measure the angular velocity resulting in the plot on the left. Then, the engineers run another test on the closed loop system where they set the desired angular velocity to 10 rad/s. They also add a constant disturbance torque on the motor shaft to help them identify the controller correctly. The second test results in the plot on the right.

Determine the control gain(s) and control law of the controller.





4. (25 points) Bama engineers hear that AU students neglect higher order dynamics in their midterm project (e.g., negligible inductance). They decide to neglect higher order dynamics on their automatic car parking system with the following EOM for the system/plant:

$$2\ddot{x} + 2\dot{x} = F$$

   a) Follow the Bama engineer's process. Neglect the inertia in the EOM and design ***proportional-only*** controller on ***position*** such that the closed loop system reaches steady state in 1 second.
   b) Sketch and label the response that the Bama engineers are expecting.
   c) Sketch and label the response that happens when the Bama engineers run their controller on the real system.