ECE 3510 Exam 1 given: Spring 11 (The space between problems has been removed.)

This part of the exam is **Closed book, Closed notes, No Calculator**.

1. (14 pts) This problem refers to the crude servo that you worked with in the first lab. It is essentially the same as the servo that I demonstrated in class the very first day.

   a) Draw a system block diagram, identifying each of the parts in specific terms (Motor, amplifier, etc.).

   Note: You may substitute any other actual, workable feedback loop (say one you drew for homework 1) as long as it has at least 4 blocks.

   b) Identify the input, output and feedback signals on the drawing. Show the units of each. (Don't worry if more than one answer for units is possible, just give one.)

   c) What is the purpose of feedback system in your drawing, i.e. what does it do?

2. (8 pts) The output of a system is given by:

$$Y(s) = \frac{b_2 \cdot s^2 + b_1 \cdot s + b_0}{s^2 + a_1 \cdot s + a_0} \cdot X(s) \quad + \quad \frac{s \cdot y(0) + \dot{y}(0) + a_1 \cdot y(0) - b_2 \cdot s \cdot x(0) - b_2 \cdot \dot{x}(0) - b_1 \cdot x(0)}{s^2 + a_1 \cdot s + a_0}$$

   a) List the variables which together fully describe the *state* of the system at time $t = 0$ (the initial state).

   b) What is $x(0)$ in the expression above. Give me a description.

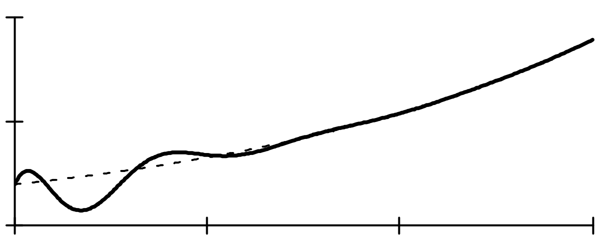
   c) What is $\dot{y}(0)$ in the expression above. Give me a description.

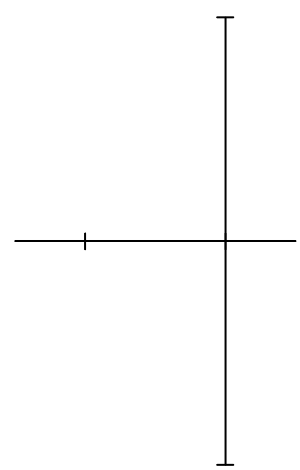
3. (7 pts) a) List Three advantages of state space over classical frequency-domain techniques.

   b) Give one advantage of the frequency domain method we are using in this class over the state-space method.

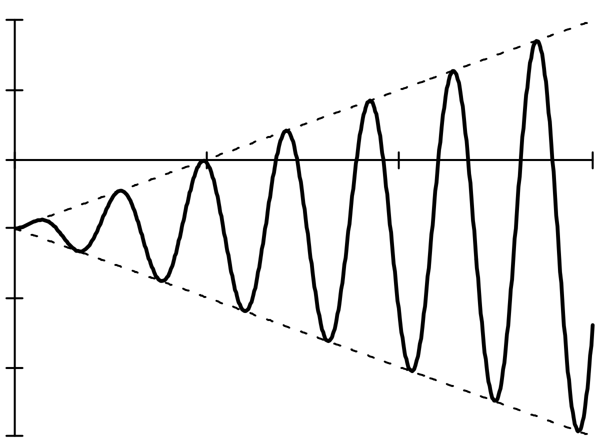
4. (10 pts) For each of the time-domain signals shown, draw the poles of the signal's Laplace transform on the axes provided. All time scales are the same. The axes below all have the same scaling. Your answers should make sense relative to one another. Clearly indicate double poles if there are any.

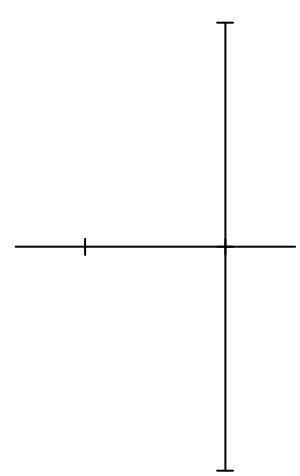
   a)





   b)

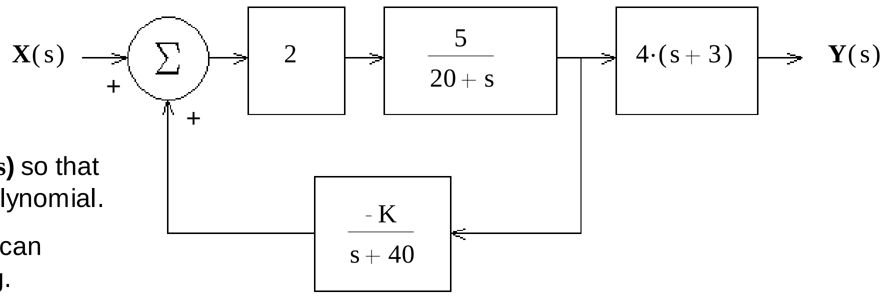




This part of the exam is **Open book, Open notes, Calculator OK**.

1. (13 pts) a) A feedback system is shown in the figure. What is the transfer function of the whole system, with feedback.

$$\mathbf{H}(s) = \frac{\mathbf{Y}(s)}{\mathbf{X}(s)} = ?$$



Simplify your expression for **H(s)** so that the denominator is a simple polynomial.

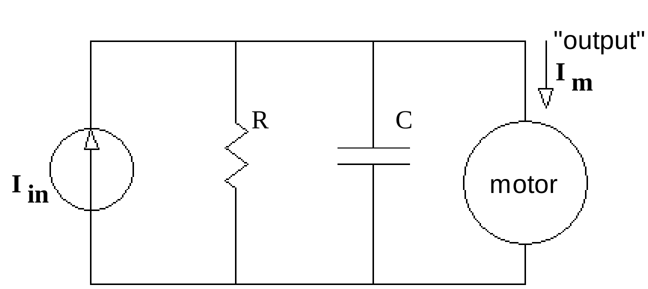
Be clear about your signs, so I can tell you know what you're doing.

b) Find the value of K to make the transfer function critically damped.

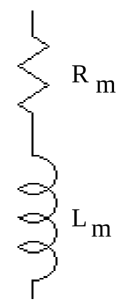
2. (13 pts) a) Find the transfer function of the circuit shown. Consider the motor current ($\mathbf{I_m}$) as the "output".

You <u>MUST</u> show work to get credit. Simplify your expression for **H(s)** so that the denominator is a simple polynomial.

$$\mathbf{H}(s) = \frac{\mathbf{I_m}(s)}{\mathbf{I_{in}}(s)} = ?$$



The motor may be modeled as a resistor in series with an inductor, like this:



b) What is the "order" of this system?

3. (12 pts) a) Using the best matching lines in **our** table, find the Laplace transform of the following function:

Combine any pieces you may find so that they have one common denominator.

$$f(t) = (7 - t)\cdot\sin(5\cdot t)\cdot u(t)$$

b) List the poles of the Laplace transform. Indicate multiple poles if there are any.

4. (12 pts) A system has this transfer function: $H(s) = \dfrac{120}{s + 64}$

What is the steady-state response of this system to the input: $x(t) = 6\cdot\sin(48\cdot t + 20\cdot deg)\cdot u(t)$

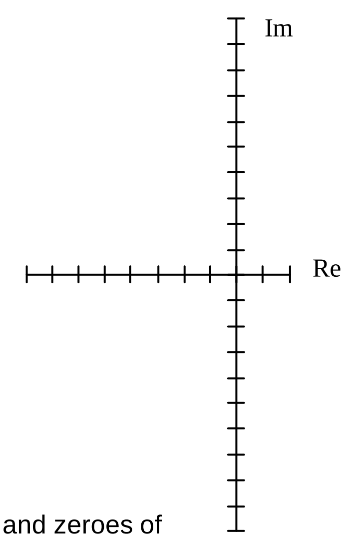
5. (11 pts) The step response of a system is:

$$y(t) = 1.5\cdot e^{-3\cdot t}\cdot(4\cdot\cos(5\cdot t) + 2\cdot\sin(5\cdot t))\cdot u(t)$$

a) Draw the poles and/or zeroes of the **system** transfer function on the s-plane at right. Make sure I can tell the values of the real & imaginary parts.

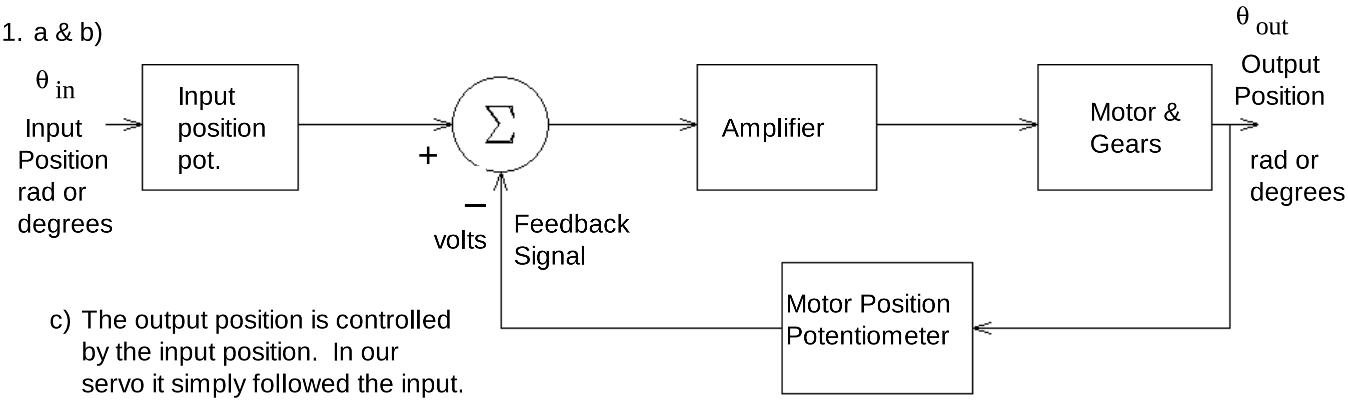
b) What is the initial value of the output? (where does it start?)

c) What is the final value of the output? (where does it end?)



The poles and zeroes of the **system**, not the signal.

1. a & b)



c) The output position is controlled by the input position. In our servo it simply followed the input.

2. a) $y(0)$ $\quad \frac{d}{dt}y(0)$ $\quad x(0)$ $\quad \frac{d}{dt}x(0)$

b) The **initial value** of the **input** variable

c) The **initial slope** of the **output** variable

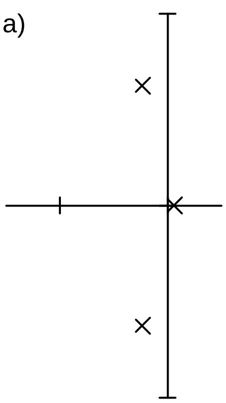
3. a) 1. Easily handles multiple inputs, multiple outputs and initial conditions
2. Can be used with nonlinear systems
3. Can be used with time-varying systems
4. Reveals unstable systems that have stable transfer functions (pole-zero cancellations). You can determine:
   Controllability: State variables can all be affected by the input
   Observability: State variables are all "observeable" from the output
5. Basis of Optimal control and adaptive control methods
6. Good computer modeling packages

3 of these

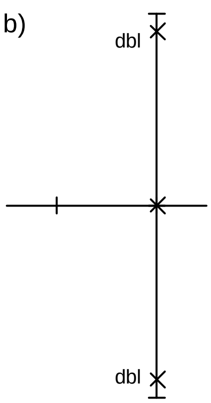
b) Easy to set up analysis and find transfer functions
Transfer functions and poles provide lots of information without a complete analysis
Rapid, easy and intuitive design

1 of these

4. a)



b)



Open Book Problems

1. a) $\mathbf{H}(s) = \dfrac{40\cdot(s+40)\cdot(s+3)}{s^2 + 60\cdot s + 800 + 10\cdot K}$ b) 10

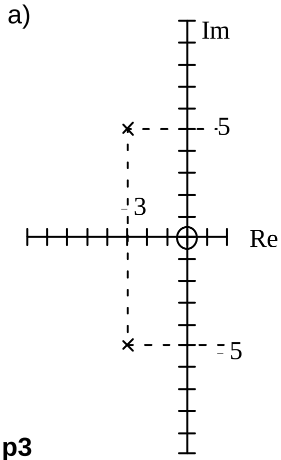
2. a) $\mathbf{H}(s) = \dfrac{\dfrac{1}{L_m\cdot C}}{s^2 + \left(\dfrac{R_m}{L_m} + \dfrac{1}{R\cdot C}\right)\cdot s + \dfrac{1}{L_m\cdot C}\cdot\left(1 + \dfrac{R_m}{R}\right)}$

b) 2nd

3. a) $\dfrac{35\cdot s^2 - 10\cdot s + 875}{\left(s^2+25\right)^2}$ b) double $5\cdot j \quad 5\cdot j$
double $-5\cdot j \quad -5\cdot j$

4. $9\cdot\cos(48\cdot t - 106.9\cdot deg)$

5. a)



b) 6 c) 0