ECE 3510 Exam 2 given: Spring 15 (Some of the space between problems has been removed.)

This part of the exam is Closed book, Closed notes, No Calculator. 3/9/15

1. (2 pts) Our time-domain signals all start at time = 0 because we use the unilateral Laplace transform to represent the signals. How are conditions and events that happened before time = 0 handled?

2. (4 pts) The output of a system is given by:

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

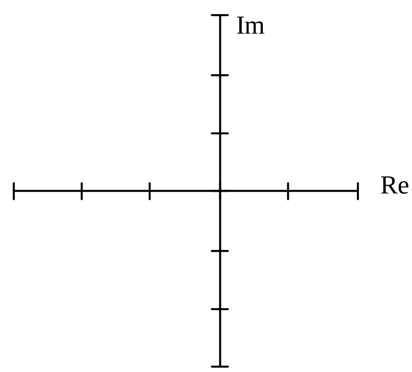
   a) What is $y(0)$ in the expression above. Give me a description.

   b) What is $\frac{d}{dt}x(0)$ 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. (8 pts) The overshoot of a system's step response must **greater** than 4%. It must ring at a frequency between 1 and 2 Hz. Does that mean the system's poles must lie in a certain region of the s-plane? If yes, show that area on drawing at right, including numbers where appropriate. Make it clear where the poles must lie. If no, write NO below.



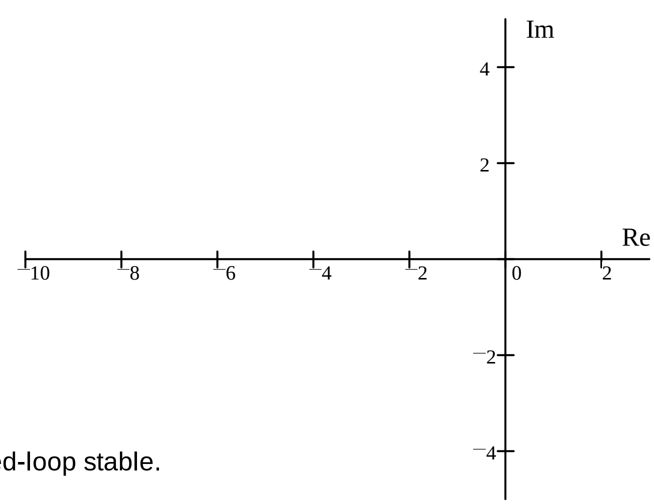
5. (5 pts) The following question is about a compensator ($C(s)$) in a standard unity-feedback system.

   a) List 2 advantages of having an integrator in the compensator.

   b) What is the disadvantage of using just an integrator (I) alone?

6. (12 pts) a) Sketch the root-locus plot for the following open-loop transfer function:
   Use only the rules you were told to memorize, that is, you may estimate details like breakaway points and departure angles from complex poles. Show your work where needed (like calculation of the centroid). Number each axis.

$$\mathbf{G}(s) = \frac{s^2 + 2 \cdot s + 5}{(s-1) \cdot (s+6) \cdot \left(s^2 + 10 \cdot s + 29\right)}$$



   b) Find the range of gain (k) for which the system is closed-loop stable.
   Assume $k > 0$. The answer may be left as a fraction.

Open-book part

1. (26 pts) This system: $\mathbf{H}(s) = \frac{10}{s^2 + 6\cdot s + 34}$ Has this input: $x(t) = 1.5\cdot\sin(4\cdot t)\cdot u(t)$

   a) Find the resulting output, $\mathbf{Y}(s)$ and separate that into partial fractions that you can find in the Laplace transform table. Show what they are, but don't find the coefficients.

   b) Use steady-state AC analysis to find the phasor representation of the steady-state output in polar form.

   $\mathbf{Y}_{ss}(j\omega) = ?$

   c) Show the steady-state output in as a time-domain expression.

   d) What is the time constant of the **transient** part the system output? $\tau = ?$

   e) What is the ringing frequency of the **transient** part the system output? (in Hz)

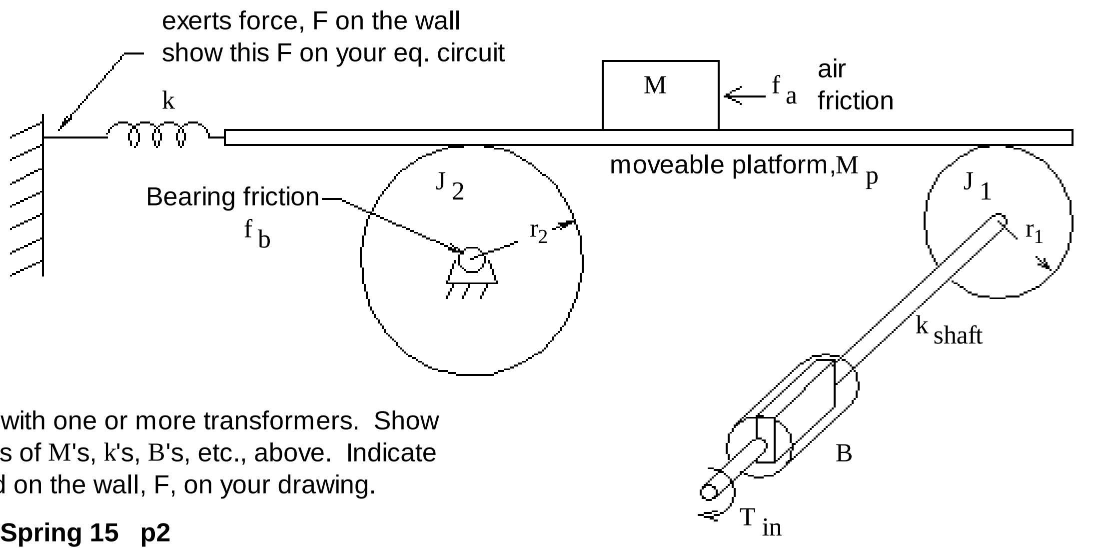
2. (12 pts) The controller and plant transfer functions shown below are part of a standard unity feedback system.

   $C(s) = \frac{1}{s+4}$ $P(s) = \frac{3\cdot s + 6}{s-2}$

   a) As is, without any extra gain in the loop, will the whole feedback system be BIBO stable? You must justify your answer.

   b) If you added gain factor to the controller, so that it is now: $C(s) = \frac{k}{s+4}$ Can you now change the stability of the system?
   (That is, make stable if it was unstable, or unstable if it was stable.)
   You must justify your answer and find the k value to make the change, if possible.

3. (24 pts) Find the equivalent electric circuit for the mechanical system shown. It is a moveable platform of mass, M_p, which rests on 2 different wheels. The input to the system is a torque, T_{in}.



   a) Show the circuit with one or more transformers. Show the parts in terms of M's, k's, B's, etc., above. Indicate the force exerted on the wall, F, on your drawing.

3. b) Show how to eliminate a transformer (choose the easiest), just like you did in the homework. Show the equivalent parts in terms of M's, k's, J's, etc., above. You don't have to redraw the whole circuit as long as I can tell how the section of the circuit you draw would connect above.

Answers

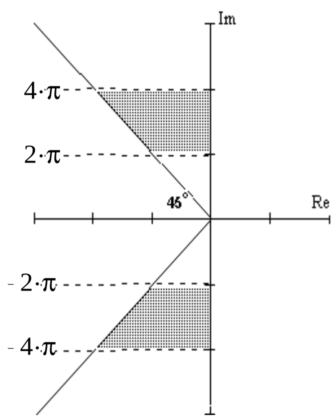
1. As initial conditions and/or as the initial state of the system.

2. a) The **initial value** of the **output** variable   b) The **initial slope** of the **input** 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) Give one advantage of the frequency domain method we are using in this class over the state-space method.
      Easy to set up analysis and find transfer functions
      Transfer functions and poles provide lots of information without a complete analysis   1 of these
      Rapid, easy and intuitive design

4. poles should be in the shaded regions

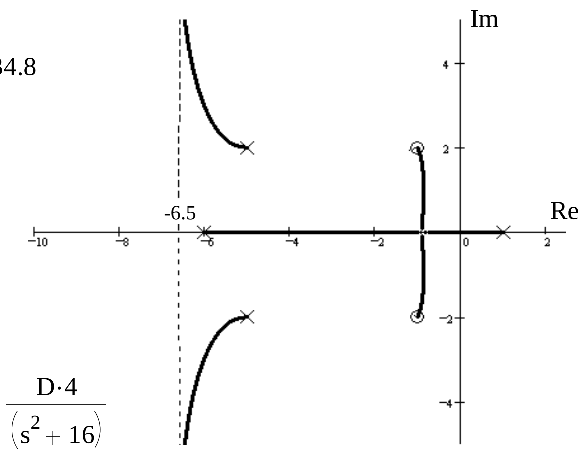


5. a) 1) Eliminates steady-state error for a step (DC) input.
      2) Eliminates the affects of a DC disturbance.

   b) What is the disadvantage of using just an integrator (I) alone?
      Slows down the speed of the system.

6. a)

   b) $k > 34.8$



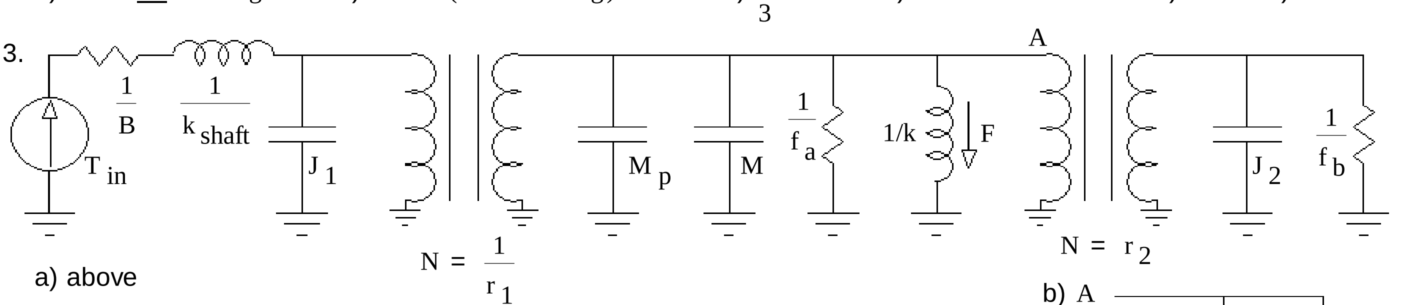
Open-book part

1. a) $\dfrac{A\cdot(s+3)}{s^2+6\cdot s+34} + \dfrac{B\cdot 5}{s^2+6\cdot s+34} + \dfrac{C\cdot s}{(s^2+16)} + \dfrac{D\cdot 4}{(s^2+16)}$

   b) $0.5\ \angle -143\cdot deg$ c) $0.5\cdot\cos(4\cdot t - 143\cdot deg)$ d) $\frac{1}{3}\cdot sec$ e) $0.796\cdot Hz$

2. a) NO   b) $k > 4/3$

3.



   a) above

   b) A