ECE 3510 Exam 2 given: Spring 16 (Some of the space between problems has been removed.)

This part of the exam is Closed book, Closed notes, No Calculator. 3/7/16

1. 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. Several transfer functions are shown below. Without doing anything more than looking at the transfer function, try to determine if it is BIBO stable. Answer Y, N, or C for each.

   Y) definitely BIBO table
   N) definitely NOT BIBO table
   C) can't tell just by looking

   a) $\dfrac{s\cdot(s+6)}{s^5+4\cdot s^4+2\cdot s^3+6\cdot s^2+2\cdot s+1}$ ____

   b) $\dfrac{s+1}{s^5+3\cdot s^4-18\cdot s^3+3\cdot s^2+s+2}$ ____

   c) $\dfrac{s-4}{s^4+2\cdot s^3+1\cdot s^2+s+0.25}$ ____

   d) $\dfrac{s^4+10\cdot s^2+s}{\left(s^2+2\cdot s+5\right)\cdot\left(s^2+4\cdot s+4\right)}$ ____

   e) $\dfrac{10\cdot s+1}{(s+2)\cdot\left(s^2+2\cdot s+4\right)\cdot s}$ ____

   f) $\dfrac{s+2}{5\cdot s^6+13\cdot s^4+8\cdot s^3+s^2+s+2}$ ____

3. In Lab 4 you characterized a DC motor. The objective was to find parameters that could be used to write a transfer function for the motor. A transfer function can only be written for a linear system. Which "linear" parameter represented the most non-linear quality of the motor?

4. You want to build a device which will show a significant ringing effect at 40Hz. The ringing should last between 5 and 10 seconds before its amplitude decays to 37% of the original value. The ringing should start when a power switch is closed. Where should the poles of this system be located. Be as specific as you can be.

5. Lately you have been drawing root-locus plots. Be specific and clear in your answers below. Used the words open-loop and closed-loop where appropriate

   a) Each locus (line) starts at:

   b) The ___________ is ___________ at this point.

   c) Each locus (line) ends at:

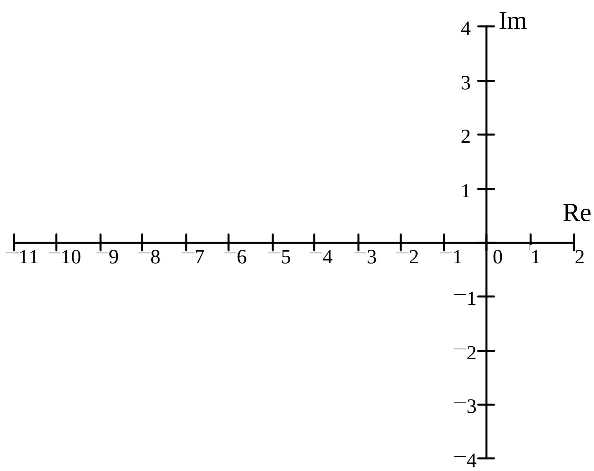
   d) The ___________ is ___________ at this point.

   e) how many locus lines are there?

   f)What do the lines actually represent?

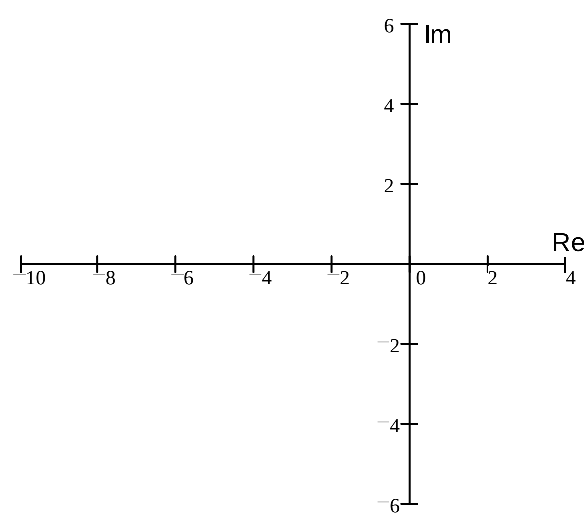
6. (20 pts) Sketch the root-locus plots for the following open-loop transfer functions:
   Use only the rules you were told to memorize, that is, you may estimate details like breakaway points and departure angles from complex poles. Show your work where needed (like calculation of the centroid).
   Draw things like the asymptote angles carefully.

   a) sketch $\mathbf{G}(s) = \mathbf{G}(s) := \dfrac{(s-1)\cdot(s+5)}{(s+8)\cdot(s+10)}$



   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.

   c) sketch $\mathbf{G}(s) = \dfrac{1}{s\cdot\left(s^2+10\cdot s+41\right)\cdot(s+2)}$



1. (24 pts) This system: $\mathbf{H}(s) = \dfrac{20 \cdot s}{s^2 + 8 \cdot s + 52}$ Has this input: $x(t) = 1.2 \cdot \sin(5 \cdot t) \cdot u(t)$

   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) Express the complete (both transient and steady-state) output as a function of time. $y(t) = ?$
   Express the steady-state part as a cosine with a phase angle.
   You don't need to find the transient coefficients, just use the letter(s) that you used in part a).

   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.

   $C(s) = \dfrac{1}{s+8}$ $P(s) = \dfrac{2 \cdot (s-1)}{s+1}$

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

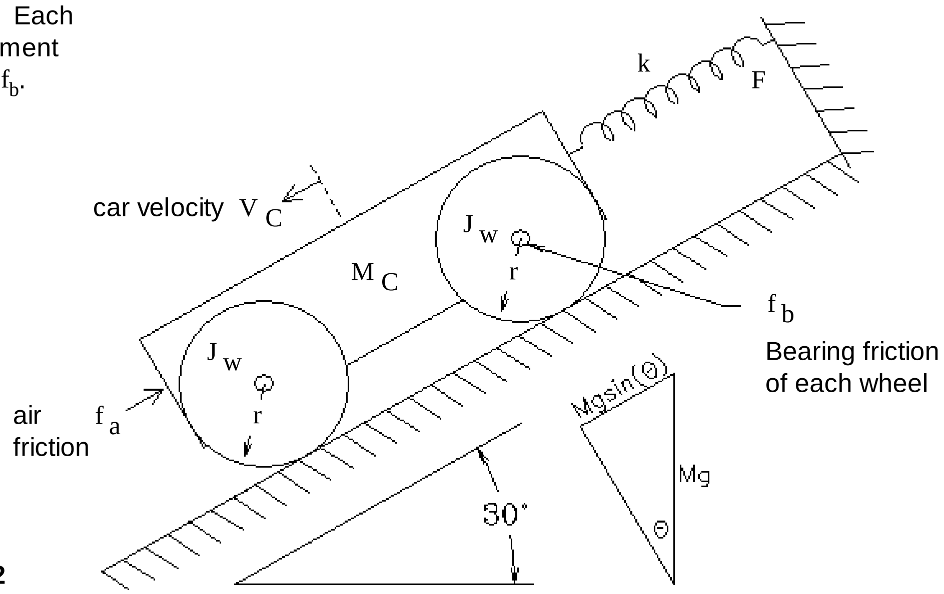
   b) If you added a gain factor to the controller, so that it is now: $C(s) = \dfrac{k}{s+8}$ Can you now change the BIBO stability of the system?
   (That is, make stable if it was unstable, or unstable if it was stable.)
   You must justify your answer and find the k value to make the change, if possible.

3. (20 pts) Find the equivalent electric circuit for the mechanical system shown. It is a 4-wheeled car of mass, M_C, on a 30^o incline. Each wheel has the same radius, r, moment of inertia, J_w, and bearing friction, f_b.

   The only input to the system is gravity. Be sure to show the force, F, on the wall and the car velocity, V_C, your drawing.

   Hint: since all 4 wheels are identical, you nay group them together.

Spring exerts force, F on the wall show this F on your eq. circuit



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, and the car velocity, V_C, your drawing.

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

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

2. a) C b) N c) C d) Y e) N f) N

3. B_m, The motor's friction

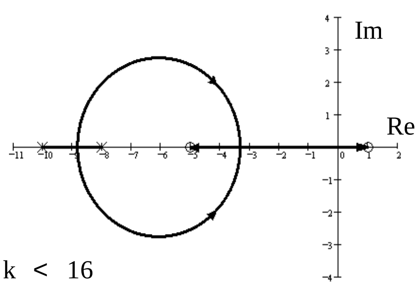
4. the poles should be between -0.2 and -0.1 at $\pm$ 251j.

5. a) An open-loop pole b) The ___gain___ is ___zero___ at this point.

   c) An open-loop zero or at infinity d) The ___gain___ is ___infinite___ at this point.

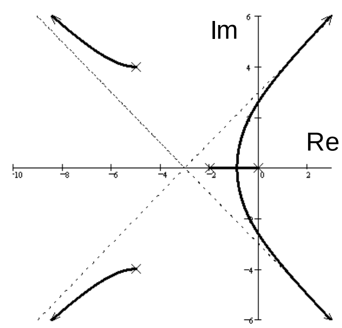
   e) The number of closed-loop poles, one per pole. f) The positions of the closed-loop poles

6. a)



b) $k < 16$

c)



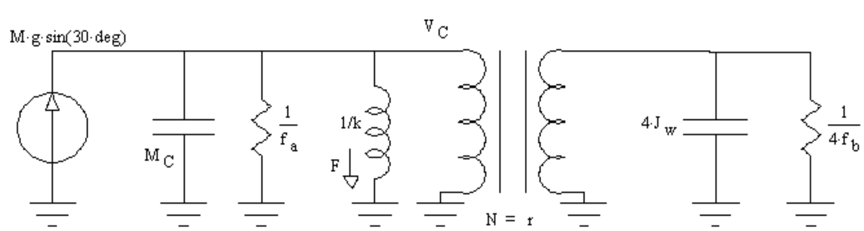
Open-book part

1. a) $\dfrac{A\cdot(s+4)}{s^2+8\cdot s+52} + \dfrac{B\cdot 6}{s^2+8\cdot s+52} + \dfrac{C\cdot s}{\left(s^2+25\right)} + \dfrac{D\cdot 5}{\left(s^2+25\right)}$ b) $2.49\ \angle -55.98\cdot deg$

   c) $\left[e^{-4\cdot t}\cdot(A\cdot\cos(6\cdot t)+B\cdot\sin(6\cdot t))+2.49\cdot\cos(5\cdot t-55.98\cdot deg)\right]\cdot u(t)$ d) $0.25\cdot sec$ e) $0.955\cdot Hz$

2. a) Yes, closed-loop system denominator is $s^2+11\cdot s+6$ 2nd order & all coeff. are + b) Becomes unstable for $k \geq 4$

3. a)



b)