EECS C128/ ME C134
Midterm (v. 1.01)
Thurs. Oct. 18,2018
1710-1830 am

Name:___________________________
SID:_____________

- Closed book. One page formula sheet. No calculators.

- There are 5 problems worth 100 points total.

In the real world, unethical actions by engineers can cost money, careers, and lives. The penalty for unethical actions on this exam will be a grade of zero and a letter will be written for your file and to the Office of Student Conduct.

Problem	Points	Score
1	22	
2	22	
3	27	
4	15	
5	14	
TOTAL	100	

Tables for reference:

$\tan^{-1}\frac{1}{10} = 5.7°$	$\tan^{-1}\frac{1}{5} = 11.3°$
$\tan^{-1}\frac{1}{4} = 14°$	$\tan^{-1}\frac{1}{3} = 18.4°$
$\tan^{-1}\frac{1}{2} = 26.6°$	$\tan^{-1}\frac{1}{\sqrt{3}} = 30°$
$\tan^{-1}\frac{2}{3} = 33.7°$	$\tan^{-1}\frac{3}{4} = 36.9°$
$\tan^{-1} 1 = 45°$	$\tan^{-1}\sqrt{3} = 60°$
$\sin 30° = \frac{1}{2}$	$\cos 30° = \frac{\sqrt{3}}{2}$
$\cos 45° = \frac{\sqrt{2}}{2}$	$\sin 45° = \frac{\sqrt{2}}{2}$

$\log_{10} 2 = 0.30$	$\log_{10} 3 = 0.48$	$\log_{10} 5 \approx 0.7$
$20\log_{10} 5 = 20db - 6dB = 14dB$	$20\log_{10}\sqrt{10} = 10$ dB	$\log_{10} 6 \approx 0.78$
$20\log_{10} 1 = 0dB$	$20\log_{10} 2 = 6dB$	$\pi \approx 3.14$
$20\log_{10}\sqrt{2} = 3dB$	$20\log_{10}\frac{1}{2} = -6dB$	$2\pi \approx 6.28$
$\sqrt{17} \approx 4.12$	$\sqrt{3.5} \approx 1.87$	$\pi/2 \approx 1.57$
$\sqrt{13} \approx 3.61$	$\sqrt{10} \approx 3.164$	$\pi/4 \approx 0.79$
$1/e \approx 0.37$	$\sqrt{2} \approx 1.41$	$\sqrt{3} \approx 1.73$
$1/e^2 \approx 0.14$	$\sqrt{5} \approx 2.24$	$\sqrt{7} \approx 2.65$
$1/e^3 \approx 0.05$	$1/\sqrt{2} \approx 0.71$	$1/\sqrt{3} \approx 0.58$

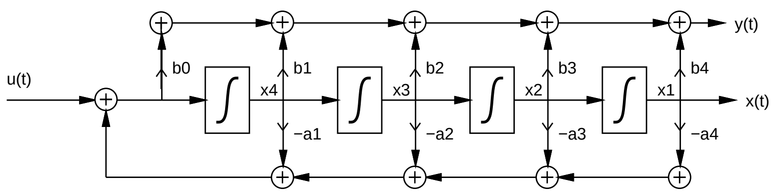
Problem 1 (22 pts)

Each part is independent.

[6 pts] a) Consider a single-input single-output system with input $u(t)$ and output $y(t)$ described by the block diagram below with coefficients as given:

$a_1 = \underline{\ 0\ }$ $a_2 = \underline{\ 0\ }$ $a_3 = \underline{\ 3\ }$ $a_4 = \underline{\ 4\ }$

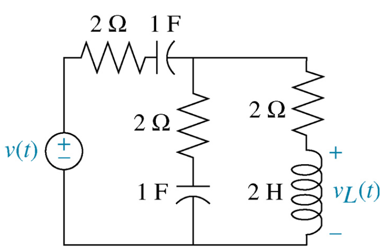
$b_0 = \underline{\ 1\ }$ $b_1 = \underline{\ 2\ }$ $b_2 = \underline{\ 0\ }$ $b_3 = \underline{\ 0\ }$ $b_4 = \underline{\ 0\ }$



Write the transfer function for the system:

$$\frac{Y(s)}{U(s)} = \underline{\hspace{4cm}}$$

[8 pts] b) Draw the equivalent mechanical circuit for this electrical system, with voltage corresponding to force and current to velocity. Input force is $v(t)$.



c) Consider a system with a **step** input which has transfer function:

$$Y(s) = \frac{10}{s(s+5)(s^2+2s+2)} = \frac{A}{s} + \frac{B}{s+5} + \frac{Cs+D}{s^2+2s+2}$$

[4 pts] i) Find the partial fraction expansion coefficients for $Y(s)$:

$A =$_________

$B =$_________

$C =$_________

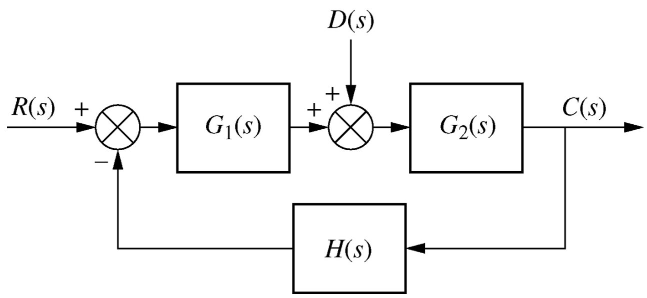
$D =$_________

[2 pts] ii) Find $y(t)$, the inverse Laplace transform of $Y(s)$, using the partial fraction expansion above.

$y(t) =$ _____________

[2 pts] iii) For the system above, the real pole is 5 times more negative than the real part of the complex pole pair. Is it reasonable to ignore the pole at $s = -5$ and treat the step response as the step response of a second order system? Briefly explain using the results above.

Problem 2 Steady State Error (22 pts)



[6 pts] a) Let $D(s) = 0$. Let $e(t) = r(t) - c(t)$. Find $\frac{E(s)}{R(s)}$ in terms of G_1, G_2, H .

$\frac{E(s)}{R(s)} =$ __________

[8 pts] b) For the system above, let $G_1(s) = k$, $G_2(s) = \frac{s}{s+2}$, $H(s) = \frac{1}{(s+1)s}$. Let $D(s) = 0$. For $r(t) = tu(t)$, a unit ramp, find the steady state expression for $e(t)$ for large t.

$\lim_{t\to\infty} e(t) =$ ______

[8 pts] c) For the system above, let $G_1(s) = k$, $G_2(s) = \frac{s}{s+2}$, $H(s) = \frac{1}{(s+1)s}$. For $d(t) = tu(t)$, a unit ramp, and $r(t) = 0$, find the steady state expression for $c(t)$ for large t.

$\lim_{t\to\infty} c(t) =$ ______

Problem 3. Root Locus Plotting (27 pts)

For the root locus ($1 + kG(s) = 0$) with $k > 0$, and given open loop transfer function $G(s)$:

$$G(s) = \frac{(s+3)}{(s+1)^2(s+2)^2}$$

[1 pts] a) Determine the number of branches of the root locus = ___

[2 pts] b) Determine the locus of poles on the real axis ____________

[3 pts] c) Determine the angles for each asymptote:_____________________

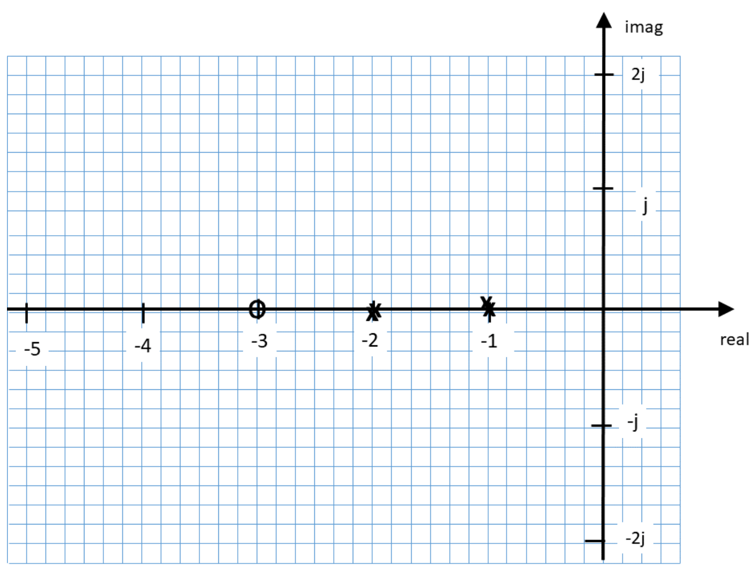
[4 pts] d) determine the real axis intercept for the asymptotes $s =$_____

[6 pts] e) Determine the break-in location on the real axis. $s =$ _____

[6 pts] f) Estimate the value of k for which $p \approx +1.9j$ is a closed-loop pole. (Show work for full credit).

$k =$ _____

[5 pts] g) Sketch the root locus below using the information found above. Draw arrows on branches showing increasing gain. Draw asymptotes.



Problem 4. Root Locus Compensation (15 pts)

Given open loop transfer function $G(s)$, where $G_3(s)$ is the open-loop plant:

$$G(s) = G_1(s)G_3(s) = G_1(s)\frac{1}{(s+2)(s+3)}$$

and $G_1(s)$ is a PI compensation of the form $G_1(s) = k_p\frac{s+z_c}{s}$. The closed loop system, using unity gain feedback and the PI controller, should have a pair of poles at $p \approx -2 \pm 4j$.

[6 pts] a. To obtain the closed loop pole at p, estimate the angle contribution (in degrees) for the following open loop poles:

pole	angle
s = 0	
s = -2	
s = - 3	

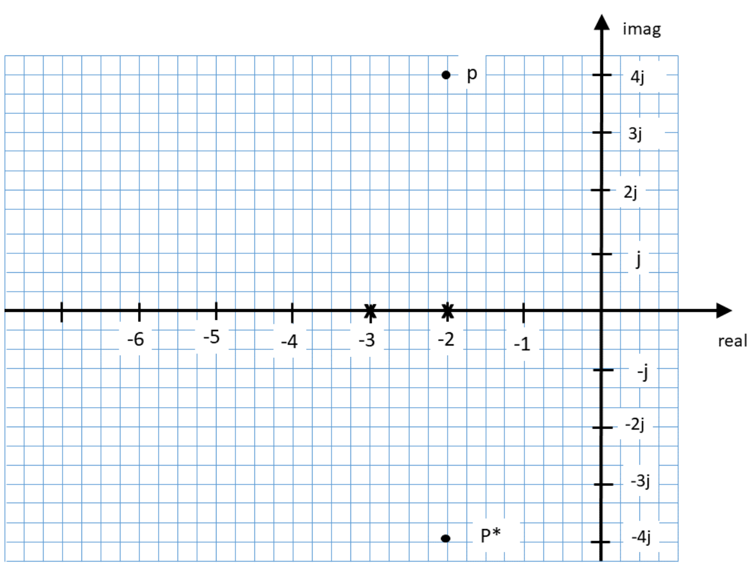
[2 pts] b. What is the necessary angle contribution of the zero z_c for the closed loop pole p to be on the root locus?

[9 pts] c. Find z_c to within ±0.1 such that p is approximately on the root locus, within ± 5 degrees. (Show work.)

$z_c =$ ____________

[2 pts] d. Estimate k_p for the pair of complex conjugate closed loop poles to be at $p \approx -2 \pm 4j$.

(Pole-Zero plot below for scratch work. It will not be graded).



Problem 5. Routh-Hurwitz (14 pts)

Given system with closed loop transfer function (assuming unity feedback)

$$T(s) = \frac{k(s+3)}{s^4 + 6s^3 + 13s^2 + (12+k)s + 4 + 3k}$$

[10 pts] a. Using the Routh-Hurwitz table, show that the maximum positive k for which the closed loop system is stable is approximately 10.

[4 pts] b. For $k \approx 10$, approximately find the pair of closed loop poles on the imaginary axis. (Show work).

$s = \pm j\omega_o = \pm j$ ______

page for scratch work