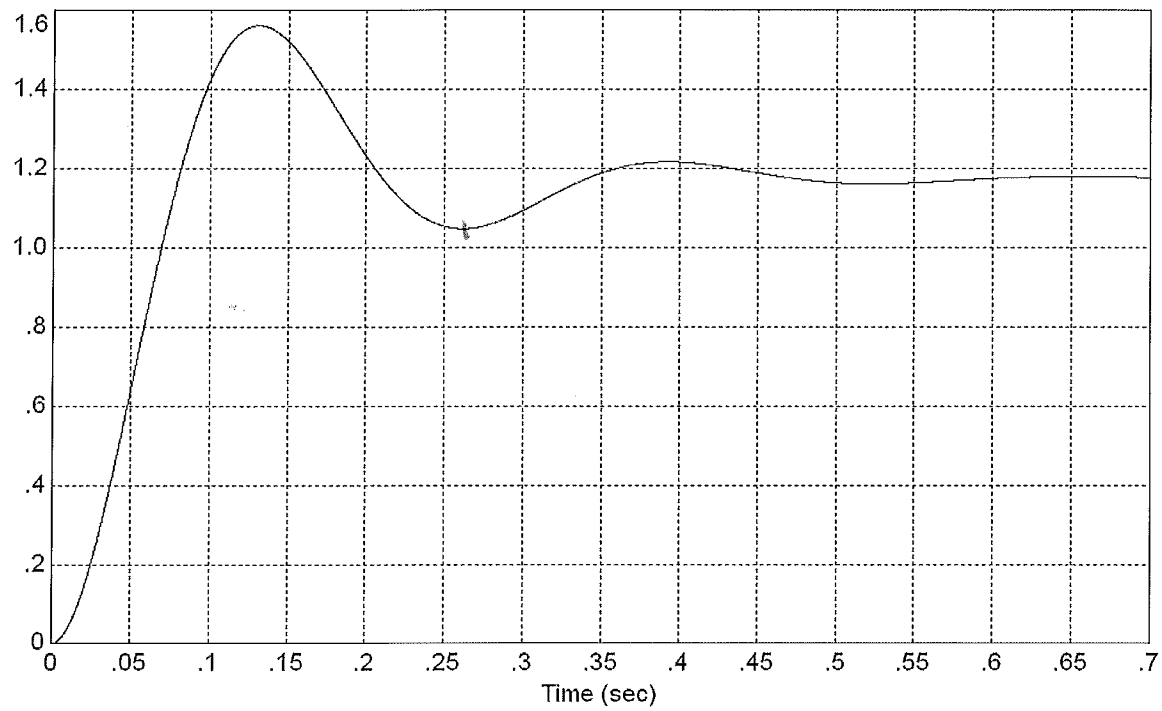
Final: ECE 461 / 661: Name ______________

Closed Book. Closed Notes. Calculators Permitted.

1) Determine the system with the following step response:

G(s) =



DC = 1.18

$\omega_d = \left(\frac{1\text{ cycle}}{.26\text{sec}}\right) 2\pi = 24.166$

$\sigma = \frac{4}{.5} = -8$

$$\boxed{\frac{764}{(s+8+j24.16)(s+8-j24.16)}}$$

2a) Determine y(t) given

$$Y = \left(\frac{20}{(s+2)(s+5)}\right)X$$

$$x(t) = 2 + 3\cos(4t)$$

$s = 0$

$(\ )_{s=0} = 2$

$y = (2)\,2 = 4$

$s = j4$

$(\ )_{j4} = .698\angle{-102°}$

$y = (.698\angle{-102°}) \cdot 3\cos(4t)$

$y = 2.09\ \cos(4t - 102°)$

$$\boxed{y = 4 + 2.09\cos(4t - 102°)}$$

2b) Determine y(t) given

$$Y = \left(\frac{20}{(s+2)(s+5)}\right)X$$

$$x(t) = 2u(t)$$

$$\frac{20}{\cancel{s}(s+2)(s+5)} \cdot \frac{2}{s} = \frac{4}{s} + \frac{-6.667}{s+2} + \frac{2.667}{s+5}$$

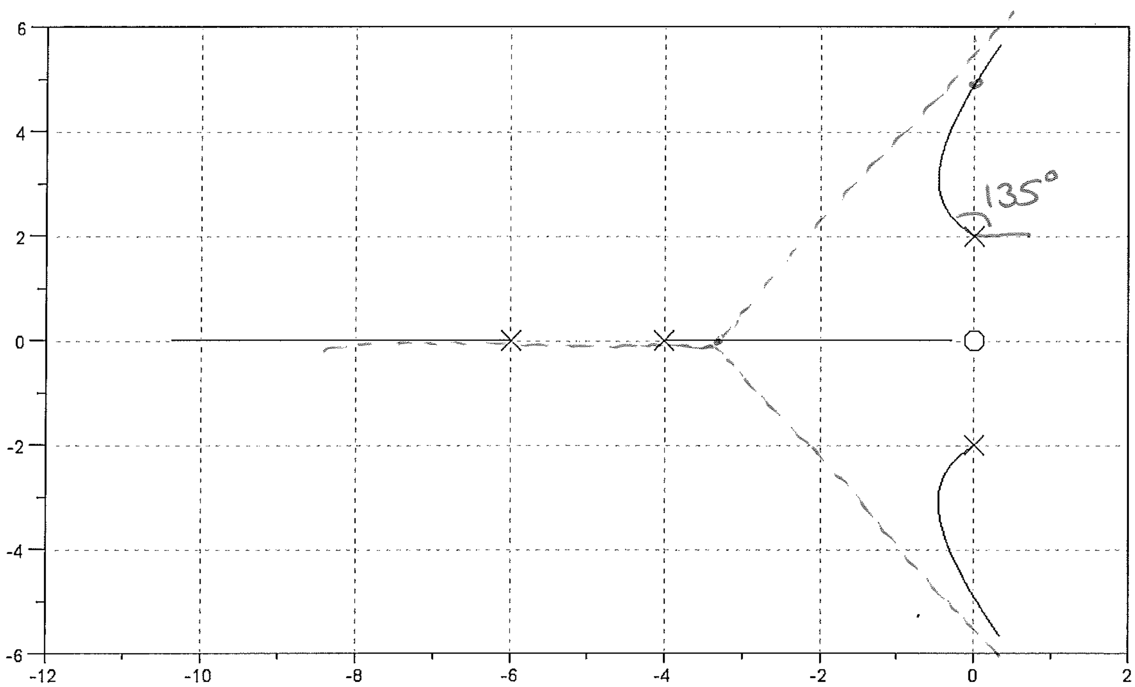
$$\boxed{y = \left(4 - 6.667\, e^{-2t} + 2.667\, e^{-5t}\right) u(t)}$$

3) The root locus for

$$G(s) = \left(\frac{2s}{(s+j2)(s-j2)(s+4)(s+6)}\right)$$

is shown below. Determine the following:

Real Axis Loci	(0, -4) (-6, -∞)	# Asymptotes	3
jw Crossing	j5	Asymptote Angles	~~-30°~~ ±60°, 180°
Departure Angle from the Pole at j2	135°	Asymptote Intersect	-3.333



$$\left.\frac{2s}{(s+j2)(s+4)(s+6)}\right|_{s=j2} = .0354\angle -45^\circ$$

for the angles to add up

$$\angle \frac{1}{s-j2} = -135^\circ$$

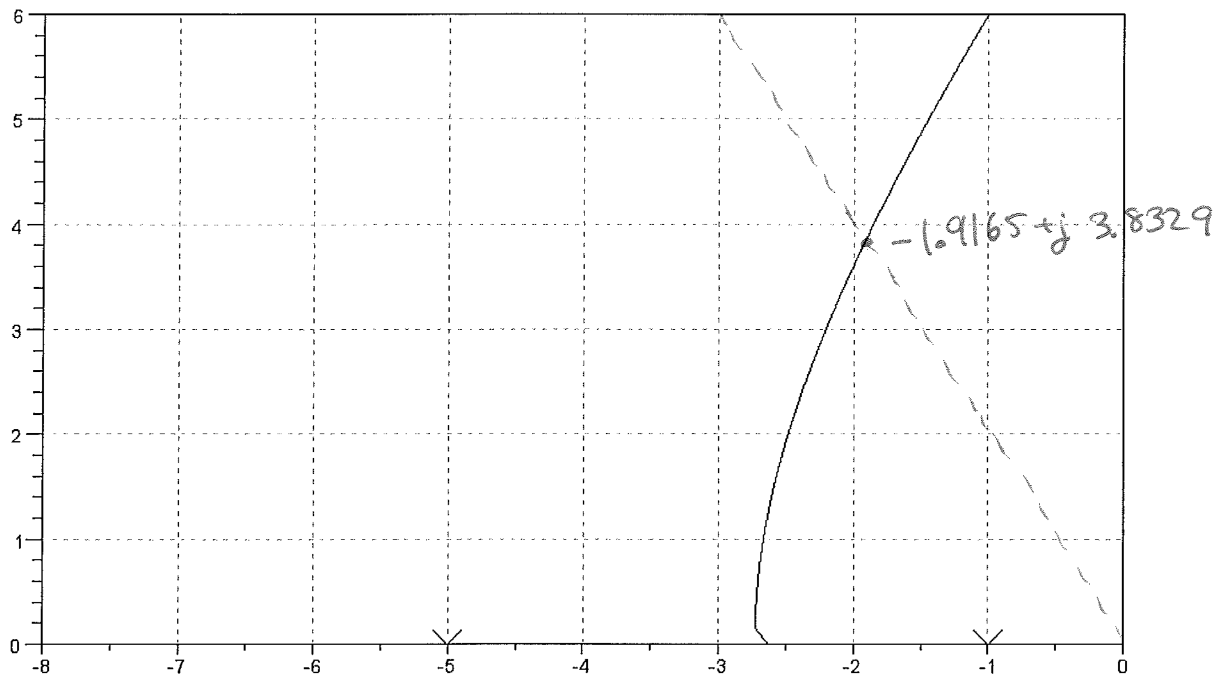
$$\angle s-j2 = +135^\circ$$

4) The root locus for

$$G(s) = \left(\frac{10}{(s+1)(s+5)(s+10)}\right)$$

is shown below. Determing a gain compensator, K(s) = k, which results in 20% overshoot for a step input. For this value of k, determine the following:

k	17.344
Closed-Loop Dominant Pole(s)	$-1.9165 + j\,3.8329$
Error Constant, Kp	3.4688



$$k \cdot G\big|_{s=0}$$

$$K_p = (17.344)\left(\frac{10}{5 \cdot 10}\right) = 3.4688$$

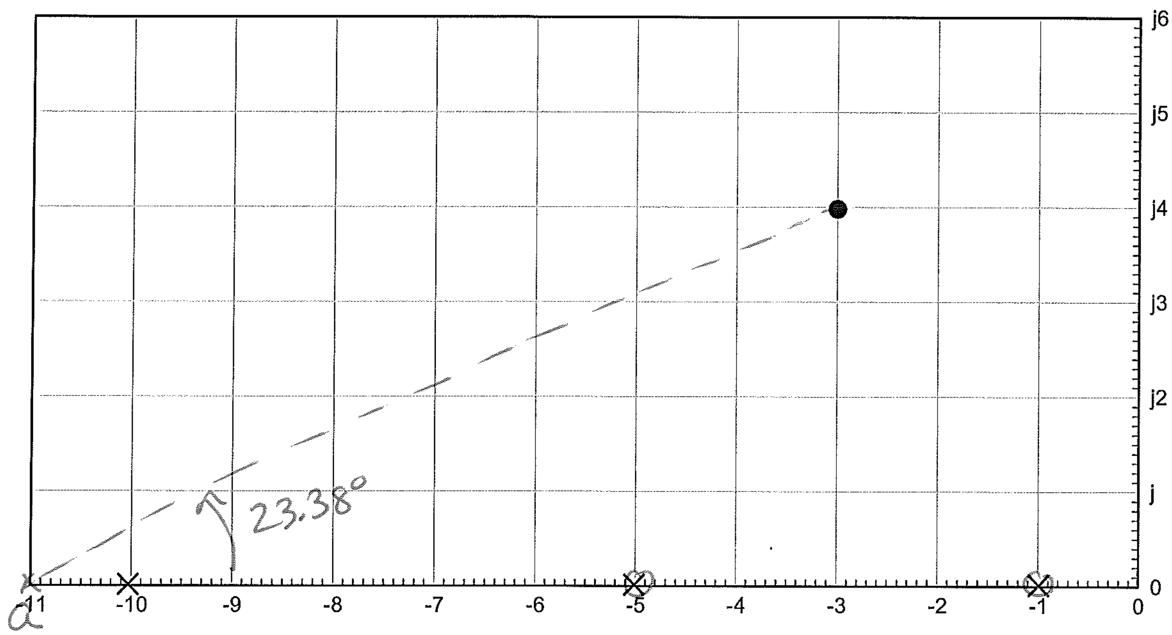
5) Compensator Design: For the system

$$G(s) = \left(\frac{10}{(s+1)(s+5)(s+10)}\right)$$

design a compensator, K(s), which results in

- No error for a step input, and
- A Closed-Loop Dominant pole at s = -3 + j4

K(s) =	$\left(40.62 \dfrac{(s+1)(s+5)}{s(s+12.25)}\right)$ or $\left(40 \dfrac{(s+1)(s+5)(s+10)}{s(s+11)^2}\right)$



$$k(s) = \frac{(s+1)(s+5)}{s(s+a)}$$

$$\left.\frac{10}{s(s+10)}\right|_{s=-3+j4} = .248\angle -156.6^\circ$$

$$\angle s+a = 23.38^\circ$$

$$a = \frac{4}{\tan(23^\circ)} + 3 = 12.25$$

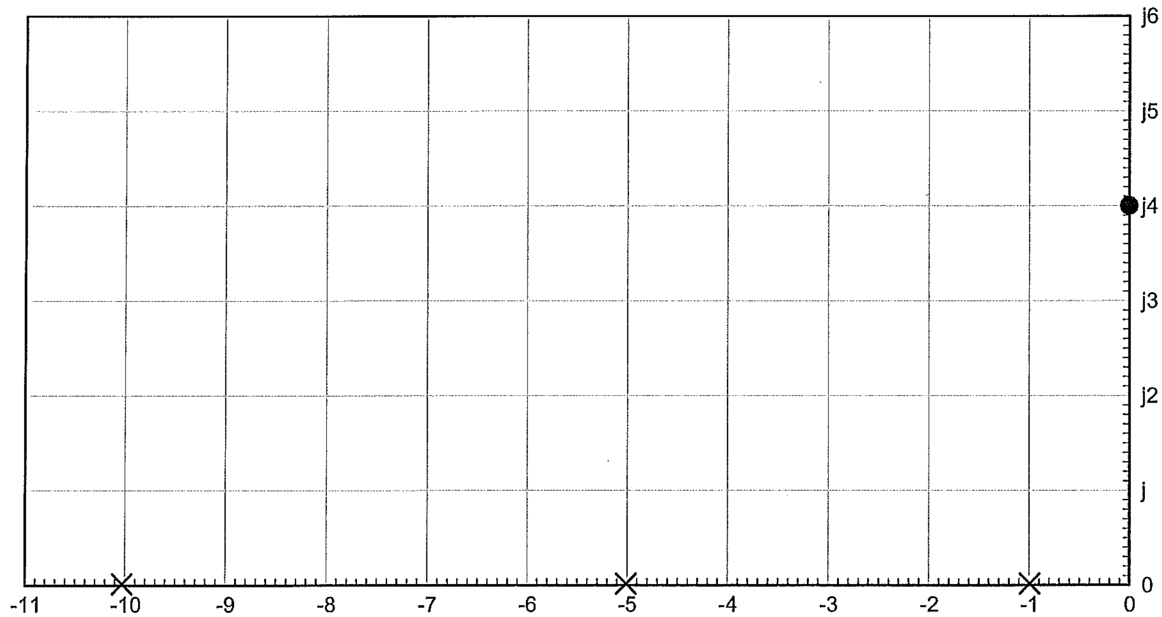
6) Compensator Design: For the system

$$G(s) = \left(\frac{10}{(s+1)(s+5)(s+10)}\right)$$

design a compensator, K(s), which results in

- No error for a step input,
- A 0dB Gain Frequency of 4 rad/sec, and
- A 60 degree phase margin

K(s) =	$\left(120.8 \dfrac{(s+1)(s+5)}{s(s+\cancel{30.776}\ 27.76)}\right)$ or $95.6 \dfrac{(s+1)(s+5)(s+10)}{(s)(s+14.93)^2}$



$GK(j4) = 1\angle -120^\circ$

$$K(s) = \frac{(s+1)(s+5)}{s(s+a)}$$

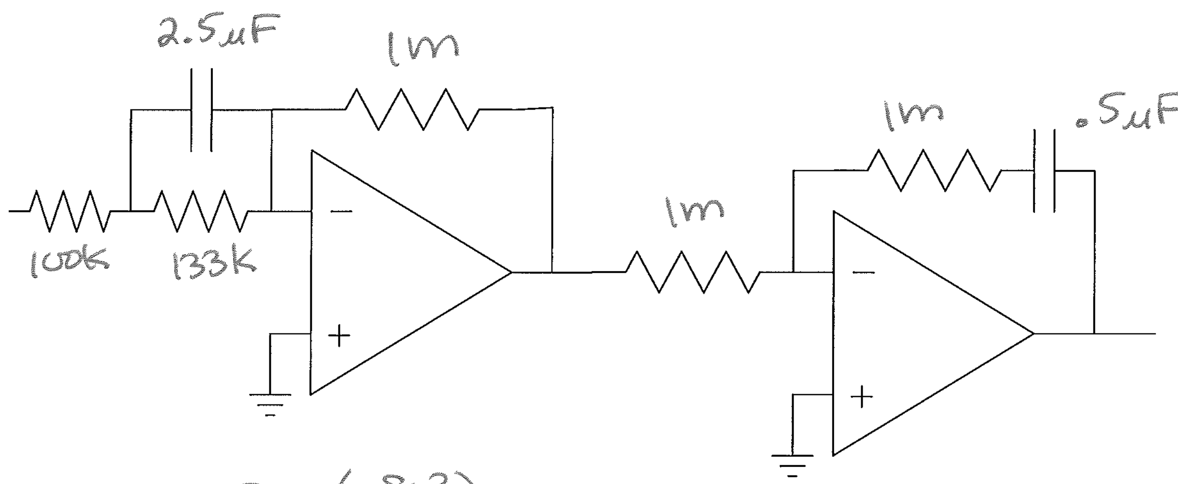
$$\left.\frac{10}{s(s+10)}\right|_{s=j4} = .232\angle -111^\circ$$

$\angle s+a = 8.1986^\circ$

$$a = \frac{4}{\tan(8.19^\circ)} \cancel{+3} = \cancel{30.776}\ 27.7629$$

7a) Design a circuit to implement K(s)

$$K(s) = 10\left(\frac{(s+2)(s+3)}{s(s+7)}\right)$$



$\cancel{S}\, 10\left(\frac{s+3}{s+7}\right)$ $\frac{s+2}{s}$

7b) Determine a discrete-time compensator, K(z), which corresponds to K(s). Assume a sampling rate of 10ms (T = 0.01).

$$K(s) = 10\left(\frac{(s+2)(s+3)}{s(s+7)}\right)$$

$z = e^{sT}$

$$10\left(\frac{(z-.98)(z-.97)}{(z-1)(z-.93)}\right)$$

$s = 0.1$

$K(s) = 91.6901$

$K(z = 1.001) = 91.6901$

$d = 10$

Bonus! Three of the following are U.S. Senators, three are monsters who faced Godzilla. Which are the Senators?

Biollante - Cornyn - Destroyah - Murkowski - Shaheen - Varan