Problem 4.5

Let s → 0

SS gain = 0.1

Therefore $Y_{SS} = \frac{1}{10} * 10 = 1$

Problem 4.7

(a) To find the TF between C and R ignore D completely.

$$G(s) = \frac{K + 11s}{s(s+1)}$$

$$H(s) = 1$$

$$\frac{C(s)}{R(s)} = \frac{K + 11s}{s(s+1) + K + 11s} = \frac{K + 11s}{s^2 + 12s + K}$$

Let s → 0

$$C_{SS} = \frac{K}{K} = 1$$

$$e_{SS} = 1 - C_{SS} = 0$$

(b) To find the TF between D and C ignore R completely.

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

$$H(s) = K + 11s$$

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + GH(s)} = \frac{1}{s(s+1) + K + 11s} = \frac{1}{s^2 + 12s + K}$$

Let s → 0

$$C_{SS} = \frac{1}{K}$$

$$e_{SS} = R_{SS} - C_{SS} = -\frac{1}{K}$$

Problem 4.14

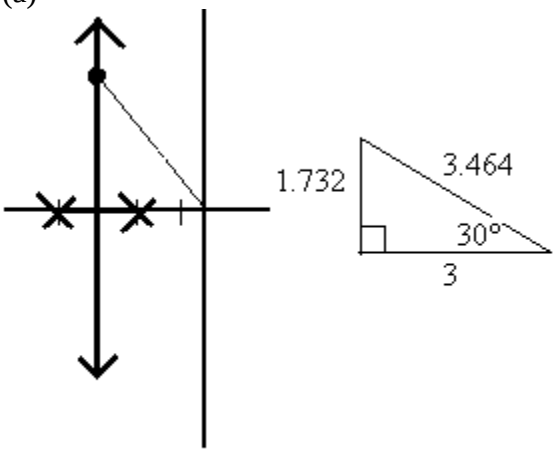
Closed loop TF:

$$\frac{C(s)}{R(s)} = \frac{8K}{(s+2)(s+4)+8K} = \frac{8K}{s^2+6s+8+8K}$$

Poles at -4 and -2

Break away at -3

(a)



(b)

$$(s-[-3+1.732i])(s-[-3-1.732i]) = s^2+6s+8+8K$$

$$9+1.732^2 = 8+8K$$

$$K = \frac{1}{2}$$

OR another way is to do this

$$\xi = 0.866$$

$$\frac{8K}{s^2+6s+8+8K} = \frac{\omega_n{}^2}{s^2+2\xi\omega_n+\omega_n{}^2}$$

$$6 = 2\xi\omega_n = 2*0.866*\omega_n \Rightarrow \omega_n = 3.464$$

$$8+8K = \omega_n{}^2 = 3.464^2 = 12 \Rightarrow K = \frac{1}{2}$$

(c)

For K = 2

$$C_{SS} = \frac{8*2}{8+8*2} = \frac{2}{3}$$

$$E_{SS} = 1 - C_{SS} = \frac{1}{3}$$

Problem 4.15

Zeros = -4

Poles = 0, -3, $-1 \pm j\sqrt{3}$

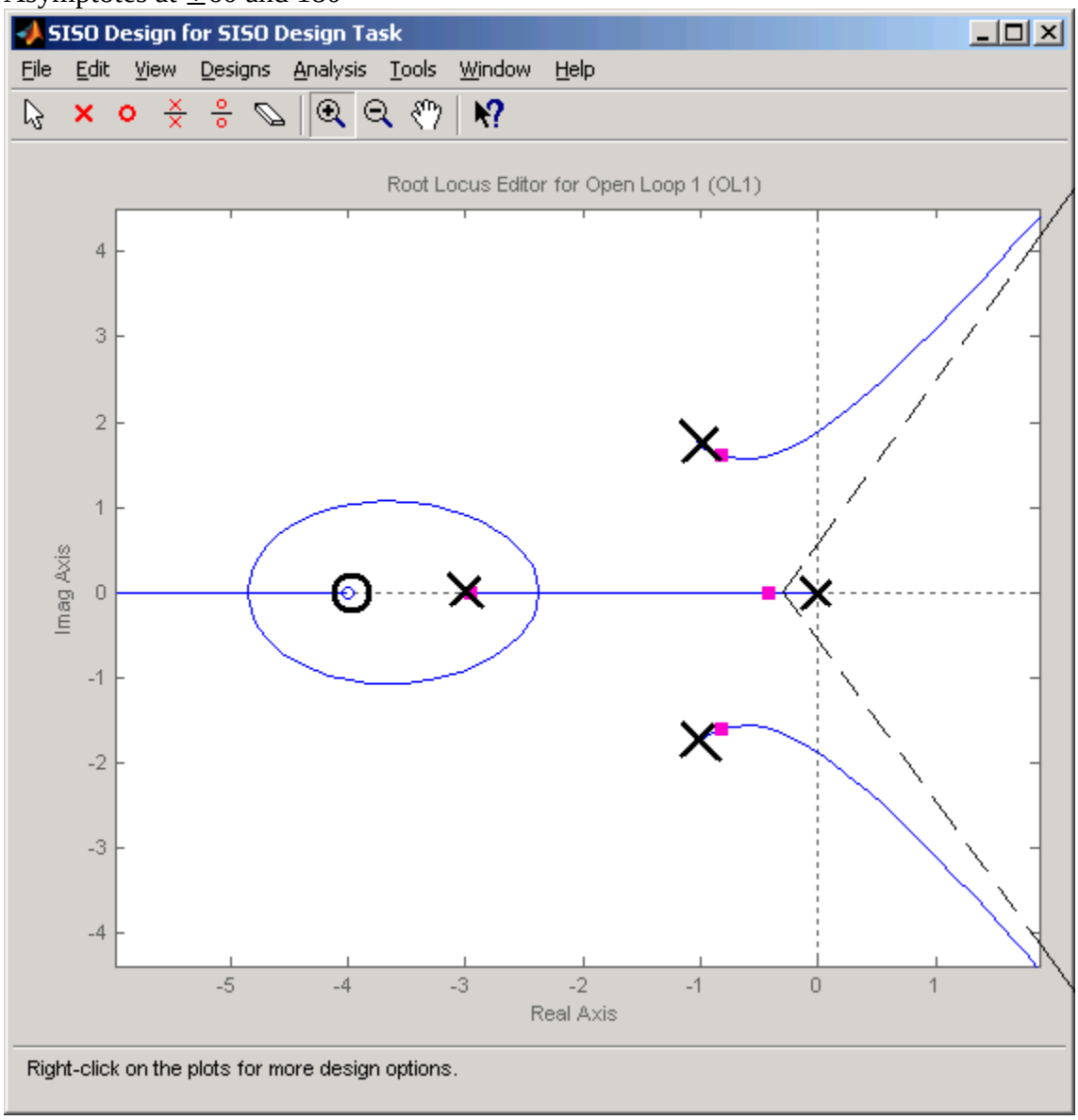
Number of Zeros = 1

Number of Poles = 4

Number of Zeros – Number of Poles = 4 - 1 = 3

Asymptotes intersect real axis = $\frac{(0-3-1-1+4)}{3} = \frac{-1}{3}$

Asymptotes at ± 60 and 180



Problem 4.18

Zeros = -2, -4

Poles = -7, -3, -1, $-1 \pm 3j$

Number of zeros = 2

Number of poles = 5

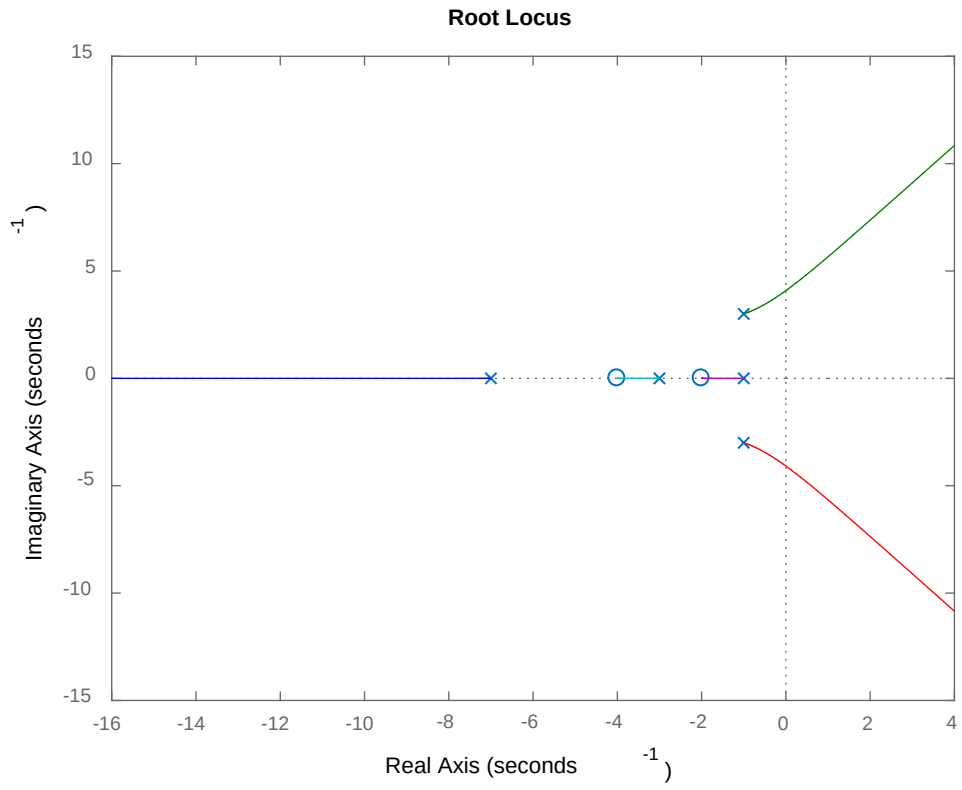
Number of poles – number of zeros = 5 – 2 = 3

Asymptotes at ± 60 and 180

Asymptotes intersect real axis = $\frac{(-7-3-1-1-1)-(-2-4)}{3} = \frac{-13-(-6)}{3} = \frac{-7}{3} = -2.333$

The loci paths include all portions of the real axis that are to the left of an odd number of poles and/or zeros that are on the real axis. The loci paths will be between:

- -1 and -2
- -3 and -4
- -7 and -∞



Problem 4.21

Type	lead	lead	lag	lag	integrator	gain
break (rad/s)	1	4	10	30		
tau (s)	1.0000	0.2500	0.1000	0.0333		
gain						3.1623

$$GH(s) = \frac{237(s+1)(s+4)}{s(s+10)(s+30)} = \frac{3.1623(s+1)(0.25s+1)}{s(0.1s+1)(0.0333s+1)}$$

Phase margin = 180 -75 = 105°