1

(1) $T_w(s) = \frac{24}{s^2+16s+15} = \frac{24}{(s+1)(s+15)}$

$s_r(\infty) = \lim_{s\to 0} s \cdot \frac{1}{s} \cdot T_w = \lim_{s\to 0} T_w = \frac{24}{15} = 1.6$

poles at $-1, -15$ $\quad -1$ dominant $\quad T_s = \frac{4}{\sigma} = 4$ sec

(2) $G_x(s) = \frac{24}{s^2+16s+15} \quad T_x = \frac{G_x}{1+G_xH} = \frac{G_x}{1+G_x} = \frac{24}{s^2+16s+15+24} = \frac{24}{s^2+16s+39} = \frac{24}{(s+3)(s+13)}$

$H=1$

$s_r(\infty) = \lim_{s\to 0} s \cdot \frac{1}{s} \cdot T_x = \lim_{s\to 0} T_x = \frac{24}{39} = 0.615$

poles at $-3, -13$ $\quad -3$ dominant $\quad T_s = \frac{4}{\sigma} = 1.\bar{3}$ sec*

* other pole at -13; T_s may not be completely accurate.

(3) $T_y(s) = \frac{10}{s^2+10s+50} = \frac{10}{(s+5)^2 + (5)^2}$ underdamped

$\underbrace{(5)}_{\omega_d}$

$\omega_n = \sqrt{50} = 5\sqrt{2} = 7.071 \quad 2\zeta\omega_n = 10 \quad \zeta = \frac{10}{2\omega_n} = \frac{1}{\sqrt{2}} = 0.7071$

$c_{step} = \lim_{s\to 0} s \cdot \frac{1}{s} \cdot T_y = \frac{1}{5} = 0.2 \quad T_s = \frac{4}{\zeta\omega_n} = \frac{4}{5} = 0.8s \quad \%OS = 4.32$

$\omega_n = 7.071$ rad/s $\quad \zeta = 0.7071 \quad \omega_d = \omega_n\sqrt{1-\zeta^2} = 5$ rad/s

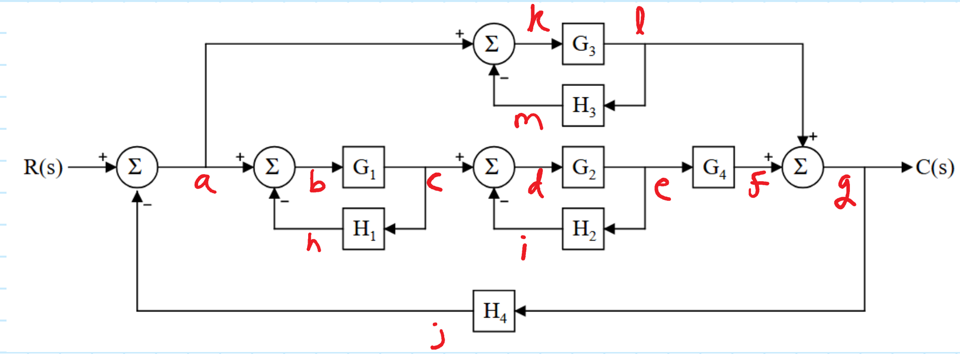
(4) $T = \frac{Ka}{s+a} \quad T_s = 3 = \frac{4}{a} \quad a = \frac{4}{3} \quad c_{step}(\infty) = K = 5 \quad T = \frac{20/3}{s+4/3} \quad$ pole @ $-4/3$

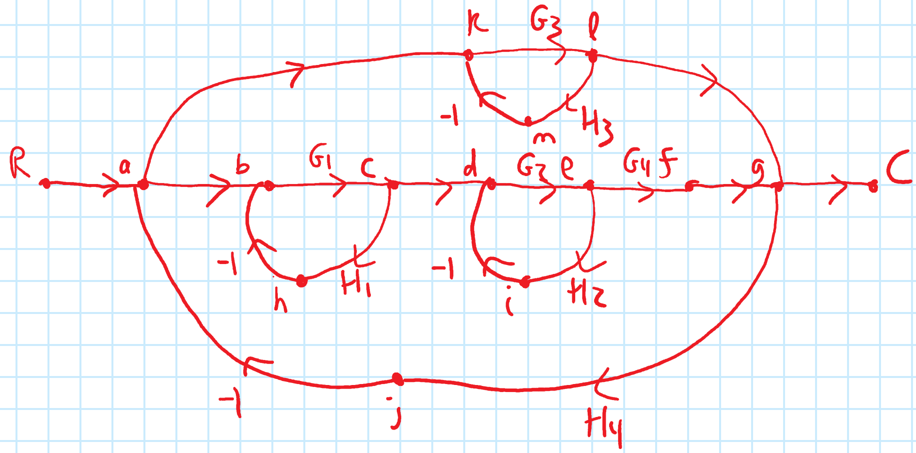
(5) 15%OS: $\zeta = \frac{-\ln(0.15)}{\sqrt{\pi^2+\ln^2(0.15)}} = 0.5167 \quad T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} \quad \omega_n = \frac{\pi}{T_p\sqrt{1-\zeta^2}} = 1.835$

$T = \frac{K\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2} = \frac{2 \cdot 3.367}{s^2+1.897s+3.367} = \frac{6.734}{s^2+1.897s+3.367}$

poles @ $-\zeta\omega_n \pm j\omega_d = -0.9485 \pm j1.571 \quad \omega_d = \frac{\pi}{T_p} = 1.571$ ✓

2





T_1: $RabcdefgC = G_1G_2G_4$

T_2: $RaklgC = G_3$

L_1: $bchb = -G_1H_1$

L_2: $deid = -G_2H_2$

L_3: $klmk = -G_3H_3$

L_4: $abcdefgja = -G_1G_2G_4H_4$

L_5: $aklgja = -G_3H_4$

$$\Delta = 1 - L_1 - L_2 - L_3 - L_4 - L_5 + L_1L_2 + L_1L_3 + L_1L_5 + L_2L_3 + L_2L_5 - L_1L_2L_3 - L_1L_2L_5$$

$$\Delta_1 = 1 - L_3$$

L_3L_4

$$\Delta_2 = 1 - L_1 - L_2 + L_1L_2$$

$$T = \frac{\Sigma T_i \Delta_i}{\Delta}$$

3

(1) $T_\alpha = \dfrac{1}{s^5 + 2s^4 - 8s^3 - 16s^2 - 9s - 18}$

1L	s^5	1	-8	-9
	s^4	2	-16	-18
NOT R	s^3	$8\cancel{0}$	$-32\cancel{0}$	
R	s^2	-8	-18	
NOT R	s^1	-50		
NOT R	s^0	-18		

1K, 1L, 2jω

$2s^4 - 16s^2 - 18$

$8s^3 - 32s$

$\dfrac{-64 + 128}{-8} = -8$

$\dfrac{-144 - 256}{+8} = -50$

2L; 1R, 2jω

2) $G_\beta = \dfrac{Ks + 4K}{s^3 + 3s^2 - 58s - 240}$ $\quad T_\beta = \dfrac{Ks + 4K}{s^3 + 3s^2 + (K-58)s + 4K - 240}$

	s^3	1	$K-58$
	s^2	3	$4K-240$
$K<66$	s^1	$\dfrac{66-K}{3}$	
$K>60$	s^0	$4K-240$	

$\dfrac{4K - 240 - 3K + 174}{-3} = \dfrac{-K + 66}{3}$

(a) $60 < K < 66$

(b) $K = 60$ $\quad s = 0$

$K = 66$ $\quad 3s^2 + 24 = 0$ $\quad s = \pm j2\sqrt{2}$

(c) TYPE 0

(d) $K_p = \lim_{s\to 0} G = \dfrac{4K}{-240} = \dfrac{-K}{60}$

$e_{step} = \dfrac{1}{1+K_p} = \dfrac{1}{1 - \frac{K}{60}} = \dfrac{60}{60-K}$

(1) OVERDAMPED

(2) $T = \frac{KG}{1+KG} = \frac{K(s+10)}{s^3+8s^2+(17+K)s+10K+10}$

s^3	1	$K+17$
s^2	8	$10K+10$
s^1	$\frac{126-2K}{8}$	
s^0	$10K+10$	

$\frac{10K+10-8(K+17)}{-8} = \frac{2K-126}{-8} = \frac{126-2K}{8}$

$K < 63$

$K > -1$

$-1 < K < 63$

(3) TYPE 0 BASED ON G

(4) P, step

(5) $K_p = \lim_{s\to 0} KG = \frac{10K}{10} = K \quad e_{step} = \frac{1}{1+K_p} = \frac{1}{1+K}$

(6) $K = 63^- \to e_{step} = \frac{1}{64}$

(7) (a) REPEAT AT -1.48

(b) CRITICAL

(8) (a) $-.772 \pm j4.05$

(b) UNDERDAMPED

$T = \frac{K(s+1)}{s^4+4s^3+6s^2+Ks+K}$ $G_{eq} = \frac{K(s+1)}{s^2(s^2+4s+6)}$

	s^4	1	6	K
	s^3	4	K	
$K<24$	s^2	$\frac{24-K}{4}$	K	
$K>0,\ K<8$	s^1	$\frac{2K-K^2/4}{(24-K)/4}$		
$K>0$	s^0	K		

$\frac{K-24}{-4} = \frac{24-K}{4}$

$\frac{4K-6K+\frac{K^2}{4}}{-\left(\frac{24-K}{4}\right)} = \frac{2K-\frac{K^2}{4}}{\frac{24-K}{4}}$

$K\left(2-\frac{K}{4}\right) > 0$

$K>0 \quad K<8$

2) TYPE II

3) K_a e_{para}

4) $K_a = \lim_{s\to 0} s^2 G_{eq} = \frac{K}{6}$ $e_{para} = \frac{1}{K_a} = \frac{6}{K}$

5) $K=8$

6) $4s^2+8=0$ $s=\pm j\sqrt{2}$