Final Exam, Control System, 108-2 (2020)
Date: Friday, June 12, 2020. Time: 2pm-4pm.
Closed books, closed notes, no calculators. Only pens and erasers are allowed.

[Helpful formula]

$\lim_{s\to\infty} sF(s)$	$f(0^+)$	Initial Value Theorem
$\lim_{s\to 0} sF(s)$	$\lim_{t\to\infty} f(t)$	Final Value Theorem

- $$t_r \cong \frac{1.8}{w_n},\quad t_p = \frac{\pi}{w_d},\quad M_p = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}},\quad t_s = \frac{4.6}{\zeta w_n} = \frac{4.6}{\sigma}$$

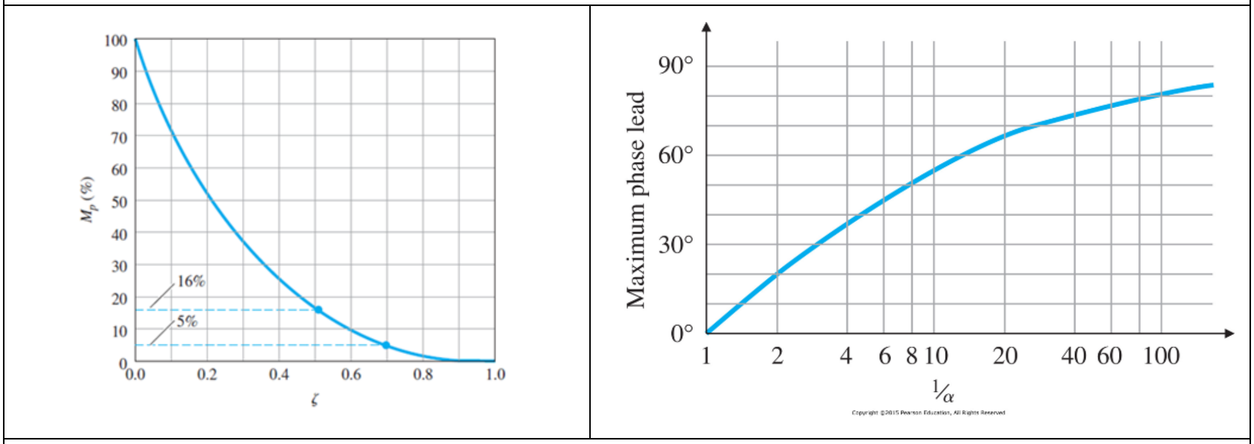


Fig. A Overshoot versus damping ratio for the second-order system and maximum phase increase for lead compensation

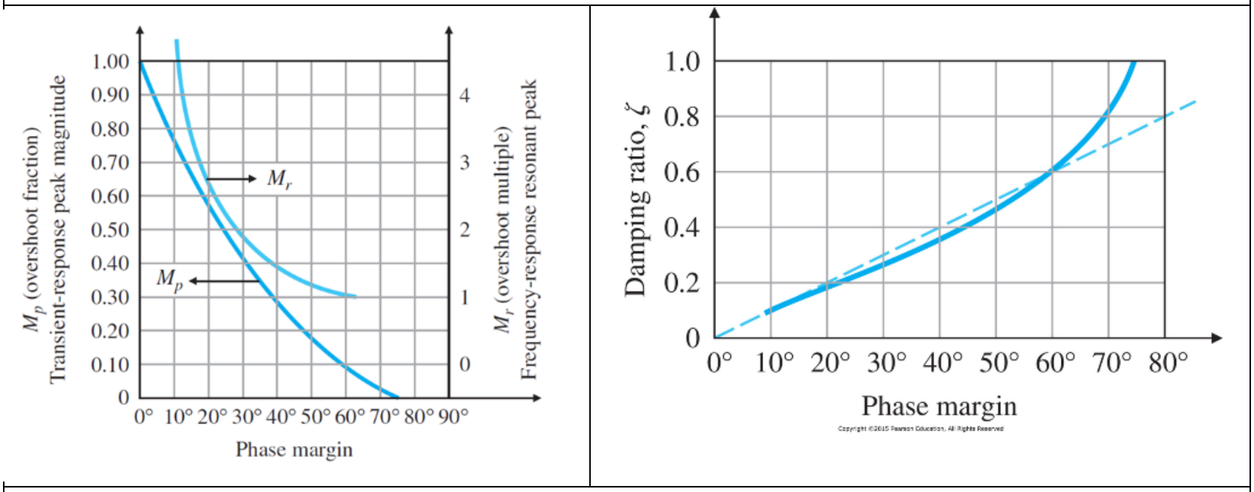
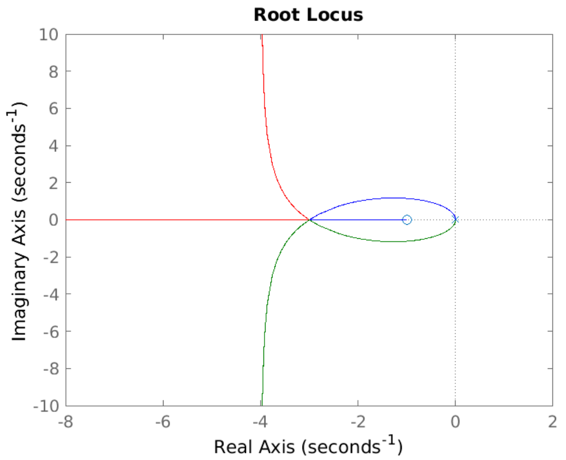
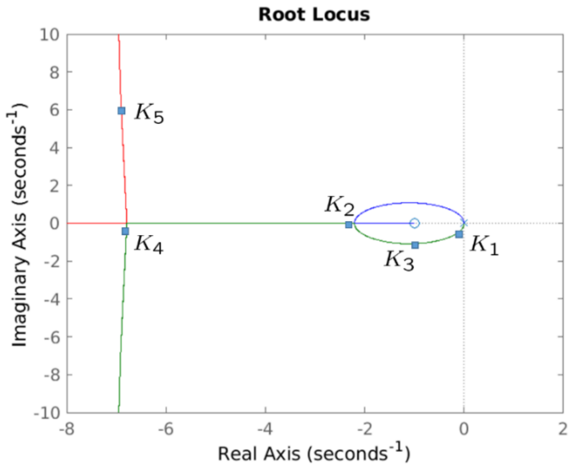


Fig. B Transient-response overshoot (Mp) and frequency-response resonant peak(Mr) versus PM for $T(s) = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$

Part A. [60%] Find the best choice. (評分標準：只需寫出正確選項)

Figure 1 and **Figure 2** show “partial” root loci of two different transfer functions. Note that “partial” means that some zeros or poles might exist in the area outside the visible area.

Figure 1	
Figure 2	

1. For **Figure 1**, please find the best possible transfer function:

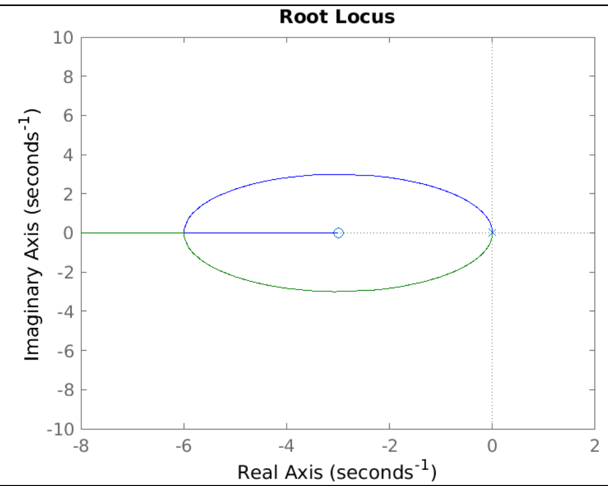
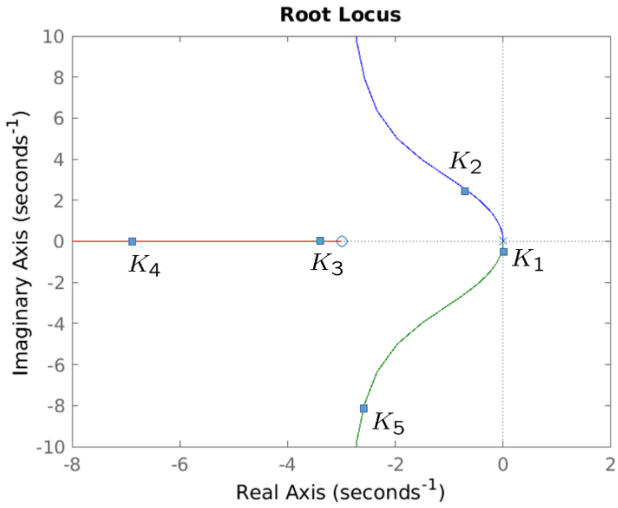
(A) $\dfrac{s+1}{s^2(s+4)}$ (B) $\dfrac{s+1}{s^2(s+9)}$ (C) $\dfrac{s+1}{s^2(s+15)}$ (D) $\dfrac{s+1}{s(s+12)}$

2. For **Figure 2**, please find the best possible transfer function:

(A) $\dfrac{s+1}{s^2(s+4)}$ (B) $\dfrac{s+1}{s^2(s+9)}$ (C) $\dfrac{s+1}{s^2(s+15)}$ (D) $\dfrac{s+1}{s(s+12)}$

3. For **Figure 2**, what is correct relationship among those Ki’s:

(A) K1=K2 (B) K2>K3 (C) K4>K5 (D) K3>K4

Figure 3 and **Figure 4** show "partial" root loci of two different transfer functions. Note that "partial" means that some zeros or poles might exist in the area outside the visible area.	
Figure 3	
Figure 4	

4. For **Figure 3**, please find the best possible transfer function:

(A) $\frac{s+3}{s^2}$ (B) $\frac{s+3}{s^2(s+4)}$ (C) $\frac{s+3}{s^2(s+9)}$ (D) $\frac{s+3}{s^2(s+20)}$

5. For **Figure 4**, please find the best possible transfer function:

(A) $\frac{s+3}{s^2}$ (B) $\frac{s+3}{s^2(s+4)}$ (C) $\frac{s+3}{s^2(s+9)}$ (D) $\frac{s+3}{s^2(s+20)}$

6. For **Figure 4**, what is correct relationship among those Ki's:

(A) K1>K5 (B) K2>K5 (C) K2>K3 (D) K3>K4

Figure 5 and **Figure 6** show the Bode plots of the unit-feedback response of two different second-order systems.

Figure 5

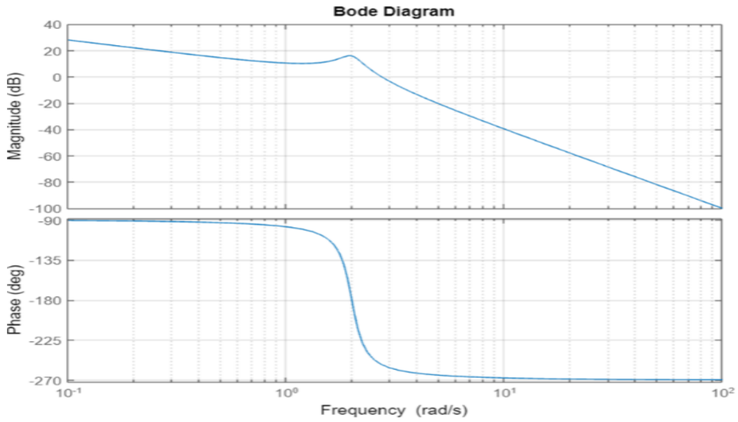
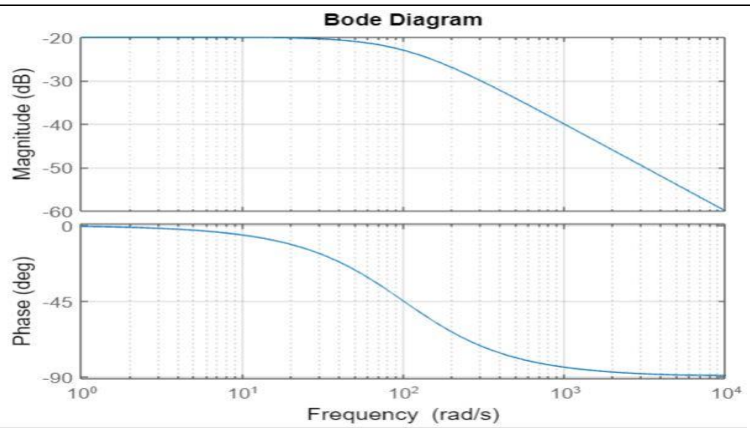


Figure 6



7. For **Figure 5**, please find the best possible transfer function

(A) $\frac{10}{s(s^2+0.4s+4)}$ (B) $\frac{10}{s(s^2+0.2s+10)}$ (C) $\frac{10}{s(s^2+4s+4)}$ (D) $\frac{10}{s(s^2+2s+10)}$

8. For **Figure 6**, please find the best possible transfer function:

(A) $\frac{10(s+10)}{(s+10)(s+100)}$ (B) $\frac{10(s+1)}{(s+10)(s+100)}$ (C) $\frac{100(s+10)}{(s+1)(s+100)}$ (D) $\frac{(s+10)}{(s+1)^2}$

9. For **Figure 5**, what is the possible gain margin:

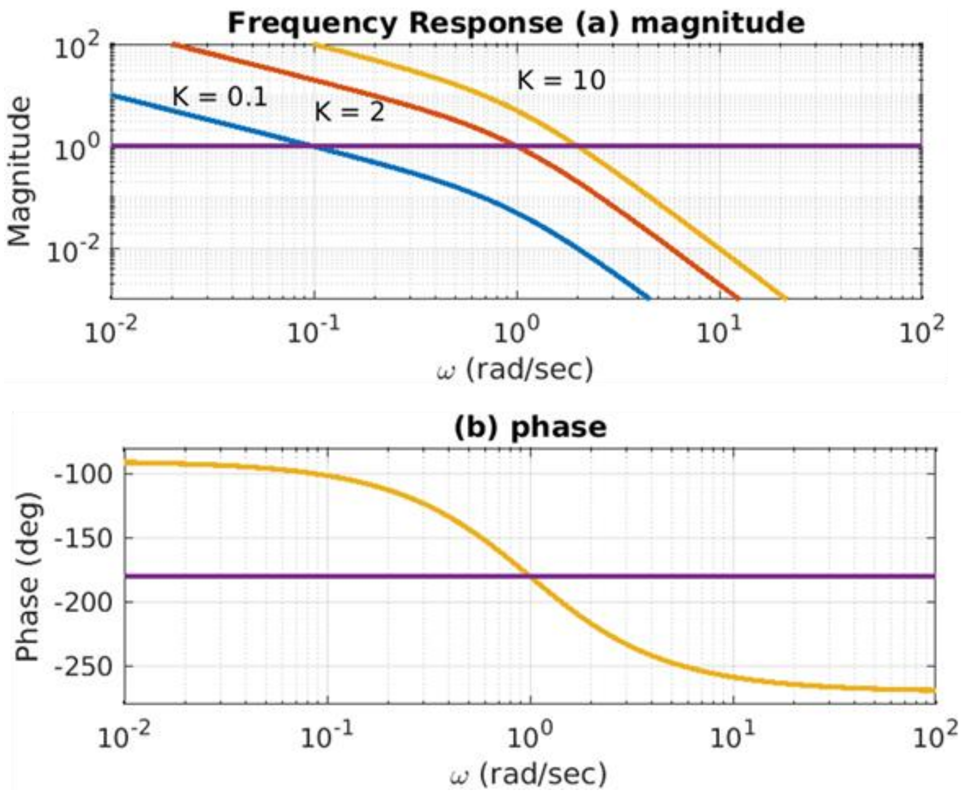
(A) -42 dB (B) 42dB (C) 18dB (D) -18 dB

10. For **Figure 5**, what is the possible phase margin:

(A) -20 deg (B) -80 deg (C) 40 deg (D) 80 deg

Figure 7 shows the Bode plot of one system with different feedback gains, that is, K=0.1, 2, and 10, respectively.

Figure 7



11. For **Figure 7**, what is the possible gain margin for K=0.1:

(A) -10 dB (B) 1 dB (C) 25 dB (D) 80 dB

12. For **Figure 7**, what is the possible phase margin for K=2:

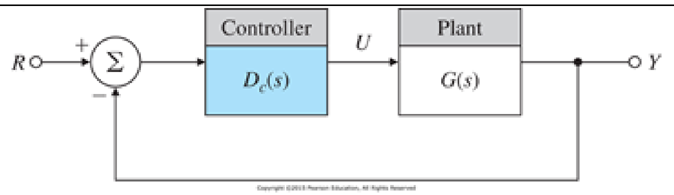
(A) -90 deg (B) -20 deg (C) 0 deg (D) 90 deg

13. For **Figure 7**, if we want to choose a gain K for the system such that it is stable, what is the suitable option?

(A) K=0.5 (B) K=2.5 (C) K=5 (D) K=10

Consider the block diagram shown in **Figure 8**.

Figure 8

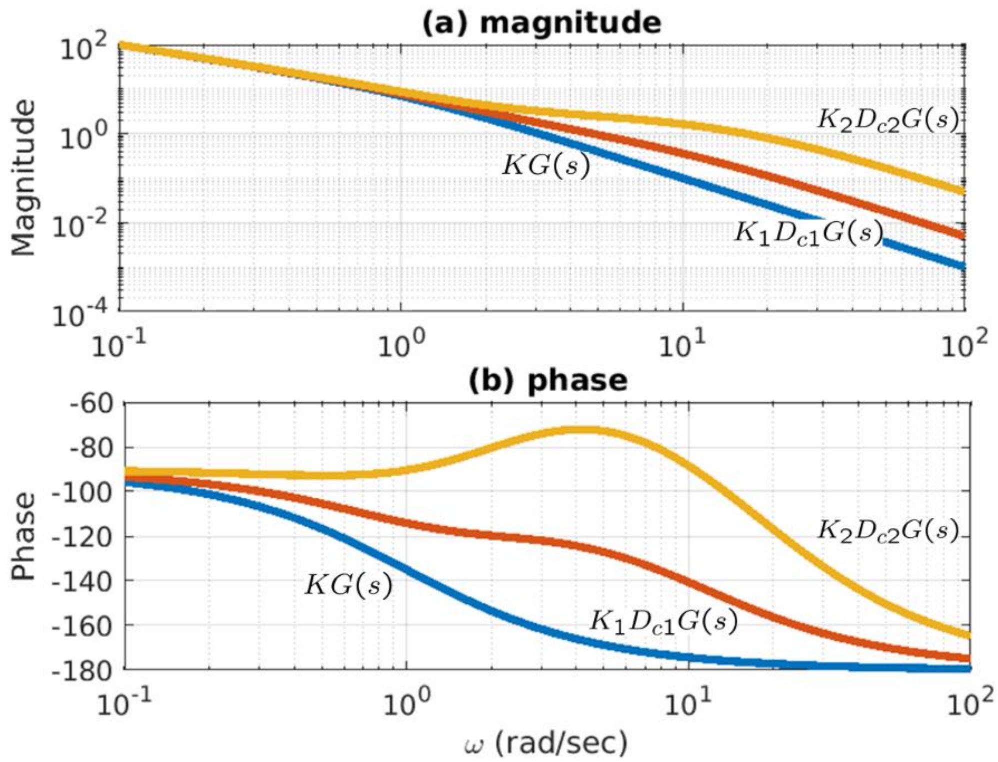


Assume that G(s)=1/s(s+1) and

$$KD_c(s) = K\left(\frac{T_D s + 1}{\alpha T_D s + 1}\right)$$

Figure 9 shows the Bode plot of the systems with different feedback gains and compensators, that is, KG(s), K1Dc1(s), K2Dc2(s), respectively.

Figure 9



14. For **Figure 9**, what is the best possible form of $K_2D_{c2}(s)$:

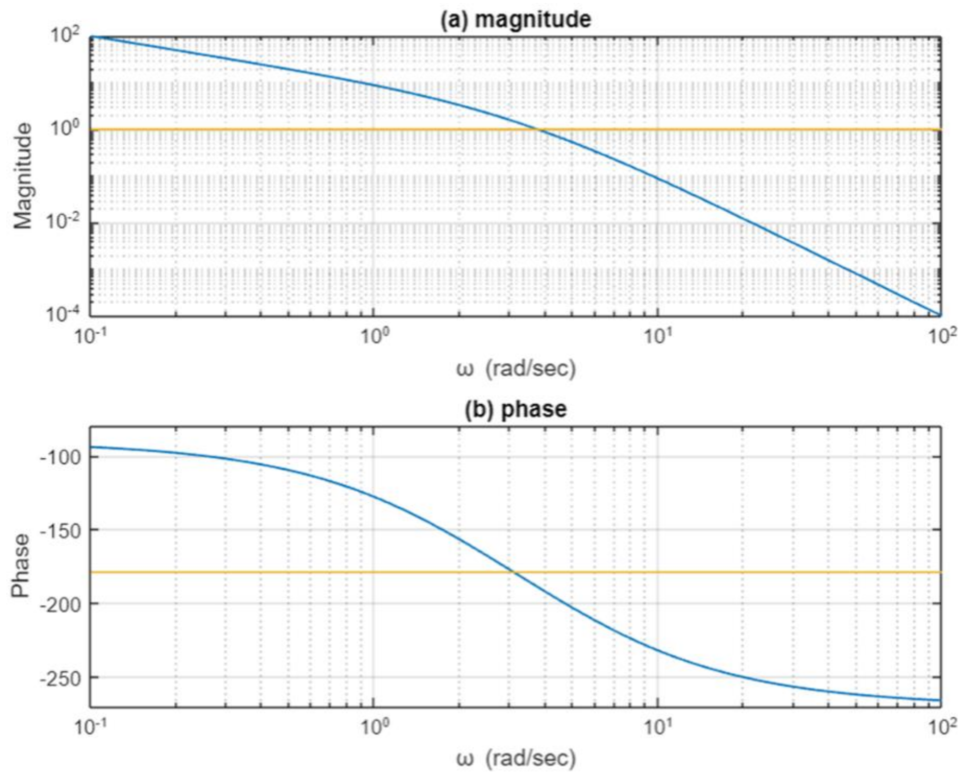
(A) $10\dfrac{\frac{s}{2}+1}{\frac{s}{20}+1}$ (B) $5\dfrac{\frac{s}{2}+1}{\frac{s}{10}+1}$ (C) $10\dfrac{\frac{s}{10}+1}{\frac{s}{2}+1}$ (D) $5\dfrac{\frac{s}{2}+1}{\frac{s}{4}+1}$

15. For **Figure 9**, what is possible phase lead with $K_2D_{c2}(s)$

(A) 2 deg (B) 30 deg (C) 60 deg (D) 90 deg

16. For **Figure 9**, what is the crossover frequency of $K_1D_{C1}G(s)$

(A) $\omega_c = 1$ (B) $\omega_c = 6$ (C) $\omega_c = 20$ (D) $\omega_c = 60$

Consider the system shown in **Figure 8** where $G(s) = \dfrac{A}{s(s/2+1)(s/5+1)}$ and the open-loop bode diagram is shown in **Figure 10.**	
Figure 10	

17. For **Figure 10**, the possible value of A is:

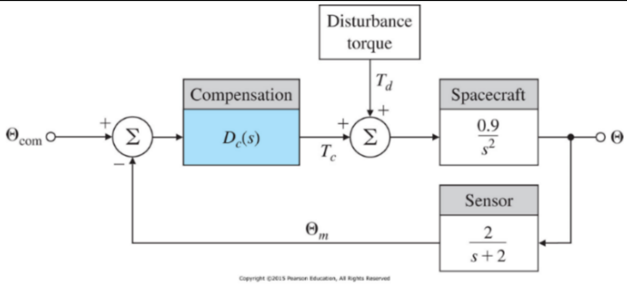
(A) A=1 (B) A=4 (C) A=10 (D) A= 20

18. If we want to have a phase margin > 55 degrees, and the compensator is $D_c(s) = \dfrac{T_D s+1}{\alpha T_D s+1}$ we can choose the value of $1/\alpha$ to be:

(A) 2 (B) 6 (C) 20 (D) 40

Consider the following system:

Figure 11

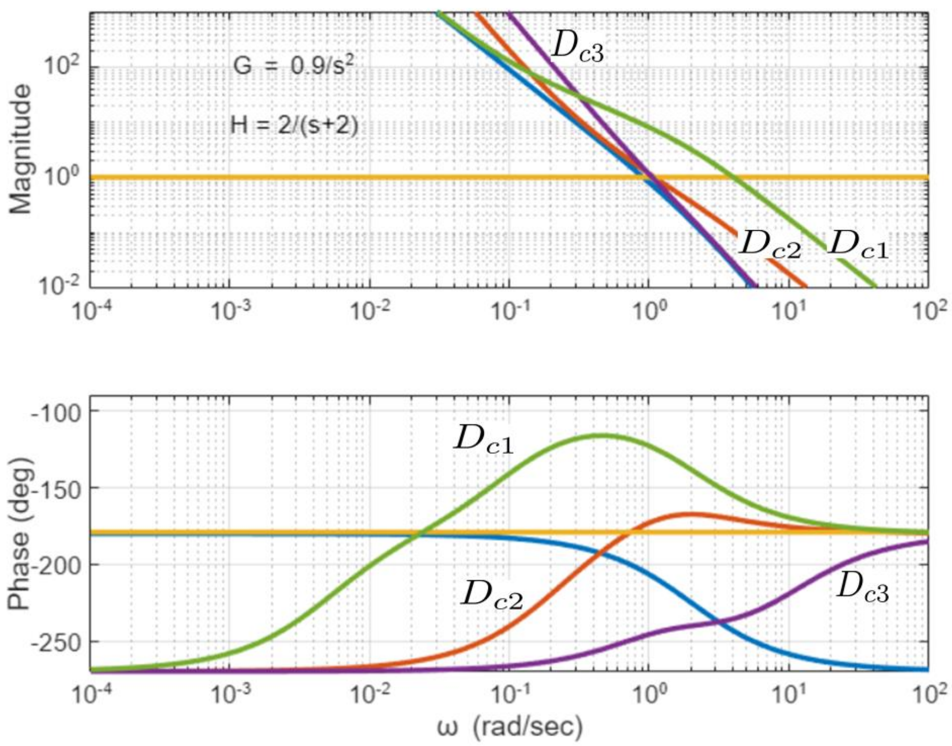


where $G(s)=0.9/s^2$, $H(s)=2/(s+2)$, and the compensation is the PID controller of the form:

$$D_c(s) = \frac{K}{s}\left[(T_D s + 1)\left(s + \frac{1}{T_I}\right)\right]$$

Figure 12 shows the Bode plot of the systems with different PID controllers with different PID gains (K's, TD's, TI's), that is, Dc1(s), Dc2(s), and Dc3(s), respectively.

Figure 12



19. For **Figure 12**, what is possible values of the controller D_{C2}:

(A) $1/T_D=1$, $1/T_I=0.2$ (B) $1/T_D=10$, $1/T_I=5$ (C) $1/T_D=10$, $1/T_I=1$
(D) $1/T_D=0.1$, $1/T_I=0.005$

20. For **Figure 12**, if PM=60 is needed, which controller will be suitable:

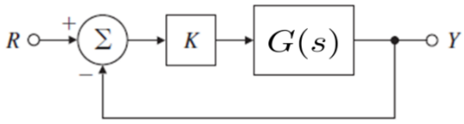
(A) K= 10 and D_{C2} (B) K= 0.5 and D_{C3} (C) K= 0.5 and D_{C1} (D) K= 0.05 and D_{C1}

Part B. [40%] Write the answers for the problems.

1. (24%)

For the system in the figure where

$$G(s) = \frac{100}{s\,(s+10)^2}$$



(a)

(a) Sketch the root locus

(b) Sketch the Bode plot

(c) Sketch the Nyquist plot

2. (16%)

For the system shown in the previous problem, where

$$G(s) = \frac{100(s+1)}{(s+10)(s+20)(s+100)}$$

(a) Sketch the root locus

(b) Sketch the Bode plot