Final Exam, Control System, 109-2 (2021)
Date: Friday, June 11, 2021. Time: 1pm-10pm

注意事項：

- 期末考的方式，將以**個別獨立考試**的方式進行，也就是，不集中在教室一起考試。
- 考試時間：**Fri, 6/11, 2021, 從 1pm 到 11pm**
  - 1pm 公告題目，11pm 之前，也就是，10 小時的作答時間。
  - 繳交答案檔案，上傳到 NTU-Cool。
- **考試規則：**
  - **可以**參考講義，課本，任何紙本或電子資料。
  - **可以**使用電腦程式（例如：Matlab）進行計算或繪製圖形。
  - **不可**以跟任何人討論（或閒聊/溝通）跟考題相關內容。
  - **不可以**跟任何人，藉由任何形式（文字，圖片，語音等）交換跟考題相關內容。
- **答案紙與答題內容：**
  - 答案紙，請用 **A4 空白紙張** 作答為原則，單面作答，(使用其他制式之有線條或格狀紙張作答者，所書寫的內容，**與線條格線同一顏色之內容**，**不計分**)。
  - 每一頁，最上方，書寫：學號，姓名，系級，第幾頁。
  - 作答內容，**僅能用手寫**，不可以使用電腦打字，不可以黏貼其他資料，例如：不可以黏貼程式碼，數據圖等。
  - 所有內容，都要**親自用筆寫或繪製**，以確認答題者瞭解需要描述或繪製的內容。
  - 作答後之答案紙，請掃描或者拍照成電子檔，然後，儘可能把所有檔案整理或轉檔成**一個 pdf 電子檔**。如果不行的話，請把所有檔案**壓縮成一個檔案**。
  - 使用拍照方式的話，**每一頁拍攝一張照片**，並確認解析度足夠辨識答案內容，不要將多張答案紙拍攝在同一張照片之中，以免造成解析度不足，因而無法辨識答題內容。請把所有檔案，壓縮成一個檔案，確認所有的圖片檔都包含在裡面。
- **評分標準：**
  - **參考與依據（0-2 分）:** 所有資料，皆需要先描述所參考的資料來源或根據或使用的工具方式等。
  - **描述，論述，佐證 （0-10 分）:** 針對題目的要求所提出的論述，佐證，想法，觀點等詳細過程的描述。
  - **結論，結果（0-2 分）:** 最終所獲得的結論或結果。
- 有的描述或圖形等資料，**僅能用筆書寫或繪製**的方式呈現。
- 其他形式所呈現的資料，**皆不計分**。

(Problem 1, 20 points)

Consider the root locus plot shown in **Figure 1**.

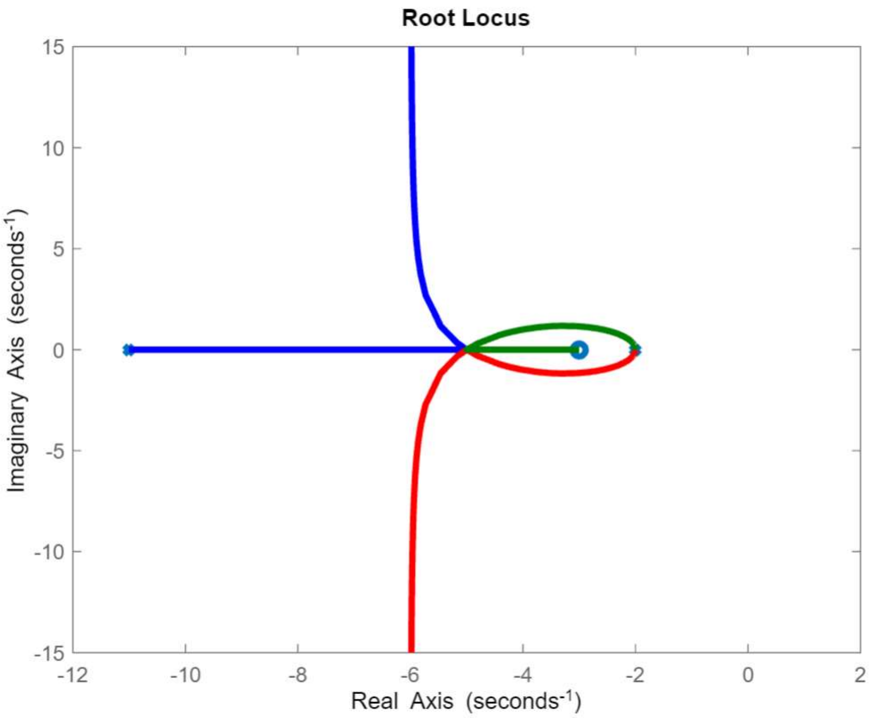

Figure 1

Find the best possible transfer function:

(A) $\frac{s+1}{s^2(s+9)}$; (B) $\frac{s+1}{s^2(s+12)}$; (C) $\frac{s+3}{(s+2)^2(s+11)}$; (D) $\frac{s+3}{(s+2)^2(s+9)}$.

(Problem 2, 10 points)

The root locus plot of one open-loop transfer function with four poles (x) and two zeros (o) is shown in **Figure 2**. On the locus, five locations with different gains are identified as K1, K2, K3, K4, and K5. Please arrange these gain values in ascending order.

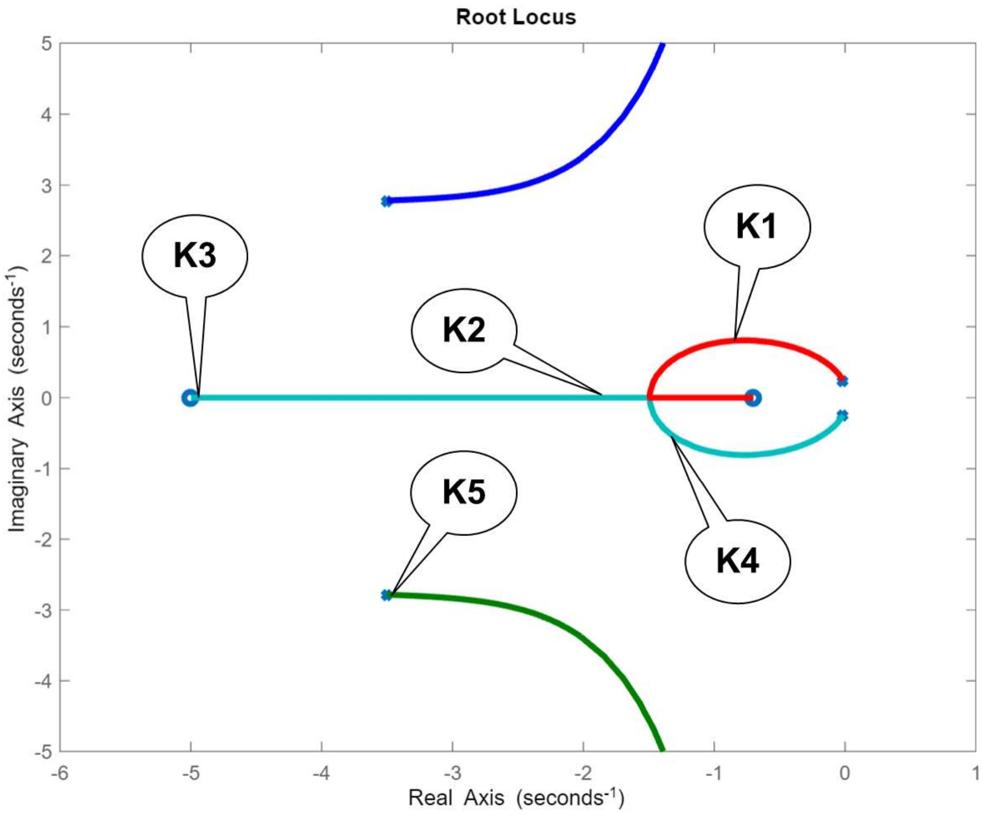

Figure 2

(Problem 3, 20 points)

The root locus plot of one open-loop transfer function with four poles (x) and two zeros (o) is shown in **Figure 3**.

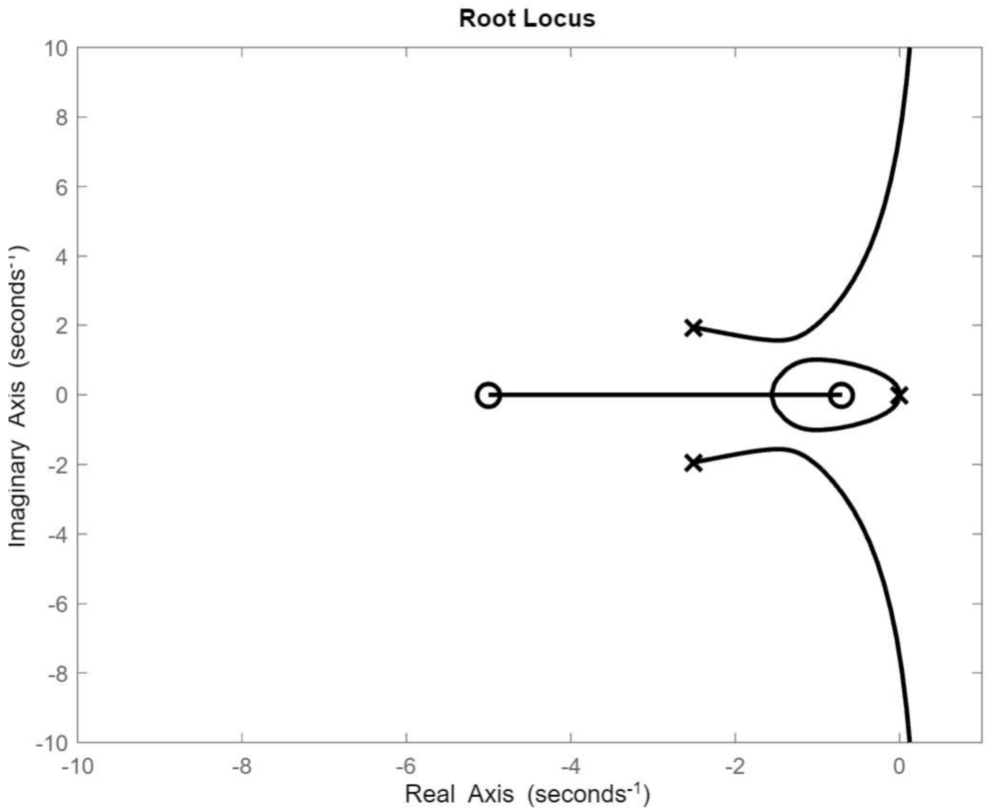

Figure 3

Moreover, four different lead or lag compensators, i.e., D(s) = (s+z)/(s+p), are designed and the root locus of the system controlled by these compensators are shown in **Figure 3(a) – Figure 3(d)**.

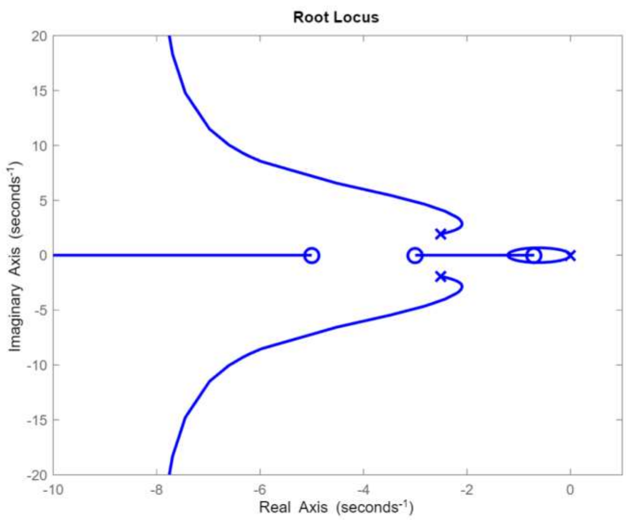

Figure 3(a)

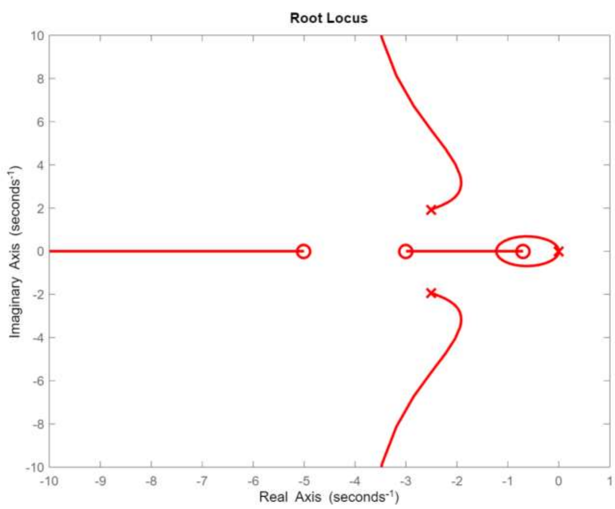

Figure 3(b)

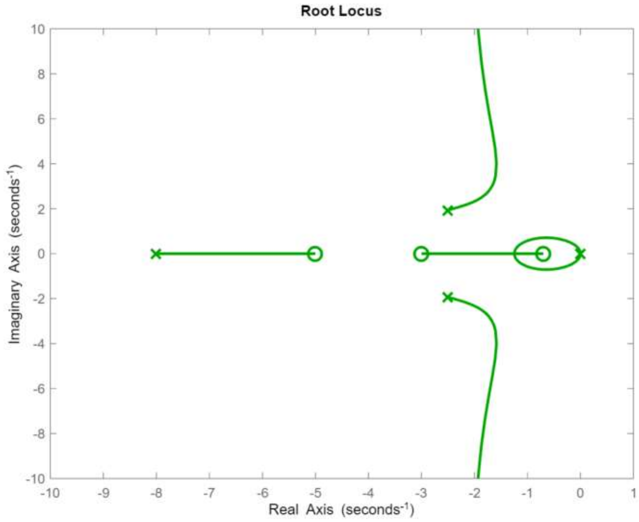

Figure 3(c)

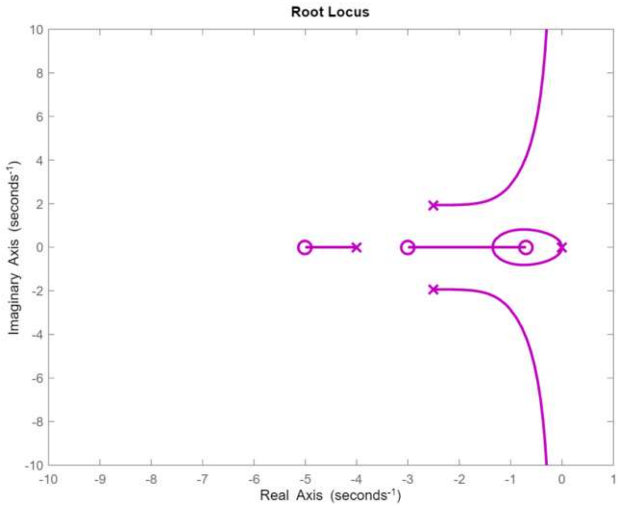

Figure 3(d)

Please identify the possible form for these four lead/lag compensators, e.g., **Figure 3(a) - Figure 3(d)**, from the following list. (For example, the answer could be that Figure 3(a) is (J), Figure 3(b) is (F), etc.)

(A) $D(s) = \frac{s+3}{(s+20)}$; (B) $D(s) = \frac{s+5}{(s+20)}$; (C) $D(s) = \frac{s+3}{(s+12)}$; (D) $D(s) = \frac{s+5}{(s+12)}$;

(E) $D(s) = \frac{s+3}{(s+8)}$; (F) $D(s) = \frac{s+5}{(s+8)}$; (G) $D(s) = \frac{s+3}{(s+4)}$; (H) $D(s) = \frac{s+5}{(s+4)}$;

(I) $D(s) = \frac{s+3}{(s+2)}$; (J) $D(s) = \frac{s+5}{(s+2)}$; (K) $D(s) = \frac{s+3}{(s+1)}$; (L) $D(s) = \frac{s+5}{(s+1)}$.

(Problem 4, 14 points)

The root locus plot of one open-loop transfer function with four poles (x) and two zeros (o) is shown in **Figure 4(a)**. Moreover, the root locus plot of the transfer function with one compensator, e.g., D(s) = (s+z)/(s+p), is shown in **Figure 4(b)**.

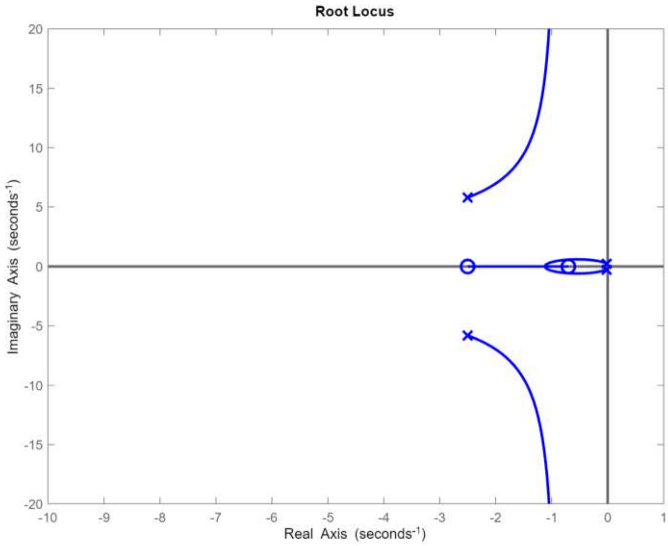

Figure 4(a)

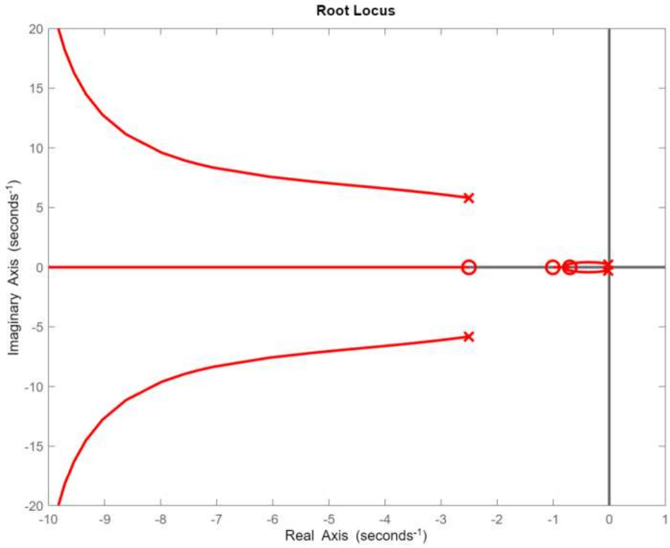

Figure 4(b)

Please find out the improvement of overshoot by the compensator D(s).

(A) From 30% to 15% ; (B) From 25% to 5% ; (C) From 20% to 10% ; (D) From 10% to 3% .

Consider the Bode plot of one open-loop transfer function shown in **Figure 5**.

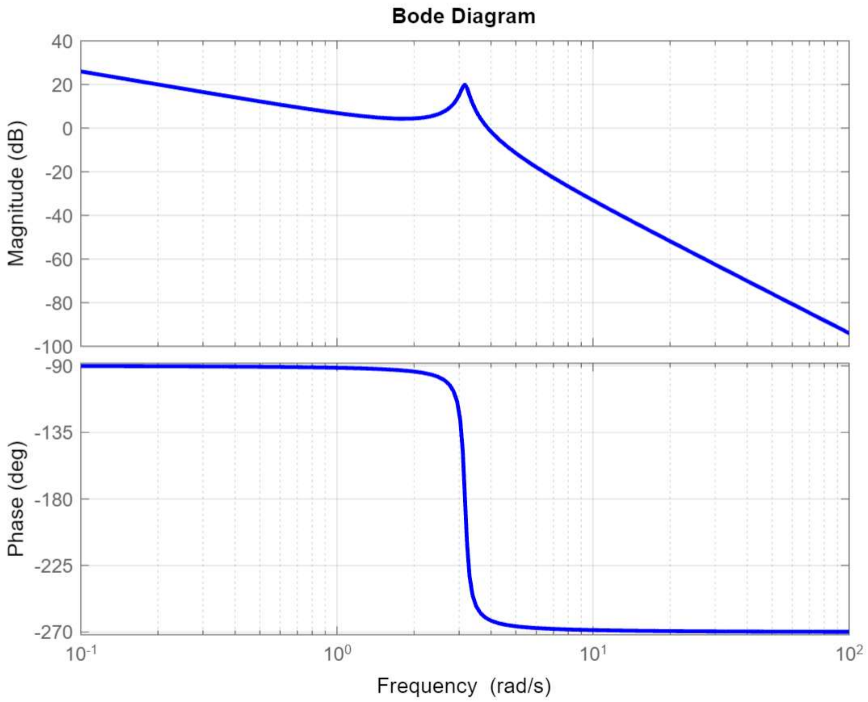

Figure 5

(Problem 5, 20 points)

Please find the best possible transfer function in **Figure 5**:

(A) $\frac{10}{s(s^2+0.4s+4)}$; (B) $\frac{20}{s(s^2+0.2s+10)}$; (C) $\frac{10}{s(s^2+4s+4)}$; (D) $\frac{20}{s(s^2+2s+10)}$.

(Problem 6, 10 points)

For the Bode plot shown in **Figure 5**, what is the possible gain margin:

(A) 0.01 (B) 0.1 (C) 10 (D) 100

(Problem 7, 10 points)

For the Bode plot shown in **Figure 5**, what is the possible phase margin:

(A) 80 deg ; (B) 5 deg ; (C) -5 deg ; (D) -80 deg .

Consider the block diagram shown in **Figure 8(a)**.

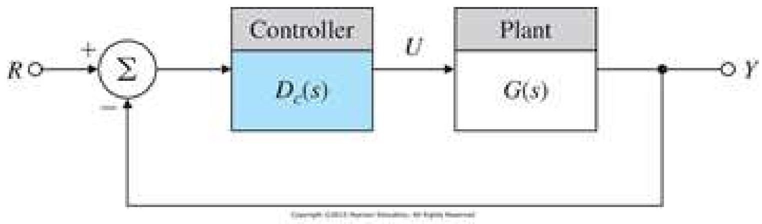

Figure 8(a)

Assume that $G(s) = \dfrac{10}{s(\frac{s}{2.5}+1)(\frac{s}{6}+1)}$ and $Dc(s) = Ki * Dci(s) = Ki * \dfrac{(Ti*s+1)}{(\alpha i*Ti*s+1)}$.

Figure 8(b) shows the Bode plot of the systems with different feedback gains and compensators, that is, K*G(s), K1*Dc1(s)*G(s), K2*Dc2(s)*G(s), K3*Dc3(s)*G(s), K4*Dc4(s)*G(s), respectively.

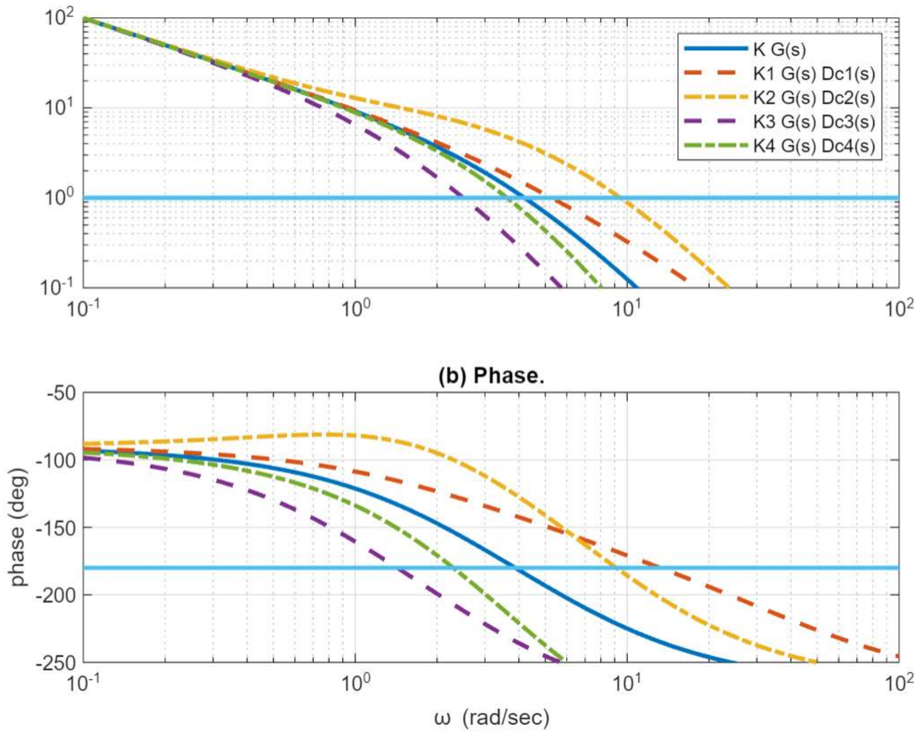

Figure 8(b)

(Problem 8, 12 points)

What is the best possible form of K2*Dc2(s)?

(A) $\dfrac{(s+1)}{(\frac{s}{10}+1)}$; (B) $\dfrac{(\frac{s}{4}+1)}{(\frac{s}{40}+1)}$; (C) $\dfrac{(\frac{s}{10}+1)}{(s+1)}$; (D) $\dfrac{(\frac{s}{40}+1)}{(\frac{s}{4}+1)}$.

(Problem 9, 32 points)

Consider the block diagram shown in **Figure 9.** Assume that $G(s) = \frac{1}{s(s^2+25s+200)}$.

D(s) and H(s) are to be designed based on following requirements.

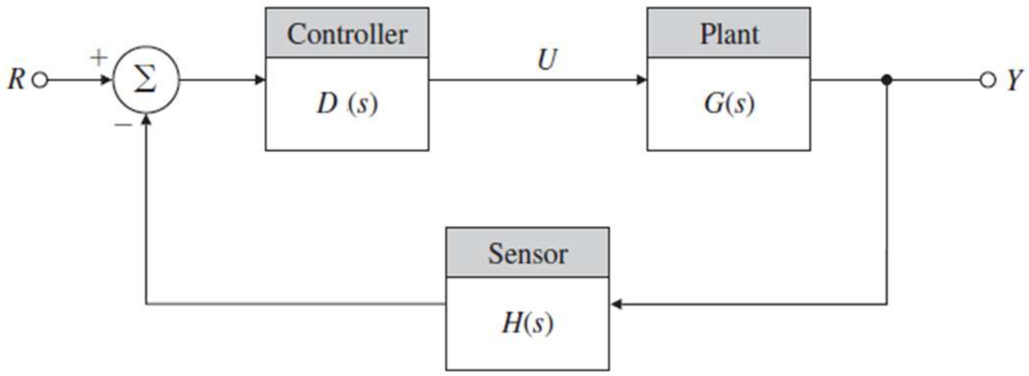

Figure 9

(a) Let $H(s) = 1$, and $D(s) = K\frac{s+z}{s+p}$, $\frac{p}{z} = 10.$

Select *z* and *K* so that the roots nearest the origin (the dominant roots) yield:

$$\zeta \geq 0.4,\ \text{RealPart(roots)} \leq -5,\ Kv \geq 4.$$

(b) Let $H(s) = 1 + Kd * s$, and $D(s) = K.$

Select *K* and *Kd* so that the dominant roots are in the same location as those of Part (a).

Compute *Kv*.

(c) Let $H(s) = 1$, and $D(s) = K\frac{s+1}{s+p}.$

Select *K* and *p* so that the compensator can generate *Kv* =*10*.

(Problem 10, 52 points)

Consider the block diagram shown in **Figure 10.**

Assume that $G(s) = \frac{1}{(s^2+2s+2)(s-1)}$, $D(s) = Kp + Kd * s$ and $H(s) = 1$.

For design and analysis simplicity, let $Kp = 2 * K$; $Kd = K$.

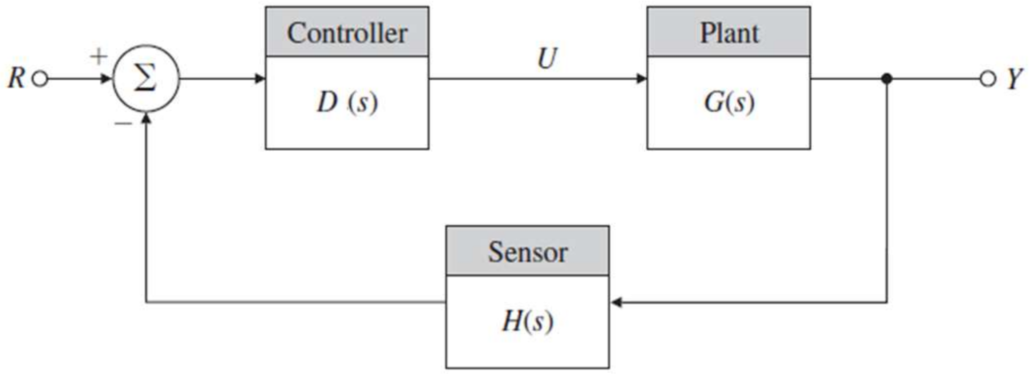

Figure 10

(a) Draw the Bode plots for $K = 1$ and use the plots to estimate the range of K for which the system will be stable.

(b) Pick up one value of K in the stable range, draw the Bode plot of the selected K, and determine the Phase Margin from the Bode plot of the selected K.

(c) Use the root locus approach to find the stable range of K.

(d) Sketch the Nyquist plot of the system, and use it to determine the number of unstable roots for the unstable ranges of K.

(e) Using Routh's criterion, determine the ranges of K for the closed-loop stability of this system.