Name________________________ ECE 3510 Homework 10 Due: Sat, 2/17/24 d2

1. Draw a control system loop like the bottom one shown on p.2 of my Control System Characteristics & Performance notes. This is a more complex version of Fig 4.7 (Bodson, p.67), including gain, a feedback sensor ($\mathbf{F}(s)$) and a disturbance input ($\mathbf{D}(s)$).

2. With $\mathbf{F}(s)$ (or $\mathbf{N_F}(s)$ and $\mathbf{D_F}(s)$) added into the following equations, find:

   a) The full $\mathbf{Y}(s)$ =

Note: you may consider k as part of $\mathbf{C}(s)$.

b) $\mathbf{E}(s)$ with disturbance ($\mathbf{D}(s)$) as zero: Eq. 4.14
Also find the "DC gain" from $\mathbf{R}(s)$ to $\mathbf{E}(s)$. Eq. 4.19

c) $\mathbf{E}(s)$ with input ($\mathbf{R}(s)$) as zero: Eq. 4.22
Also find the "DC gain" from $\mathbf{D}(s)$ to $\mathbf{E}(s)$. Eq. 4.23

3. List 5 measures of a control system's quality (see p. 64) and list one or two things that can be done to achieve each.

   1.

   2.

   3.

   4.

   5.

4. The transfer functions of $\mathbf{C}(s)$ and $\mathbf{P}(s)$ are given below. In each case determine if the steady-state error will go to zero and whether disturbances will be completely rejected. Be sure to check for closed-loop stability when needed.

   a) $\mathbf{C}(s) = \dfrac{s+4}{s^2+3\cdot s+2}$ $\qquad \mathbf{P}(s) = \dfrac{s+1}{s^2+3\cdot s}$

b) $\mathbf{C}(s) = \dfrac{s+1}{s^2+3\cdot s}$ $\mathbf{P}(s) = \dfrac{s+4}{s^2+3\cdot s+2}$

c) $\mathbf{C}(s) = \dfrac{s\cdot(s+6)}{s^2+3\cdot s+2}$ $\mathbf{P}(s) = \dfrac{s+8}{s^2+12\cdot s}$

d) $\mathbf{C}(s) = \dfrac{s+9}{s^2+3\cdot s+2}$ $\mathbf{P}(s) = \dfrac{s}{s+16}$

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e) $\mathbf{C}(s) = \dfrac{s+1}{s^2+5\cdot s+6}$ $\mathbf{P}(s) = \dfrac{s+1}{s^2+8\cdot s+15}$

f) $\mathbf{C}(s) = \dfrac{s+1}{s^3+7\cdot s^2+12\cdot s}$ $\mathbf{P}(s) = \dfrac{s+1}{s+3}$

5. Problem 4.2 (p.108) in the text. Determine whether all the roots of the following polynomials are in the open left half-plane. Use your calculator or Matlab to find the actual roots, or use the Routh-Hurwitz method.

a) $\mathbf{D}(s) = s^4+4\cdot s^3+3\cdot s^2+4\cdot s+1$

b) $\mathbf{D}(s) = s^5 + 5 \cdot s^4 + 8 \cdot s^3 + 4 \cdot s^2 - s - 1$

c) $\mathbf{D}(s) = s^4 + 2 \cdot s^3 + 2 \cdot s^2 + 2 \cdot s + 1$

Answers

1.& 2. See notes and read sections 4.1 - 4.2 in text (Bodson).

3. a) $\mathbf{Y}(s) = \dfrac{P \cdot C \cdot R + P \cdot D}{1 + P \cdot C \cdot F} \quad = \quad \dfrac{P \cdot k \cdot C \cdot R + P \cdot D}{1 + P \cdot k \cdot C \cdot F}$

k as part of $\mathbf{C}(s)$ k separate from $\mathbf{C}(s)$

3. b) Eq. 4.14 $\dfrac{1}{1 + F \cdot P \cdot k \cdot C} \cdot R$ Eq. 4.19 $\dfrac{1}{1 + F(0) \cdot P(0) \cdot C(0)}$ OR $\dfrac{D_F(0) \cdot D_P(0) \cdot D_C(0)}{D_F(0) \cdot D_P(0) \cdot D_C(0) + N_F(0) \cdot N_P(0) \cdot N_C(0)}$

c) Eq. 4.22 $\dfrac{-F \cdot P}{1 + P \cdot k \cdot C \cdot F} \cdot D$ Eq. 4.23 $\dfrac{-F(0) \cdot P(0)}{1 + F(0) \cdot P(0) \cdot C(0)}$ OR $\dfrac{-N_F(0) \cdot N_P(0) \cdot D_C(0)}{D_F(0) \cdot D_P(0) \cdot D_C(0) + N_F(0) \cdot N_P(0) \cdot N_C(0)}$

4. a) Yes No b) Yes Yes
c) No No d) No Yes
e) No No f) Yes Yes

5. a) Yes b) No c) No

6. EXTRA CREDIT a) $0 < K < 0.4975$
b) $0 < K < 2.25$

6. EXTRA CREDIT
Characteristic equations of feedback systems are shown below. In each case, use the Routh-Hurwitz method to determine the value range of K that will produce a stable system. You must show your work.

a) $0 = s^4 + 20 \cdot s^3 + 10 \cdot s^2 + s + K$

b) $0 = s^4 + 2 \cdot K \cdot s^3 + 5 \cdot s^2 + K \cdot s + K$