AC-1
August 2015 QE

General Instructions:

- AC-1 has seven problems.

- Write all your answers in your answer book(s).

- Show your work. Your grade depends on the clarity of your arguments.

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1. **(10 pts)** Find the transfer function $E(s)/U(s)$ of the block diagram, shown in Figure 1.

   $$E(s)/U(s) =$$

2. **(10 pts)** For the closed-loop system, shown in Figure 2, find the settling time, using the 2% criterion (in secs).

   $$t_s =$$

3. **(20 pts)** A negative unity feedback closed-loop system has the open-loop transfer function

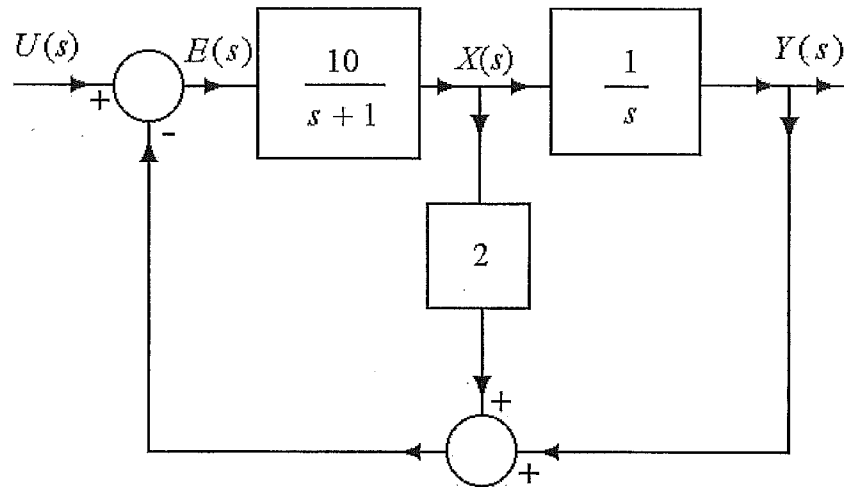$$G(s) = \frac{3}{s(s+2)^2}.$$

Write in Exam Book Only

Figure 1: Block diagram for Problem 1.

Find the gain margin, K_g, of the closed-loop system in numbers.

- **(8 pts)** Find the phase crossover frequency, ω_π.

  $$\omega_\pi =$$

- **(7 pts)** Find the gain margin, K_g, of the closed-loop system in numbers.

  $$K_g =$$

- **(5 pts)** Is the closed-loop system asymptotically stable? Explain why or why not.

4. **(15 pts)** We wish the dominant complex conjugate poles of the closed-loop system to be located at $-1 \pm j2$. The deficiency angle of the uncompensated closed-loop system
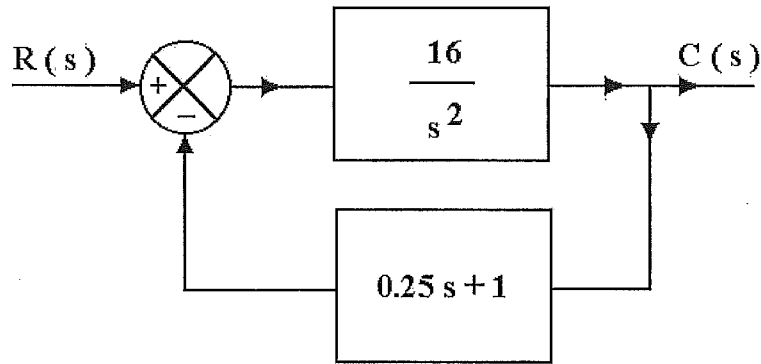
Figure 2: Closed-loop system for Problem 2.

at the upper dominant pole is 45°. We use a PD compensator in the forward path. The transfer function of the compensator is

$$G_c(s) = K_c \left(1 + T_d s\right).$$

Find T_d that achieves this design goal.

$$T_d =$$

5. **(15 pts)** We wish the dominant complex conjugate poles of the closed-loop system to be located at $-4 \pm j2\sqrt{3}$. The argument of the open loop-transfer function evaluated at the upper dominant pole is 150°. We use a lead compensator in forward path. The transfer function of the compensator is

$$G_c(s) = K_c \frac{s - z_c}{s - p_c}.$$

We set $z_c = -4$. Find p_c.

$$p_c =$$

6. **(15 pts)** The velocity error coefficient of an uncompensated unity feedback closed-loop system is $K_v = 2.5$. We wish to improve the steady-state performance of the closed-loop system by placing a lag compensator in the forward path. The transfer function of the compensator is

$$G_c(s) = \hat{K}_c \beta \frac{0.1s + 1}{0.1\beta s + 1}.$$

To keep the dominant closed-loop poles in the desired location, we use the gain $\hat{K}_c = 2$. The desired velocity error coefficient of the compensated closed-loop system is $\hat{K}_v = 40$. Find β that achieves this design goal.

$$\beta =$$

7. **(15 pts)** In Figure 3, on the next page, Bode diagrams are shown of the uncompensated open-loop system with the gain adjusted for the desired error coefficient. It is required that the phase margin of the compensated closed-loop system, using a lag compensator, be 55 degrees. Add 5 deg to compensate for the phase lag of the compensator. Select the corner frequency corresponding to the zero of the compensator one decade below the new gain crossover frequency. Find the location of the zero of the lag compensator.
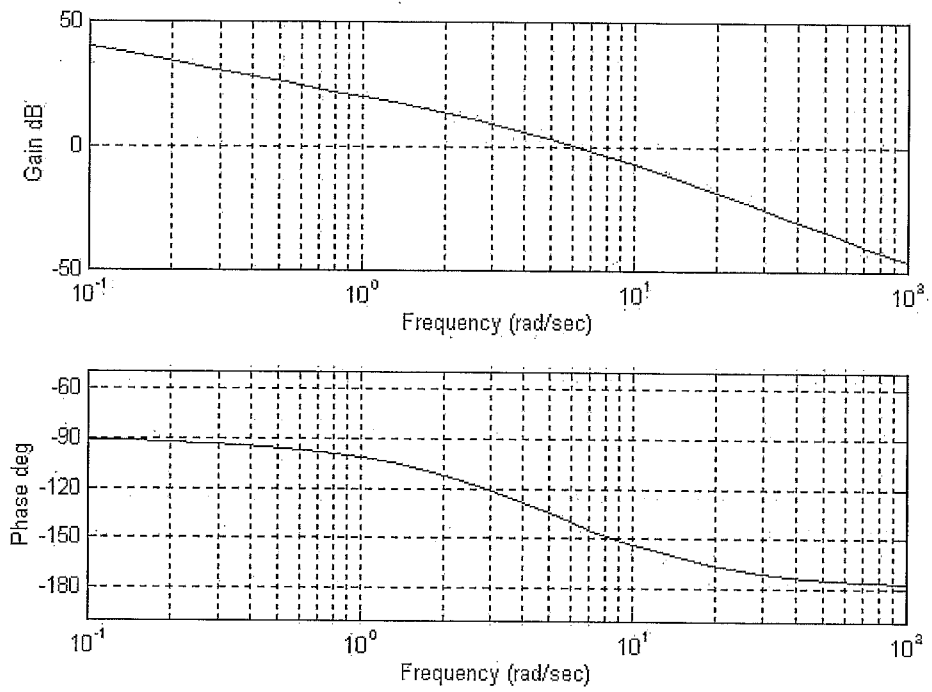
$$z_c =$$

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Figure 3: Bode diagrams for Problem 7.