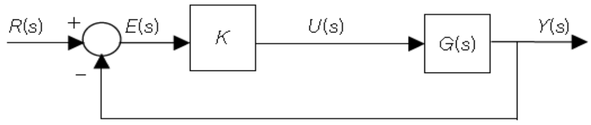
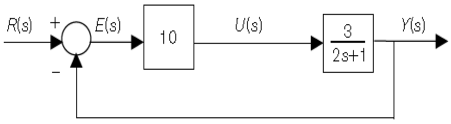
The problems survey the parts for the control system related 3rd year student for academic year 2021-2022 in the mechanical & mechatronic engineering department/ university of Salahaddin-Erbil

2. In a typical control loop, the aim is to control:



(a) $R(s)$
(b) $E(s)$
(c) $U(s)$
(d) $Y(s)$

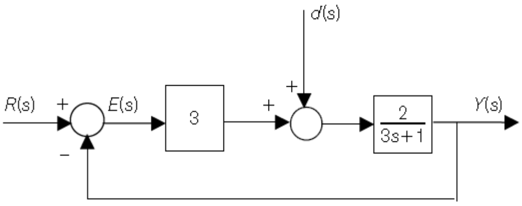
1. The forward, feedback and closed-loop transfer function for the following system are:



(a) $\frac{3}{2s+1}, 0, \frac{30}{2s+31}$ (b) $\frac{30}{2s+1}, 1, \frac{30}{2s+30}$

(c) $\frac{30}{2s+1}, 1, \frac{30}{2s+31}$ (d) $\frac{30}{2s+1}, 0, \frac{30}{2s+31}$

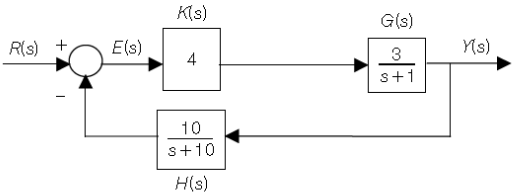
7. The transfer function from $d(s)$ to $Y(s)$ is



(a) $\frac{2}{3s+7}$ (b) $\frac{2}{3s+1}$

(c) $\frac{6}{3s+7}$ (d) $\frac{2}{3s+6}$

6. What is the characteristic equation of the following closed-loop system?



(a) $s^2 + 11s + 10$
(b) $s^2 + 11s + 130$
(c) $s^2 + 10s + 120$
(d) $s^2 + 10s + 12$

4. Reduce the block diagram in Fig. 3P-1.

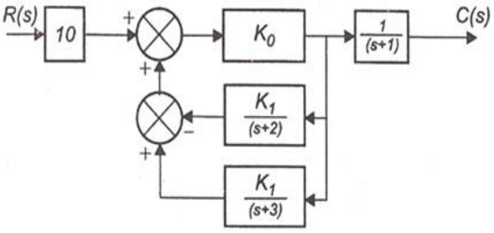
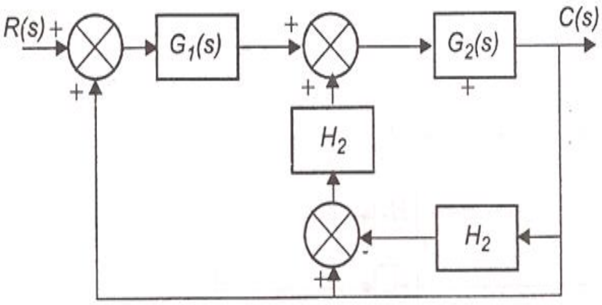
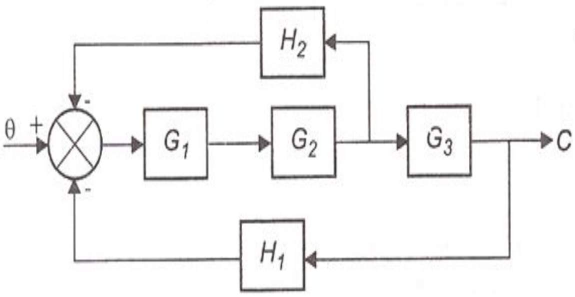


Fig. 3P-1

5. Reduce the system block diagram of Fig. 3P-2.



3. Reduce the block diagram in Fig. 3P-3.



9. Reduce the multiple loop feedback system described in the block diagram of Fig. 3P-4.

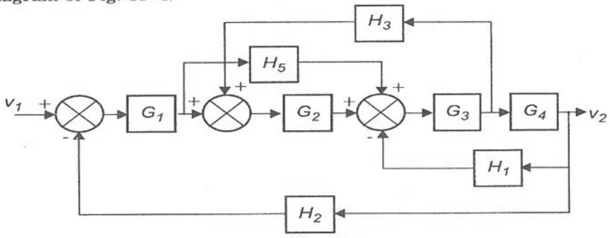
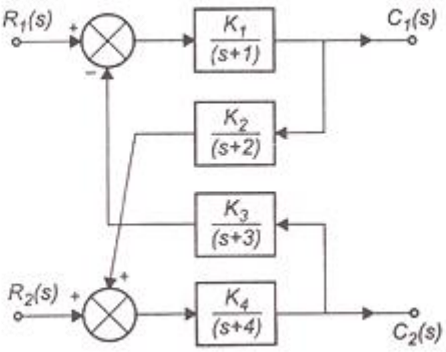


Fig. 3P-4

8. Find the transfer functions $\frac{C_1(s)}{R_1(s)}, \frac{C_1(s)}{R_2(s)}, \frac{C_2(s)}{R_1(s)}$, & $\frac{C_2(s)}{R_2(s)}$



10. Reduce the block diagram in Fig. 3P-5 and determine the system output $\omega(s)$.

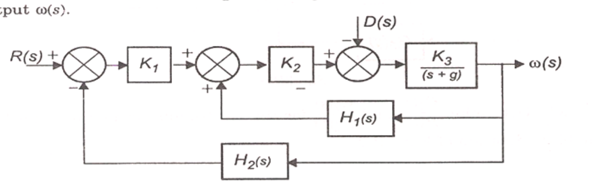


Fig. 3P-5

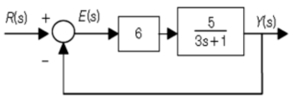
11. For the following systems evaluate:

$G_{CL}(s)$, where $Y(s) = G_{CL}(s)R(s)$

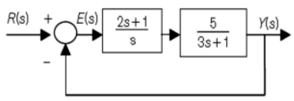
and

$G_E(s)$, where $E(s) = G_E(s)R(s)$

(a)



(b)



In each case (a) and (b), what do you notice about the denominator and numerator of each transfer function?

12. Determine $\frac{C}{R}$ in the block diagram of Fig. 3P-10.

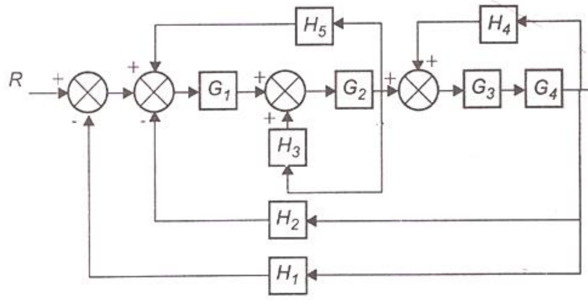


Fig. 3P-10

13. For the set of equations given below construct the signal flow

$$i_1 = \frac{v_1}{R_1} - \frac{v_2}{R_1} \qquad v_2 = R_3 i_1 - R_3 i_2$$

$$i_2 = \frac{v_2}{R_2} - \frac{v_3}{R_2} \qquad v_3 = R_4 i_2 - R_4 i_3$$

$$i_3 = \frac{v_3}{R_3} - \frac{v_4}{R_4}.$$

14. Draw the signal flow graph of the electrical network shown in Fig. 3P-11 and determine $\frac{v_0}{v_1}$.

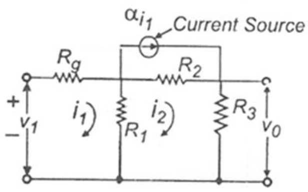


Fig. 3P-11

15. By method of reduction determine $\frac{n}{a}$ in the signal flow graph of Fig. 3P-13.

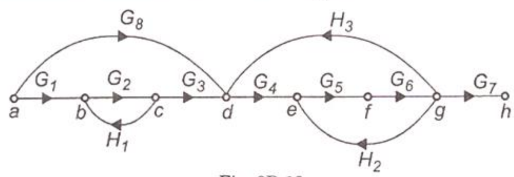


Fig. 3P-13

16. Reduce the signal flow graph of Fig. 3P-12 and hence determine $\frac{x_2}{x_1}$.

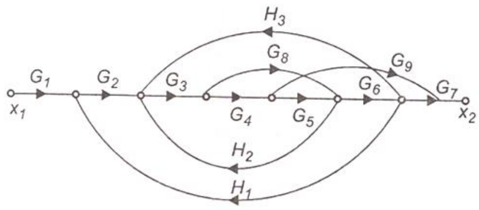
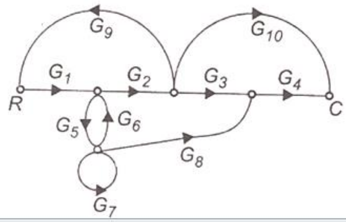


Fig. 3P-12

17. Using Mason's gain formula determine $\frac{C}{R}$ for the signal flow graph shown in Fig. 3P-14.



18. The block diagram of a feedback control system is shown in Fig. P2.12.
(*a*) Draw an equivalent signal-flow graph for the system.
(*b*) Find the Δ of the system by means of Mason's gain formula.

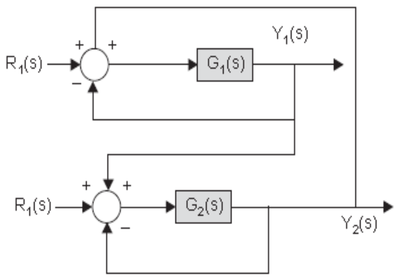


Fig. P2.12

19. ***For the multiple loop electrical system described in Fig. 4.5 determine system equations.***

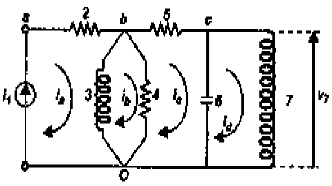


Fig. 4.5. An electrical system with multiple loops.

20 *The equivalent circuit of a loudspeaker is drawn in Fig. 4.37. R, L and C are the resistance, inductance, and capacitance of the loudspeaker coil. M, K and f_m are mass, stiffness and friction in the loudspeaker cone and its accessories. Determine the transfer function of the loudspeaker when the input is electrical voltage $e_1(t)$ and the output is the cone displacement $x(t)$.*

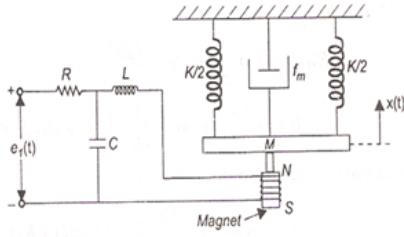


Fig. 4.37. An equivalent circuit of a loudspeaker.

21. ***The block diagram of a system is described in Fig. 4.41. Determine (i) the closed loop transfer function (ii) the system of characteristic equation.***

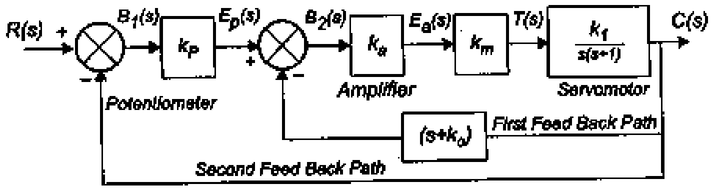


Fig. 4.41

22. **For the electrical system shown in Fig. 4P-1 determine system equation. Hence determine the transfer function.**

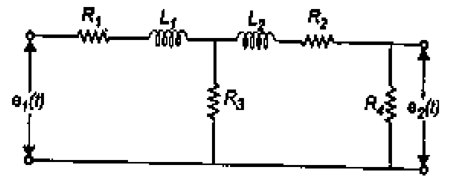


Fig. 4P-1.

28. **Find the system equations for the mechanical system described in Fig. 4P-5.**

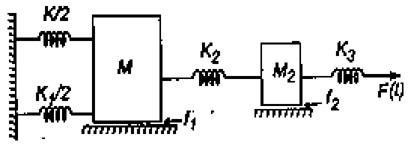


Fig. 4P-5.

27. **For the rotational mechanical system in Fig. 4P-8 determine system equation and calculate the transfer function $\frac{T_2(s)}{T_1(s)}$.**

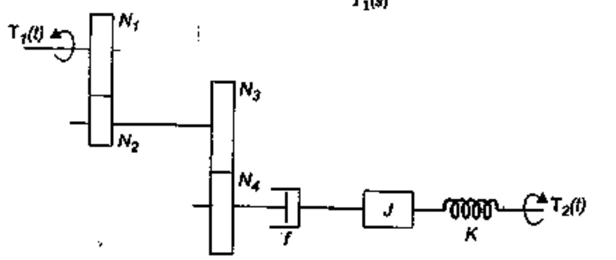


Fig. 4P-8.

26. **For the system described in Fig. 4P-9 determine the transfer function.**

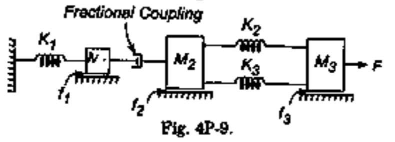


Fig. 4P-9.

24.

25 **Write system equations for the mechanical model shown in Fig. 4P-10.**

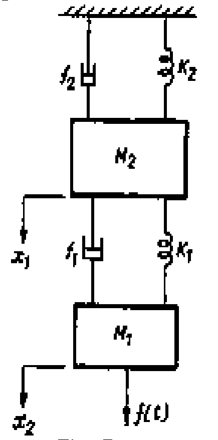


Fig. 4P-10.

23.

4.12. Form the pole zero plot of the transfer function in Fig. 4P-12 determine the linear transfer function. When the system gain is 1.25.

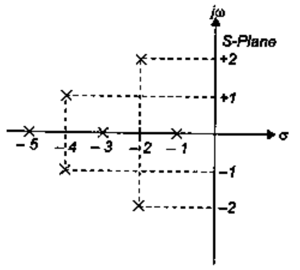


Fig. 4P-12.

B–3–25. Consider the system shown in Figure 3-90. An armature-controlled dc servomotor drives a load consisting of the moment of inertia J_L. The torque developed by the motor is T. The moment of inertia of the motor rotor is J_m. The angular displacements of the motor rotor and the load element are θ_m and θ, respectively. The gear ratio is $n = \theta/\theta_m$. Obtain the transfer function $\Theta(s)/E_i(s)$.

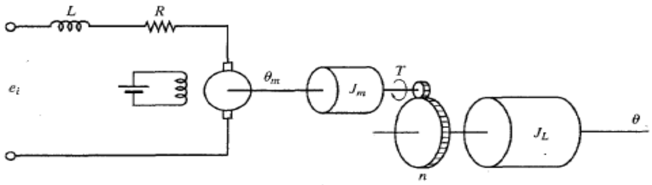


Figure 3–90
Armature-controlled dc servomotor system.

32. Obtain the transfer functions $X_1(s)/U(s)$ and $X_2(s)/U(s)$ of the mechanical system shown in Figure 3–83.

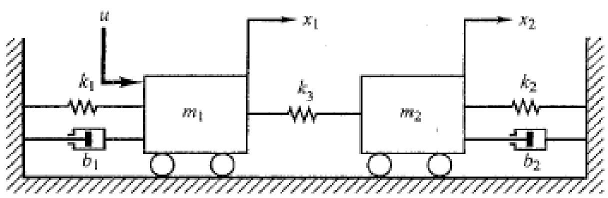


Figure 3–83
inical system.

30. Obtain a state-space representation of the mechanical system shown in Figure 3–80, where u_1 and u_2 are the inputs and y_1 and y_2 are the outputs.

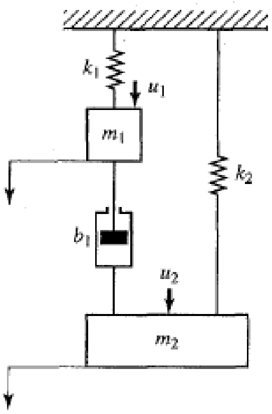


Figure 3–80
Mechanical system.

31. Consider the electrical circuit shown in Figure 3–85. Obtain the transfer function $E_o(s)/E_i(s)$ by use of the block diagram approach.

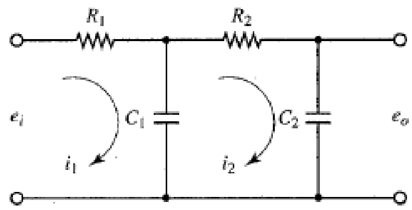


Figure 3–85
Electrical circuit.

29. An equivalent model of a galvanometer is shown in Fig. 4P-16, where R and L are the resistance and inductance of the galvanometer. The

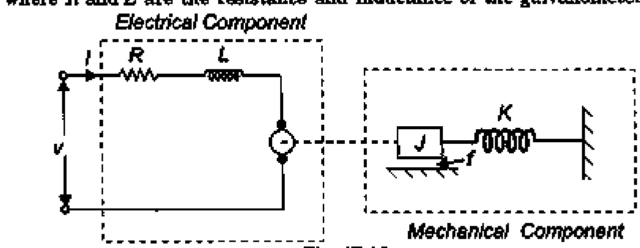
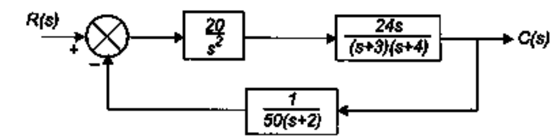


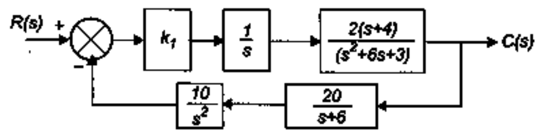
Fig. 4P-16.

mechanical components of the galvanometer are J, f and K. Derive the transfer function relating to needle displacement θ and the input current.

33. Determine the type and order of systems for which the block diagram drawn in Fig. 4P-20.



(a)



(b)
Fig. 4P-20.

35. **For the unity feedback system of Fig. 5P-7 determine the steady state error of the system with and without feedback in the system.**

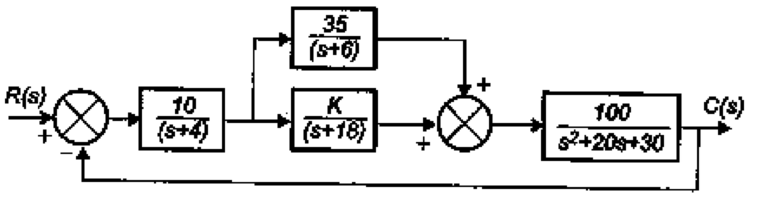
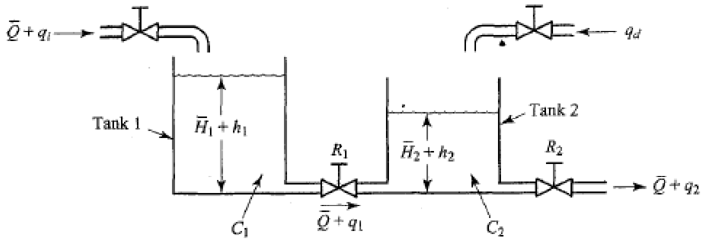


Fig. 5P-7

34. Consider the liquid-level system shown in Figure 4–49. At steady state the inflow rate is $\bar{Q}$ and the outflow rate is also $\bar{Q}$. Assume that at $t = 0$ the inflow rate is changed from $\bar{Q}$ to $\bar{Q} + q_i$, where q_i is a small quantity. The disturbance input is q_d, which is also a small quantity. Draw a block diagram of the system and simplify it to obtain $H_2(s)$ as a function of $Q_i(s)$ and $Q_d(s)$, where $H_2(s) = \mathscr{L}[h_2(t)]$, $Q_i(s) = \mathscr{L}[q_i(t)]$, and $Q_d(s) = \mathscr{L}[q_d(t)]$. The, capacitances of tanks 1 and 2 are C_1 and C_2, respectively.



36. Consider the liquid-level control system shown in Figure 4–50. The controller is of the proportional type. The set point of the controller is fixed.

Draw a block diagram of the system, assuming that changes in the variables are small. Obtain the transfer function between the level of the second tank and the disturbance input q_d. Obtain the steady-state error when the disturbance q_d is a unit-step function.

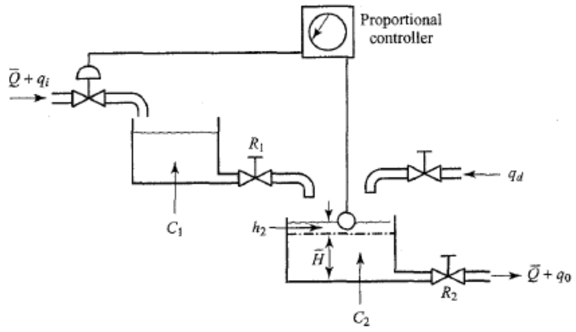


Figure 4–50
Liquid-level control system.

a device is frequently used in hydraulic servos as the first-stage valve in two-stage servovalves. This usage occurs because considerable force may be needed to stroke larger spool valves that result from the steady-state flow force. To reduce or compensate this force, two-stage valve configuration is often employed; a flapper valve or jet pipe is used as the first-stage valve to provide a necessary force to stroke the second-stage spool valve.

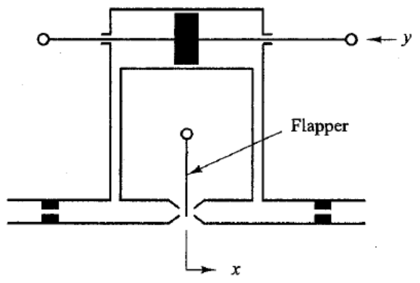


Figure 4–56
Flapper valve.

Figure 4–57 shows a schematic diagram of a hydraulic servomotor in which the error signal is amplified in two stages using a jet pipe and a pilot valve. Draw a block diagram of the system of Figure 4–57 and then find the transfer function between y and x, where x is the air pressure and y is the displacement of the power piston.

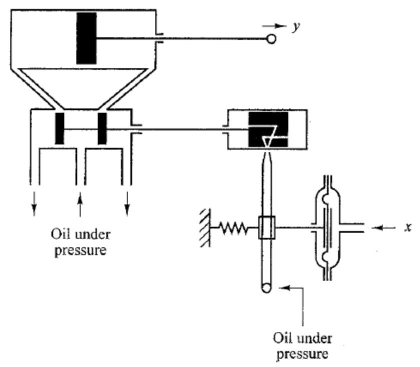


Figure 4–57
Schematic diagram of a hydraulic servomotor.

B-4-11. Figure 4-58 is a schematic diagram of an aircraft elevator control system. The input to the system is the deflection angle θ of the control lever, and the output is the elevator angle ϕ. Assume that angles θ and ϕ are relatively small. Show that for each angle θ of the control lever there is a corresponding (steady-state) elevator angle ϕ.

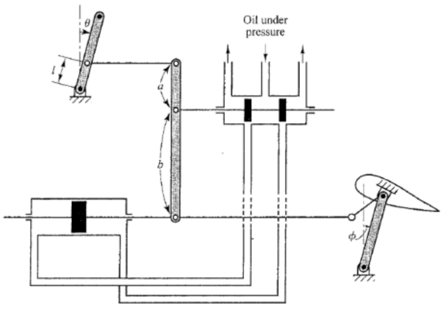
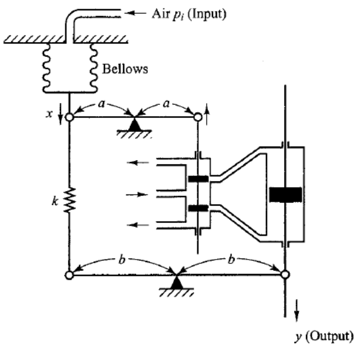


Figure 4-58
Aircraft elevator control system.



B-4-13. Consider the controller shown in Figure 4-60. The input is the air pressure p_i measured from some steady-state reference pressure $\bar{P}$ and the output is the displacement y of the power piston. Obtain the transfer function $Y(s)/P_i(s)$.

Figure 4-60
Controller.

B-4-14. A thermocouple has a time constant of 2 sec. A thermal well has a time constant of 30 sec. When the thermocouple is inserted into the well, this temperature-measuring device can be considered a two-capacitance system.

Determine the time constants of the combined thermocouple-thermal well system. Assume that the weight of the thermocouple is 8 g and the weight of the thermal well is 40 g. Assume also that the specific heats of the thermocouple and thermal well are the same.

39. **6.1.** For the network shown in Fig. 6P-1 determine the response $v_o(t)$ when the excitation applied is $v_1(t) = 10$ volts.

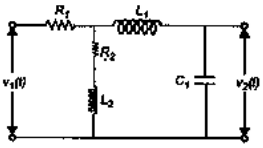
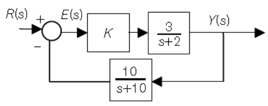


Fig. 6P-1

38. The system shown represents a process control plant with an output measurement transducer



Find the range of values of K such that the roots of the characteristic equation are
(a) overdamped
(b) underdamped

37. Consider the system shown in Figure 9.3. What are the values of gain K which will achieve the following design specifications?

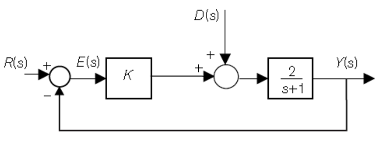


Figure 9.3 Control system for design problem.

(a) $e_{ss} \leq 0.1$ for a unit step input in $R(s)$

40. Given the system in Figure 9.4, what would be the value of the controller gain K to achieve a steady state error of $e_{ss} \leq 0.2$ to a unit step input?

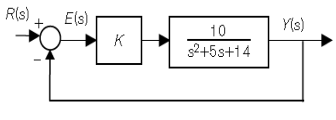


Figure 9.4 Control system for second-order design problem.

41. For the electrical system shown in Fig. 6P-2 obtain the response of current $i_0(t)$ when a unit step is applied to the input terminals of the system.

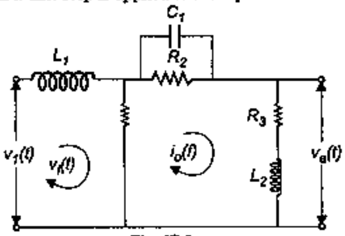


Fig. 6P-2

42. The forward path transfer function of a unity feedback control system is given by

$$G(s) = \frac{K(s+1)}{s^3 + \beta s^2 + 2s + 1}$$

Determine the values of K and β such that the system oscillates at a frequency of 3 rad/s.

43. For the electrical network shown in Fig. 6P-3 determine the voltage response $v_2(t)$ when the excitation applied is $v_1(t) = 6t^2$.

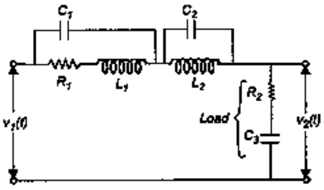


Fig. 6P-3

54 For the mechanical system described in Fig. 6P-4 determine the displacement of Mass M_2 when a ramp force of slope 2 is applied to mass M_1. What will be steady state displacement of the system ?

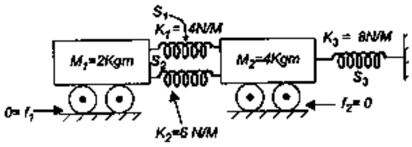
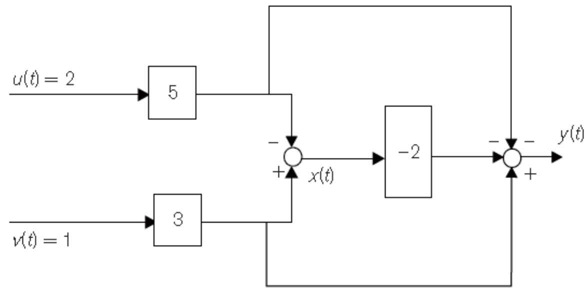


Fig. 6P-4

55 Consider the signal diagram shown below.



(a) Find the Laplace transform of $u(t)$ and $v(t)$.
(b) Find the Laplace transform of $x(t)$ and $y(t)$.
(c) Find the poles and zeros of $Y(s)$.

56 What is the steady state value of the output from the following systems when a step of magnitude 4 is applied?

(a) $G(s) = \dfrac{6}{3s^2+2s+1}$ (b) $G(s) = \dfrac{10}{5s^2+2s+3}$ (c) $G(s) = \dfrac{7}{s^2+4s-2}$

57 Consider the Laplace transform of the signals $x_1(t)$ and $x_2(t)$:

$$X_1(s) = \frac{2s+3}{(s^2+3s+2)}, \quad X_2(s) = \frac{1}{(s^2+2s+2)}$$

(a) Find the poles of $X_1(s)$ and $X_2(s)$.
(b) Find the final values of $x_1(t)$ and $x_2(t)$.

58 For plots A and B, determine

(a) the percentage overshoot
(b) the damping ratio
(c) $t_r(10\%, 90\%)$
(d) t_s (5%)
(e) the damped frequency, ω_d
(f) the natural frequency, ω_n

Hence write down the second-order transfer functions for Plot A and Plot B.

59 Consider the unit-step response of a unity-feedback control system whose open-loop transfer function is

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

Obtain the rise time, peak time, maximum overshoot, and settling time.

60 Consider the closed-loop system given by

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

Determine the values of ζ and ω_n so that the system responds to a step input with approximately 5% overshoot and with a settling time of 2 sec. (Use the 2% criterion.)

61 Figure 5–79 is a block diagram of a space-vehicle attitude-control system. Assuming the time constant T of the controller to be 3 sec and the ratio K/J to be $\frac{2}{9}$ rad^2/sec^2, find the damping ratio of the system.

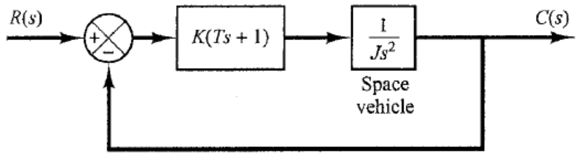


Figure 5–79
Space-vehicle attitude-control system.

61 Obtain the unit-impulse response and the unit-step response of a unity-feedback system whose open-loop transfer function is

$$G(s) = \frac{2s+1}{s^2}$$

62 Consider the system shown in Figure 5–81. Show that the transfer function $Y(s)/X(s)$ has a zero in the right-half s plane. Then obtain $y(t)$ when $x(t)$ is a unit step. Plot $y(t)$ versus t.

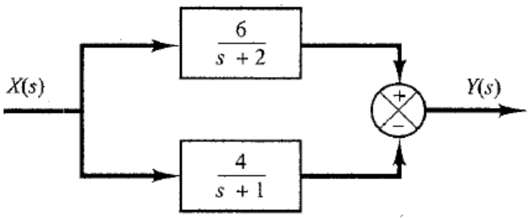


Figure 5–81
System with zero in the right-half s plane.

63 **For the circuit shown in Fig. 6P-6 determine the response of voltage $v_2(t)$ when $v_1(t) = v(t)$. Assume zero initial conditions.**

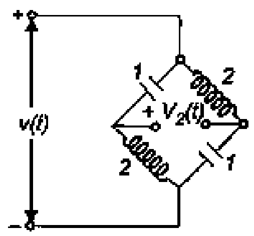


Fig. 6P-6

64 Two identical D.C. machines are connected to form the motor generator set as shown in Fig. 6P-5. With one unit of field current the generated voltage $v_g(t)$ is given by $v_g = 0.2 \times$ rotor speed and the generated torque T is given by $T = 0.2 \times$ armature current. The total inertia of the motor shaft is 0.5 units. The motor load includes a friction of $\frac{\omega_2}{500}$ unit. The viscous friction and the generator shaft inertia are negligible. Find the load speed $\omega_2(t)$ when a step of 10 unit is applied at the field of the generator. Determine the steady state value of $\omega_2(t)$.

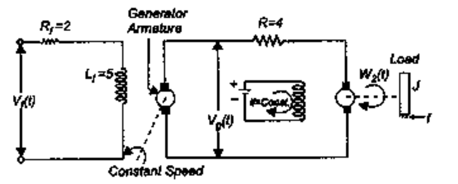


Fig. 6P-5

65 **For the system in Fig. 6P-7 determine the response $\theta(t)$ when a step of 100 volts is applied at the input terminals. The system parameters are**

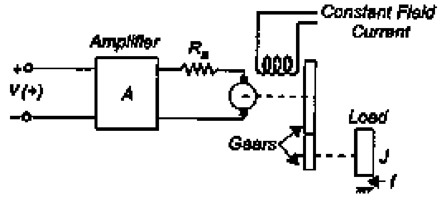


Fig. 6P-7

K_t = motor torque constant = 0.6×10^{-4} Nm/A

K_b = back e.m.f. constant = 0.25 volt-sec/revolution

A = gain of isolation amplifier = 0.2

J_m = motor armature inertia = 1.5×10^{-6} kg-m^2

J_L = Load inertia = 6×10^{-6} kg m^2

f = Load friction co-efficient = 6.5×10^{-4} Nm/rad/s

n = motor load gear ratio = 50 : 1

R_a = Motor armature resistance = 0.5 ohm.

66 **Determine the response of the load position $\theta_L(t)$ in Fig. 6P-8 when the excitation to system is $\theta_i(t) = 10$ rad. What is the steady state value of the load position. The parameters of the system are**

K_p = potentiometer constant = 0.02 volt/rad.

K_t = motor torque constant = 0.5×10^{-4} Nm/A

K_b = back e.m.f. constant = 0.2 volt/revolution/sec

A_1 = gain of voltage amplifier = 50

A_2 = gain of isolation amplifier = 0.4

J_m = motor armature inertia = 1×10^{-6} kg m^2

J_L = Load inertia = 120×10^{-6} kg m^2

f = Load friction coefficient = 8×10^{-4} Nm/rad/s

n = motor load gear ratio = 10 : 1

R_a = motor armature resistance = 0.2 ohm.

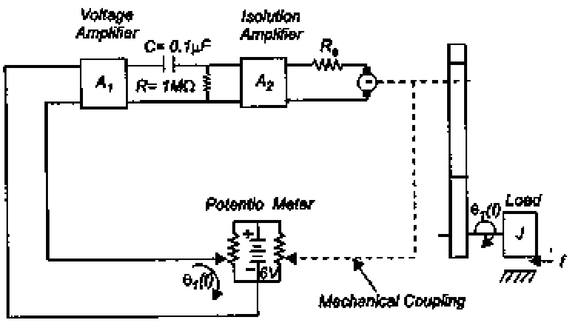


Fig. 6P-8

67 **Determine the time response of the system in Fig. 6P-9 when the input is (i) $r(t) = 4t$, (ii) $r(t) = (3 + 7t + 6t^2)$, (iii) $5(0.1 + 10e^{-2t})$. What is the steady state value of the system output for these excitations.**

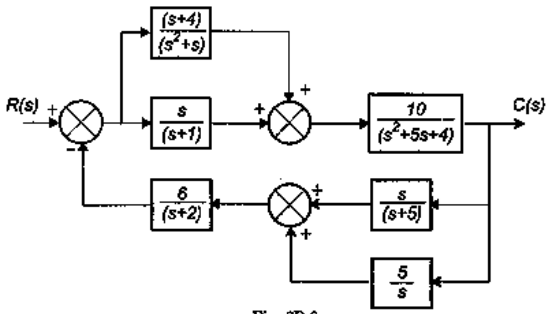


Fig. 6P-9

68 Find the position, velocity and acceleration constants of the unity feedback systems for which the loop transfer functions are

(i) $G(s) = \dfrac{K}{(s+20)(s+80)}$ (ii) $G(s) = \dfrac{100}{s(s+5)(s+60)}$

(iii) $G(s) = \dfrac{10s}{(s^2+3s+2)(s+4)}$ (iv) $G(s) = \dfrac{(10K+s)}{s(s+1)(s^2+6s+5)}$

(v) $G(s) = \dfrac{100(s+2)(s+4)}{s(s+6)(s^3+12s+100)}$.

69 For the system described in Fig. 6P-10 determine the position, velocity and acceleration constants. Hence determine the steady state errors of the system when the excitations are

(i) Unit step displacement
(ii) Unit step velocity
(iii) Unit step acceleration.

(iii) $G(s) = \dfrac{100(s+2)}{s^2(s+5)(s^2+8s+7)}$, $H(s) = \dfrac{K}{(s+3)}$

(iv) $G(s) = \dfrac{A+10s}{s^4(s+3)(s+7)}$, $H(s) = \dfrac{5}{(s+1)}$.

71 For the system described in Fig. 6P-11 find the order and type of the system. Calculate the constants K_p, K_v, and K_a. Hence determine the steady state error of the system when the excitation applied is (i) $v_1(t) = 10$, (ii) $v_1(t) = \frac{2}{7}t$ and (iii) $v_1(t) = 6t^2$.

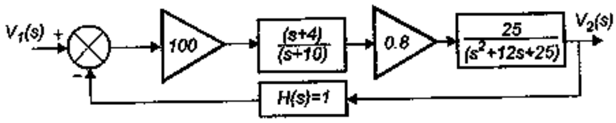
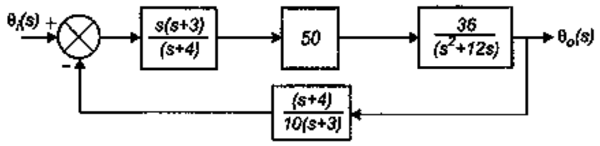


Fig. 6P-11

72 For the system of Fig. 6P-12 find the value of the steady state output when an input $\theta_i(t) = (2t + 5e^{-3t})$ is applied. Determine the steady state error of the system. What is the type and order of the system ?



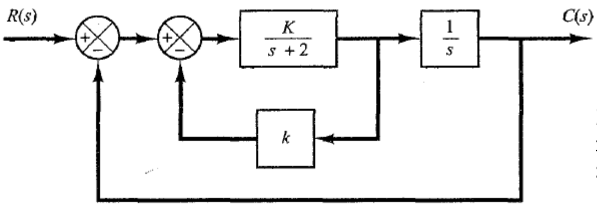
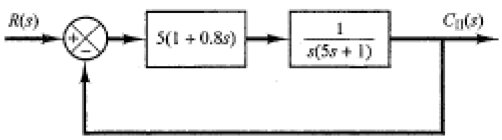


Figure 5–84
Closed-loop system.

B–5–15. Figure 5–86 shows three systems. System I is a positional servo system. System II is a positional servo system with PD control action. System III is a positional servo system with velocity feedback. Compare the unit-step, unit-impulse, and unit-ramp responses of the three systems. Which system is best with respect to the speed of response and maximum overshoot in the step response?



System II

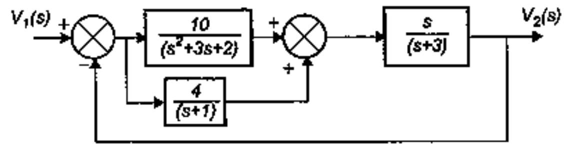


Fig. 6P-10

70 For the non-unity feedback system s given below determine the type of the system. Hence obtain the steady state error of the system when the excitation applied is (i) step displacement of 5, (ii) unit step velocity, (iii) unit step acceleration. The transfer functions of forward and feedback paths are

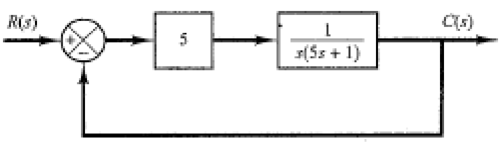
(i) $G(s) = \dfrac{10}{s(s+2)(s^2+6s+5)}$, $H(s) = \dfrac{5s}{(s^2+3s+2)}$

(ii) $G(s) = \dfrac{K}{s^2(s+2)(s+4)(s+6)}$, $H(s) = \dfrac{5s^2+3s}{(s+10)^2}$

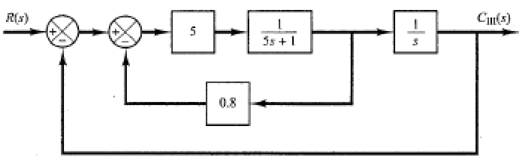
73 Consider the system shown in Figure 5–85. Determine the value of k such that the damping ratio ζ is 0.5. Then obtain the rise time t_r, peak time t_p, maximum overshoot M_p, and settling time t_s in the unit-step response.

B–5–14. Obtain both analytically and computationally the rise time, peak time, maximum overshoot, and settling time in the unit-step response of a closed-loop system given by

$$\frac{C(s)}{R(s)} = \frac{36}{s^2 + 2s + 36}$$



System I



System III

Figure 5–86
Positional servo system (System I), positional servo system with PD control action (System II), and positional servo system with velocity feedback (System III).

76 Consider the closed-loop system shown in Figure 5–88. Determine the range of K for stability. Assume that $K > 0$.

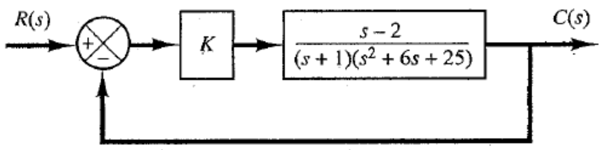


Figure 5–88
Closed-loop system.

77 **For a negative feedback control system $G(s) = \frac{10}{s(0.4s+1)}$ and $H(s) = \frac{5}{(s+4)}$. Using generalized error series determine the steady state error of the system when the input applied is (i) $r(t) = 3t$, (ii) $r(t) = \frac{4t^2}{3}$ and (iii) $r(t) = (1 + 3t + 4t^2)$.**

78 **For the system shown in Fig. 6P-13, using generalized error series determine the steady state error of the system when the input applied to the system is $r(t) = (2 + 3t + 4t^2 + 6t^4)$.**

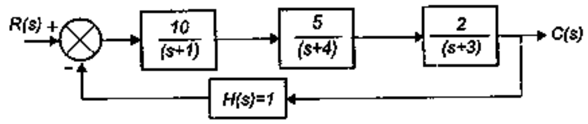


Fig. 6P-13

79 Consider the unity-feedback control system with the following open-loop transfer function:

$$G(s) = \frac{10}{s(s-1)(2s+3)}$$

Is this system stable?

80 Consider the following characteristic equation:

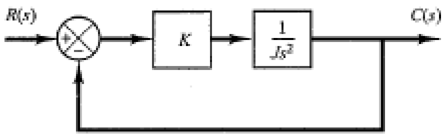
$$s^4 + 2s^3 + (4 + K)s^2 + 9s + 25 = 0$$

Using Routh stability criterion, determine the range of K for stability.

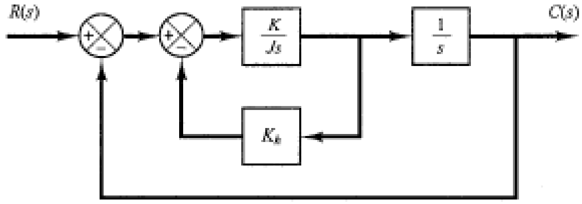
81 Determine the range of K for stability of a unity-feedback control system whose open-loop transfer function is

$$G(s) = \frac{K}{s(s+1)(s+2)}$$

82 Consider the satellite attitude control system shown in Figure 5–89(a). The output of this system exhibits continued oscillations and is not desirable. This system can be stabilized by use of tachometer feedback, as shown in Figure 5–89(b). If $K/J = 4$, what value of K_h will yield the damping ratio to be 0.6?

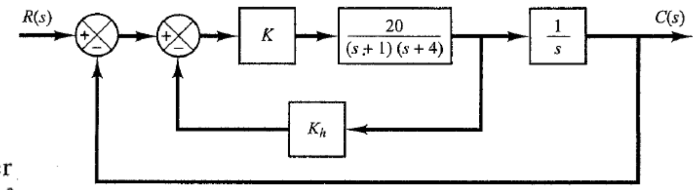


(a)



(b)

Figure 5–89
(a) Unstable satellite attitude control system; (b) stabilized system.



83 Consider the servo system with tachometer feedback shown in Figure 5–90. Determine the ranges of stability for K and K_h. (Note that K_h must be positive.)

Figure 5–90
Servo system with tachometer feedback.

84 For a non-unity feedback system $G(s) = \frac{100}{s(s^2+4s+100)}$ and $H(s) = \frac{0.1}{(s+1)}$. Using generalized error series determine the steady state error of the system when the input applied to the system is $r(t) = 0.1\,t(1+2t^2+4t^3)$.

85 The open loop transfer function of a unity feedback system is given by $G(s) = \frac{100}{s\,(0.2s+1)}$. Evaluate the steady state error of the system when the input applied is (*i*) $r(t) = 10t$, (*ii*) $r(t) = t + 2t^2$, (*iii*) $r(t) = t(3 + 4t^2)$.

86 For a unity feedback system $G(s) = \frac{36}{s\,(s+0.72)}$. Determine the characteristic equation of the system. Hence calculate the undamped frequency of oscillations, damped frequency of oscillations, damping ratio, damping factor, peak overshoot, time required to reach the peak output, settling time and the number of cycles completed before the output is settled. A unit step input is applied to the system.

87 The closed loop transfer function of a second order system is $M(s) = \frac{K}{s^2 + 10s + (7+K)}$. Determine ω_n, ω_d, ζ, t_p, M_p, and t_s when the forward gain of the amplifier is (*i*) $K = 18$, (*ii*) $K = 218$, (*iii*) $K = 618$. Tabulate these values and discuss the effect of increasing the gain K on the response of the system.

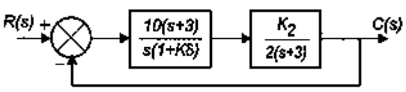


Fig. 6P-14

88 For the system of Fig. 6P-15 determine (*i*) the value of K_1 and K_2 so that the damping ratio of the system $\zeta = 0.6$ and the damped frequency of oscillations $\omega_d = 10$ rad/s, (*ii*) the peak overshoot for a unit step excitation, (*iii*) the time required to stabilize the system within 2% of the final value, (*iv*) No. of cycles completed before the output is stabilized.

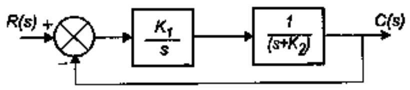


Fig. 6P-15

89 For the system shown in Fig. 6P-14 determine (*i*) the factor by which the amplifier gain K should be multiplied so that the damping ratio is reduced from 0.7 to 0.5 ; (*ii*) the factor by which the amplifier gain K should be multiplied so that the overshoot for a step excitation is reduced by 10%.

90 A single loop unity feedback system is described by the equation

$$J\frac{d^2\theta_0}{dt^2} + f\frac{d\theta_0}{dt} = Ke$$

$$e = \theta_i - \theta_0$$

where $K = 335$, $J = 1.5$ and $f = 20$. (*i*) A step displacement of 20° is applied at the input terminals. Calculate the maximum overshoot time to reach the peak overshoot, settling time and steady state error of the system (*ii*) A step velocity input of 0.5 rad/sec is applied at the input terminals. Calculate the maximum overshoot, time required to reach the peak overshoot and the time required for the error to stay within 5% of the steady state value.

91. The closed loop transfer function of a fifth order system is

$$M(s) = \frac{100}{s(s^4 + 88s^3 + 81s^2 + 1370s + 800)}.$$

Find the approximate transfer function of the system. Hence calculate the approximate time response of the system when a step of 5 is applied at the input terminals.

92. For the second order unity feedback system of Fig. 6P-16 determine the peak overshoot and time to reach the peak output when the component X is connected and disconnected from the system. Compare and discuss the effect of component X on the time response of the system.

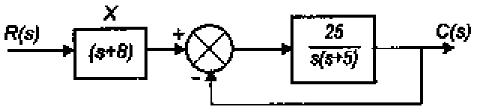


Fig. 6P-16

93 The closed loop transfer function of a sixth order system is

$$M(s) = \frac{200(s+3)}{s(s^5 + 17s^4 + 103s^3 + 175s^2 + 328s + 140)}.$$

Determine the time response of the system when a unity step is applied at the input terminals.

94. For the derivative error controlled feedback system shown in Fig. 6P-18 determine the damping ratio, peak overshoot and time required to reach the peak output when the component D is connected and disconnected from the system and a unit step input is applied. Discuss the effect of D on the system time response.

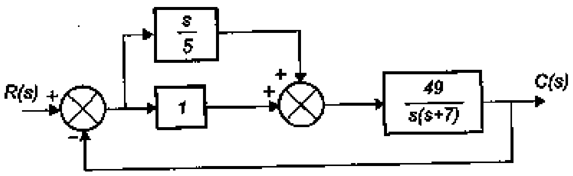


Fig. 6P-18

95. For the second order unity feedback system of Fig. 6P-17 determine the peak overshoot and time to reach the peak output when the component X is connected and disconnected from the system. Discuss the effect of component X on the time response of the system.

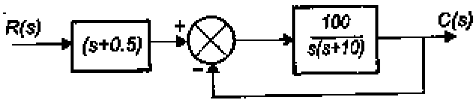


Fig. 6P-17

96. For the derivative output controlled feedback system shown in Fig. 6P-19 determine the damping ratio, peak overshoot and time required to reach the peak output when the component D is connected and disconnected from the system, and a unit step input is applied. Discuss the effect of D on the system time response.

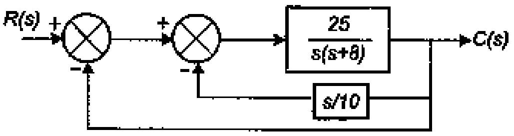
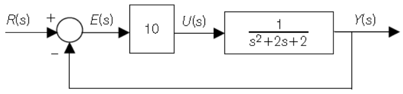


Fig. 6P-19

97 Which of the following describes the step response of this closed-loop system?



(a) underdamped
(b) critically damped
(c) overdamped
(d) the output does not reach a steady state value

98
B–5–30. Consider a unity-feedback control system with the closed-loop transfer function

$$\frac{C(s)}{R(s)} = \frac{Ks + b}{s^2 + as + b}$$

Determine the open-loop transfer function $G(s)$.

Show that the steady-state error in the unit-ramp response is given by

$$e_{ss} = \frac{1}{K_v} = \frac{a - K}{b}$$

99 7.1. Determine the number of roots with positive real part for the following polynomials.

(*a*) $s^4 + 2s^3 + 4s^2 + 3s + 10 = 0$

(*b*) $s^4 + 2s^3 + 10s^2 + 10s + 8 = 0$

(*c*) $s^4 + 4s^3 + 6s^2 + 4s + 4 = 0$.

100 7.2. For what values of K does the polynomial given below have zero real part roots

(*a*) $s^4 + 8s^3 + 24s^2 + 32s + K = 0$

(*b*) $s^4 + 5s^3 + 8s^2 + 6s + K = 0$

(c) $s^3 + 4s^2 + 3s + K = 0$

(d) $s^4 + 10s^3 + 37s^2 + 78s + K = 0.$

101 Apply Routh criterion for assessment of stability of the system having given its characteristic equation as below :

(a) $s^4 + 4Ks^3 + s^2 + (K+1)s + 4 = 0$

(b) $s^4 + 4s^3 + 2s^2 + (K+2)s + 10 = 0.$

104 Apply Routh criterion to determine stability of the following :

(a) $G(s)H(s) = \dfrac{K}{s(s+2)(s+4)}$

(b) $G(s)H(s) = \dfrac{K(s+2)}{s(s+3)(s^2+2s+5)}$

(c) $\dfrac{C(s)}{R(s)} = \dfrac{K}{s(s+4)(s^2+2s+2)+K}$

(d) $G(s) = \dfrac{5K(s+1)}{s(s^2+3s+2)+10}$

(e) $G(s)H(s) = \dfrac{10K(s+2)}{s^3+4s^2+2s+10}.$

106 Use Nyquist plot method to determine stability/instability for the systems having following transfer functions

(a) $G(s)H(s) = \dfrac{K(s-2)}{(s+2)}$

(b) $G(s) = \dfrac{K(1+2s)}{s^2(1+0.5s)(1+0.1s)}$ for $K = 2$ and $K = 20$.

107 Draw the magnitude and phase Bode plot for the following transfer functions.

(i) $G(s) = \dfrac{10}{s^2}$

(ii) $G(s) = \dfrac{20(s+3)}{s(s+5)}$

(iii) $G(s) = \dfrac{15(s+1)}{s^2(s+4)}$

(iv) $G(s) = \dfrac{8(s+1)}{s(s^2+4s+5)}$

(v) $G(s) = \dfrac{10(s+1)(s+3)(s+10)}{s^2(s+2)(s+5)(s+20)}.$

109 Sketch the approximate Bode plots for the voltage ratio $\dfrac{V_2(s)}{V_1(s)}$ in the circuits shown in Fig. 7P-1.

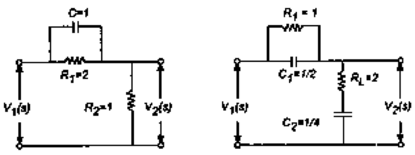


Fig. 7P-1. Diagram for problem no. 7.10.

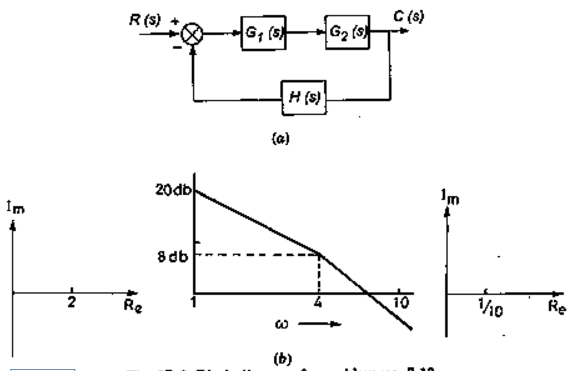


Fig. 7P-3. Block diagram for problem no. 7.13.

113 7.14. For the Bode plot shown in Fig. 7P-4 determine the transfer function of the system.

102 Sketch the polar plot for the following transfer functions

(a) $G(s) = \dfrac{K}{(1+0.5s)}$

(b) $G(s) = \dfrac{10}{(1+3s)}$

(c) $G(s) = \dfrac{K(1+7s)}{s(s+10)}$

(d) $G(s) = \dfrac{20(s+3)}{s(s+5)(s+8)}.$

103 Sketch Nyquist plot for the following open loop transfer functions and examine closed-loop stability.

(a) $G(s)H(s) = \dfrac{3}{s(s+1)(s+2)}$

(b) $G(s) = \dfrac{K}{(1+0.5s)(1+0.2s)(1+0.1s)}$

(c) $G(s)H(s) = \dfrac{K}{(s+1)(s^2+2s+5)}$

(d) $G(s) = \dfrac{4(s+1)}{s(s^3+2s+1)}$

(e) $G(s)H(s) = \dfrac{5(0.2s-1)}{s(s+1)}.$

105 Determine closed-loop stability of the following type 2 open-loop transfer functions. Apply Nyquist criterion

(a) $G(s)H(s) = \dfrac{K(1+0.5s)}{s^2(1+0.2s)}$

(b) $G(s)H(s) = \dfrac{K(1+0.2s)}{s^2(1+0.5s)}.$

108 The block diagram of a closed-loop control system is shown in fig. 7P-2. Draw Bode plot and determine gain margin and phase margin.

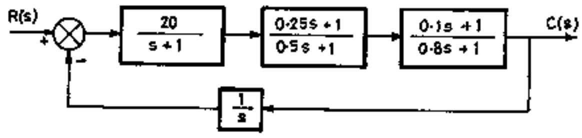


Fig. 7P-2. Block diagram for problem no. 7.11.

110 Sketch Bode plot for the system having following open-loop transfer function and determine the value of K to have phase margin = 40°. Determine gain margin also

$$G(s) = \frac{K}{s(s^2+s+5)}$$

111 For the system shown in Fig. 7P-3 (a) determine the damping ratio natural frequency of oscillation, t_p and $c(t)_{max}$ when a unit step input is applied. The transfer function of each block is shown in 7P-3 (b).

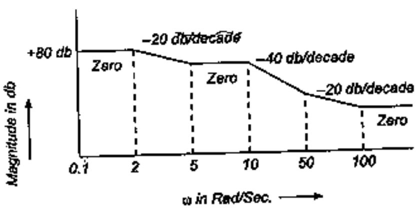


Fig. 7P-4. Bode plot for Problem no. 7.14.

112 7.15. For the Bode plot shown in Fig. 7P-5 determine the transfer function, and plot phase angle versus ω graph. Determine gain margin and phase margin.

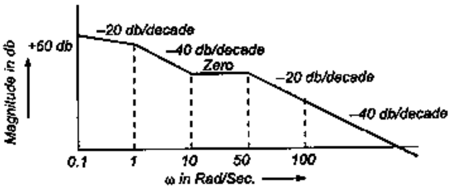


Fig. 7P-5. Bode plot for problem no. 7.15.

114 Sketch the Bode plot, polar plot and gain-phase plot of the function $G(s) = \dfrac{10(1+0.1s)}{s(1+0.5s)(1+0.25s)}$ and indicate the gain and phase crossover points on the plot. Hence from these plots obtain gain margin and phase margin.

115 Sketch the magnitude *versus* phase plots for the following loop functions and determine the gain and phase crossover frequencies.

(*i*) $G(s)H(s) = \dfrac{10(s+3)}{s(s+4)}$ (*ii*) $G(s)H(s) = \dfrac{20(s+6)}{s^2(s+1)(s+2)}$

(*iii*) $G(s)H(s) = \dfrac{50(s+1)}{s(s^2+6s+13)}$

(*iv*) $G(s)H(s) = \dfrac{30s}{(s+2)(s^2+10s+29)}$.

116 Sketch the polar plot, Bode diagram and gain phase plot for the following transfer functions.

(*i*) $G(s) = \dfrac{10}{s(s+2)}$ (*ii*) $G(s) = \dfrac{5}{s^2(s+4)}$

(*iii*) $G(s) = \dfrac{20(s+4)}{s(s+1)(s+3)}$ (*iv*) $G(s) = \dfrac{15(s+1)(s+8)}{s(1+0.2s)(1+0.5s)(s+4)}$.

117 The open loop transfer function of a unity feedback system is $G(s) = \dfrac{20}{s(s+2)(s+4)}$. Using constant M circles obtain the closed loop frequency response of the system.

7.20. Using Nicholas chart obtain the gain phase plot for the closed loop transfer function $M(s)$ when the open loop transfer function of the system is

$$G(s) = \frac{30}{s(s^2+4s+3)}.$$

118 A vertical take-off system of an aircraft is described in the block diagram of Fig. 7P-6. Using Nicholas chart determine the closed loop frequency response of the system.

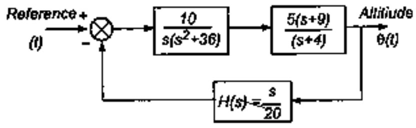


Fig. 7P-6. Block diagram for Problem no. 7.21.

120 The open loop transfer function of a unity feedback control system is $G(s) = \dfrac{3K}{s(s+1)(s+3)}$. Determine

(*i*) the value of K so that the peak resonance in the frequency response is $M_r = 1.0$.

(*ii*) the value of K so that the peak resonance in the frequency response is $M_r = 1.3$.

(*iii*) the value of K so that the gain margin is $-3db$.

(*iv*) the value of K so that the phase margin is 10°.

119 The steering control of an automobile is described in the block diagram of Fig. 7P-7. Using Nicholas chart determine the value of K which will result in a system with peak resonance of the closed loop frequency response M_r less than or equal to 4 db. Hence obtain the gain and phase margin of the system.

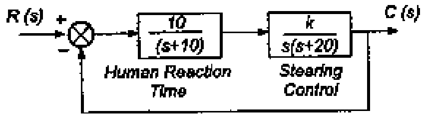


Fig. 7P-7. Block diagram for problem no. 7.23.

In the unity feedback system having $G(s) = \dfrac{K}{s(s+30)^2}$ find the gain and phase margin of the system.

In a unity feedback system having $G(s) = \dfrac{K}{s(s+40)^2}$ find the maximum value of K which will make the system specifications as (*i*) $M_r \le 1.3$, (*ii*) Phase margin ≤46° and (*iii*) gain margin ≤ 4.5 db.