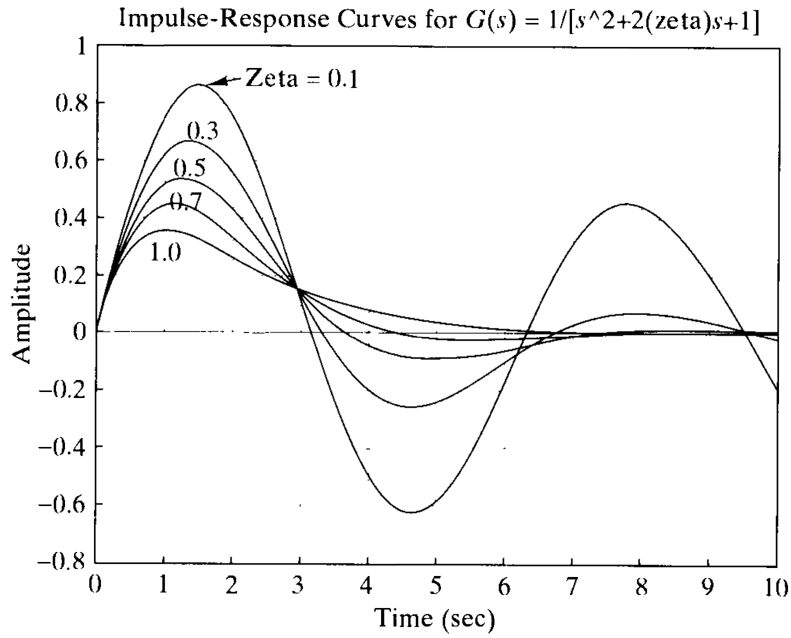

Figure 4–52 Unit-impulse response curves.

PROBLEMS

B-4-1. A thermometer requires 1 min to indicate 98% of the response to a step input. Assuming the thermometer to be a first-order system, find the time constant.

If the thermometer is placed in a bath, the temperature of which is changing linearly at a rate of 10°/min, how much error does the thermometer show?

B-4-2. Consider the system shown in Figure 4–53. 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 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 $\Theta(s)/E_i(s)$.

B-4-3. Consider the system shown in Figure 4–54(a). The damping ratio of this system is 0.158 and the undamped natural frequency is 3.16 rad/sec. To improve the relative stability, we employ tachometer feedback. Figure 4–54(b) shows such a tachometer-feedback system.

Determine the value of K_h so that the damping ratio of the system is 0.5. Draw unit-step response curves of both the original and tachometer-feedback systems. Also draw the error-versus-time curves for the unit-ramp response of both systems.

B-4-4. Obtain the unit-step response of a unity-feedback system whose open-loop transfer function is

$$G(s) = \frac{4}{s(s+5)}$$

B-4-5. Consider the unit-step response of a unity-feedback control system whose open-loop transfer function is

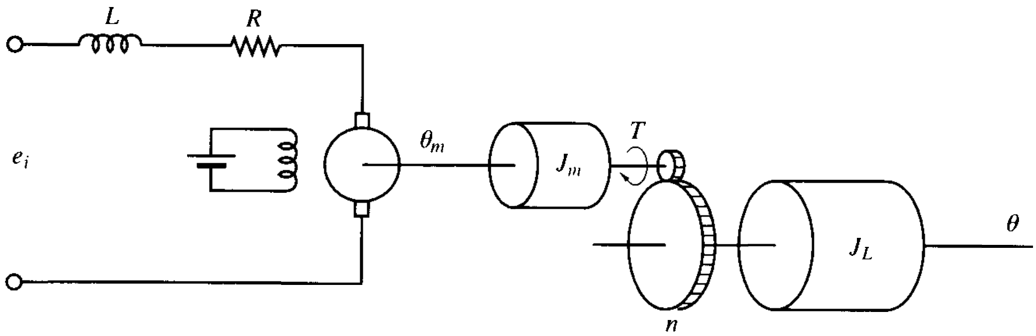

Figure 4–53 Armature-controlled dc servomotor system.

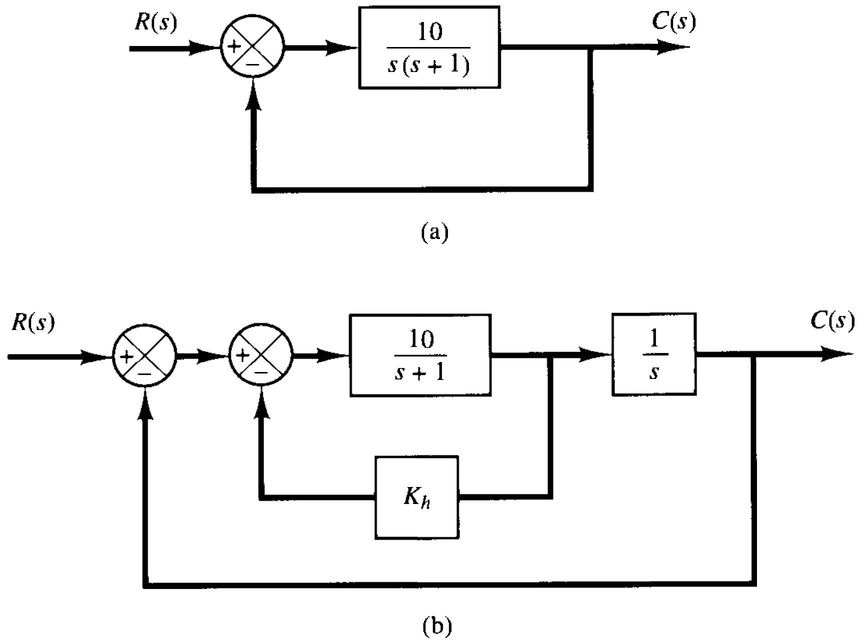

Figure 4–54
(a) Control system; (b) control system with tachometer feedback.

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

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

B-4-6. 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.)

B-4-7. Figure 4–55 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 of torque to inertia K/J to be $\frac{2}{9}$ rad²/sec², find the damping ratio of the system.

B-4-8. Consider the system shown in Figure 4–56. The system is initially at rest. Suppose that the cart is set into motion by an impulsive force whose strength is unity. Can it be stopped by another such impulsive force?

B-4-9. Obtain the unit-impulse response and the unit-step response of a unity-feedback system whose open-loop transfer function is

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

B-4-10. Consider the system shown in Figure 4–57. Show that the transfer function $Y(s)/X(s)$ has a zero in the right-

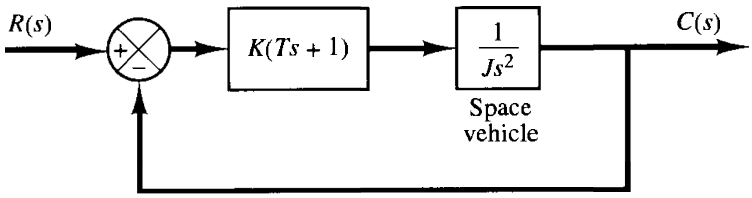

Figure 4–55
Space-vehicle attitude-control system.

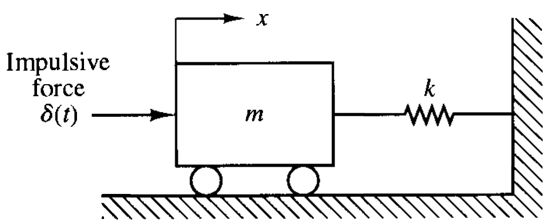

Figure 4–56
Mechanical system.

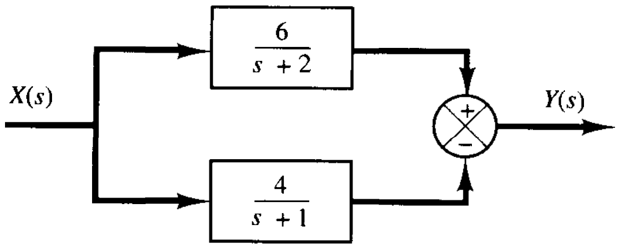

Figure 4–57
System with zero in the right-half s plane.

half s plane. Then obtain $y(t)$ when $x(t)$ is a unit step. Plot $y(t)$ versus t.

B-4-11. An oscillatory system is known to have a transfer function of the following form:

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

Assume that a record of a damped oscillation is available as shown in Figure 4–58. Determine the damping ratio ζ of the system from the graph.

B-4-12. Referring to the system shown in Figure 4–59, determine the values of K and k such that the system has a damping ratio ζ of 0.7 and an undamped natural frequency ω_n of 4 rad/sec.

B-4-13. Consider the system shown in Figure 4–60. 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-4-14. Using MATLAB, obtain the unit-step response, unit-ramp response, and unit-impulse response of the following system:

$$\frac{C(s)}{R(s)} = \frac{10}{s^2 + 2s + 10}$$

where $R(s)$ and $C(s)$ are Laplace transforms of the input $r(t)$ and output $c(t)$, respectively.

B-4-15. Using MATLAB, obtain the unit-step response, unit-ramp response, and unit-impulse response of the

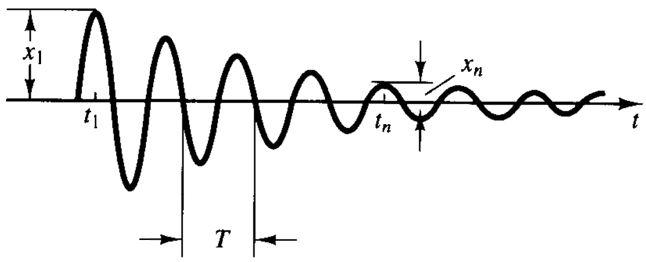

Figure 4–58
Decaying oscillation.

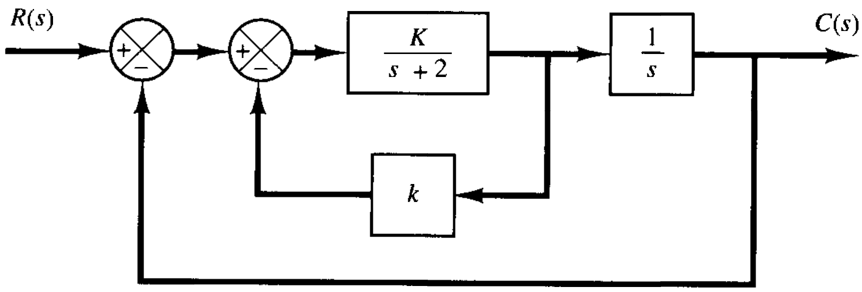

Figure 4–59
Closed-loop system.

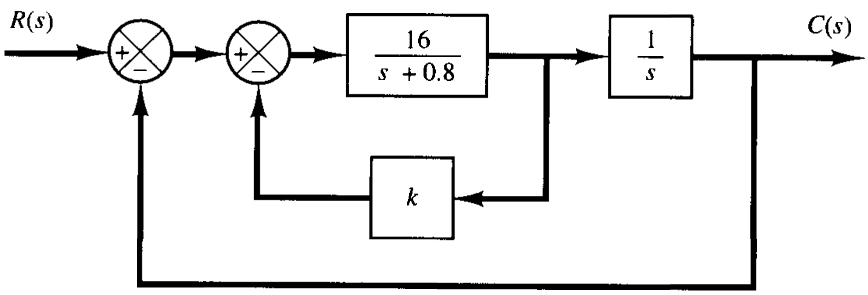

Figure 4–60
Block diagram of a system.

following system:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -1 & -0.5 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0.5 \\ 0 \end{bmatrix} u$$

$$y = [1 \quad 0] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

where u is the input and y is the output.

B-4-16. Consider the same problem as discussed in Problem A-4-16. It is desired to use different marks for different curves (such as 'o', '×', '--', '-', ':'). Modify MATLAB Program 4–14 for this purpose.