block diagram shown in Figure P2.2. Assume that $r(t) = 3t^3$. [Section: 2.3]

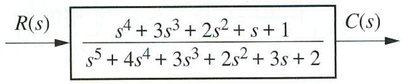

FIGURE P2.2

11. A system is described by the following differential equation: [Section 2.3]

$$\frac{d^2x}{dt^2} + 3\frac{dx}{dt} + 3x = 1$$

with the initial conditions $x(0) = 2$, $\dot{x}(0) = -1$. Show a block diagram of the system, giving its transfer function and all pertinent inputs and outputs. (Hint: the initial conditions will show up as added inputs to an effective system with zero initial conditions.)

12. Use MATLAB to generate the transfer function: [Section: 2.3] MATLAB **ML**

$$G(s) = \frac{5(s+15)(s+26)(s+72)}{s(s+55)(s^2+5s+30)(s+56)(s^2+27s+52)}$$

in the following ways:

a. the ratio of factors;

b. the ratio of polynomials.

13. Repeat Problem 12 for the following transfer function: [Section: 2.3] MATLAB **ML**

$$G(s) = \frac{s^4+25s^3+20s^2+15s+42}{s^5+13s^4+9s^3+37s^2+35s+50}$$

14. Use MATLAB to generate the partial-fraction expansion of the following function: [Section: 2.3]

$$F(s) = \frac{10^4(s+5)(s+70)}{s(s+45)(s+55)(s^2+7s+110)(s^2+6s+95)}$$

15. Use MATLAB and the Symbolic Math Toolbox to input and form LTI objects in polynomial and factored form for the following frequency functions: [Section: 2.3] Symbolic Math **SM**

a. $G(s) = \frac{45(s^2+37s+74)(s^3+28s^2+32s+16)}{(s+39)(s+47)(s^2+2s+100)(s^3+27s^2+18s+15)}$

b. $G(s) = \frac{56(s+14)(s^3+49s^2+62s+53)}{(s^3+81s^2+76s+65)(s^2+88s+33)(s^2+56s+77)}$

16. Find the transfer function, $G(s) = V_o(s)/V_i(s)$, for each network shown in Figure P2.3. [Section: 2.4]

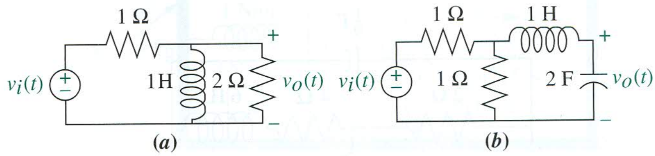

FIGURE P2.3

17. Find the transfer function, $G(s) = V_L(s)/V(s)$, for each network shown in Figure P2.4. [Section: 2.4]

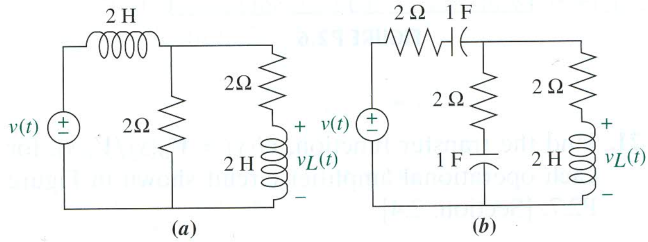

FIGURE P2.4

18. Find the transfer function, $G(s) = V_o(s)/V_i(s)$, for each network shown in Figure P2.5. Solve the problem using mesh analysis. [Section: 2.4] WileyPLUS **WPCS** Control Solutions

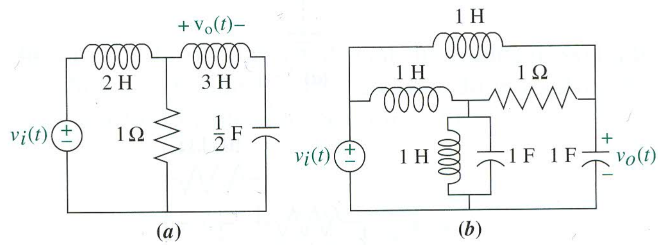

FIGURE P2.5

19. Repeat Problem 18 using nodal equations. [Section: 2.4]

20. **a.** Write, but do not solve, the mesh and nodal equations for the network of Figure P2.6. [Section: 2.4]

b. Use MATLAB, the Symbolic Math Toolbox, and the equations found in part a to solve for the transfer function, $G(s) = V_o(s)/V(s)$. Use both the Symbolic Math **SM**

mesh and nodal equations and show that either set yields the same transfer function. [Section: 2.4]

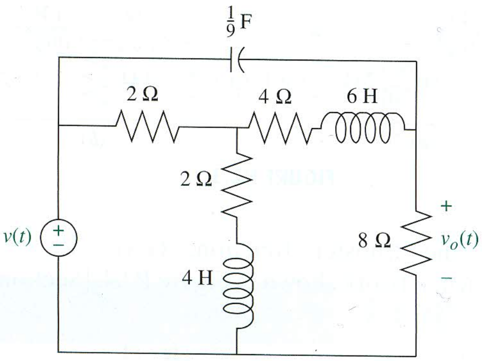

FIGURE P2.6

21. Find the transfer function, $G(s) = V_o(s)/V_i(s)$, for each operational amplifier circuit shown in Figure P2.7. [Section: 2.4]

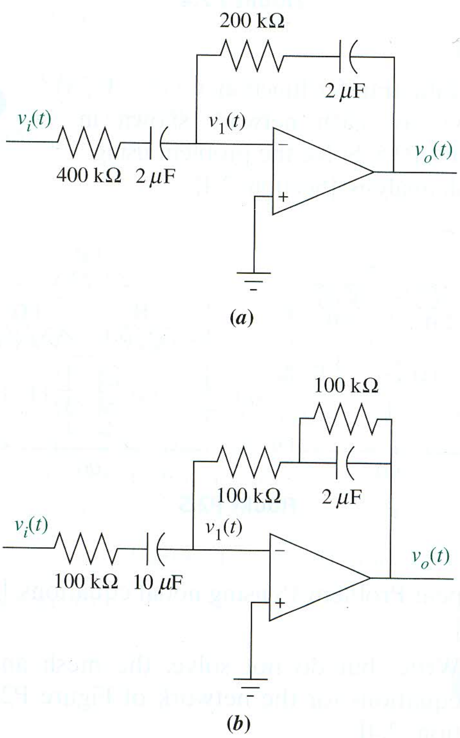

FIGURE P2.7

22. Find the transfer function, $G(s) = V_o(s)/V_i(s)$, for each operational amplifier circuit shown in Figure P2.8. [Section: 2.4]

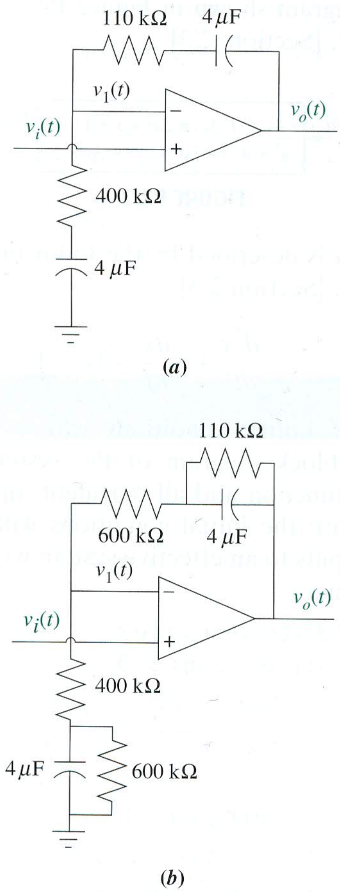

FIGURE P2.8

23. Find the transfer function, $G(s) = X_1(s)/F(s)$, for the translational mechanical system shown in Figure P2.9. [Section: 2.5]

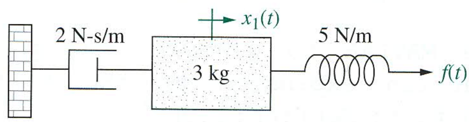

FIGURE P2.9

24. Find the transfer function, $G(s) = X_2(s)/F(s)$, for the translational mechanical network shown in Figure P2.10. [Section: 2.5]

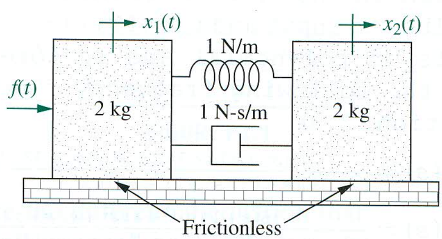

FIGURE P2.10

25. Find the transfer function, $G(s) = X_2(s)/F(s)$, for the translational mechanical system shown in Figure P2.11. (Hint: place a zero mass at $x_2(t)$.) [Section: 2.5]

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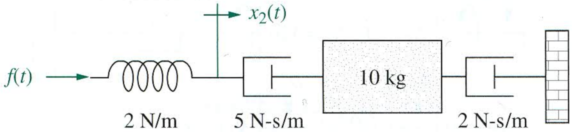


FIGURE P2.11

26. For the system of Figure P2.12 find the transfer function, $G(s) = X_1(s)/F(s)$. [Section: 2.5]

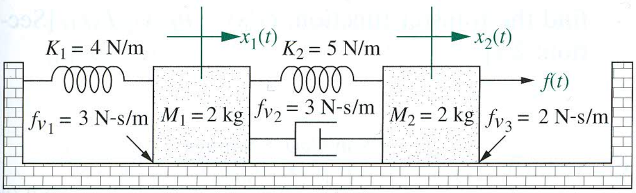


FIGURE P2.12

27. Find the transfer function, $G(s) = X_3(s)/F(s)$, for the translational mechanical system shown in Figure P2.13. [Section: 2.5]

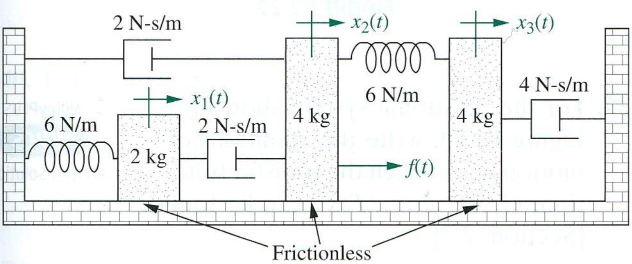
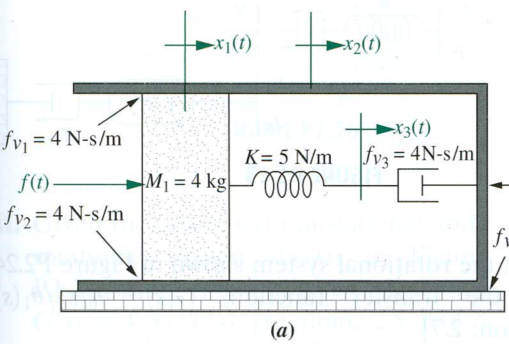


FIGURE P2.13

28. Find the transfer function, $X_3(s)/F(s)$, for each system shown in Figure P2.14. [Section: 2.5]



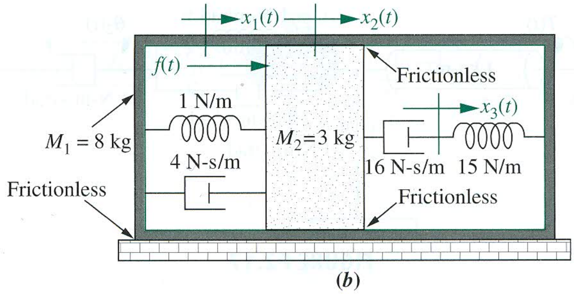


FIGURE P2.14

29. Write, but do not solve, the equations of motion for the translational mechanical system shown in Figure P2.15. [Section: 2.5]

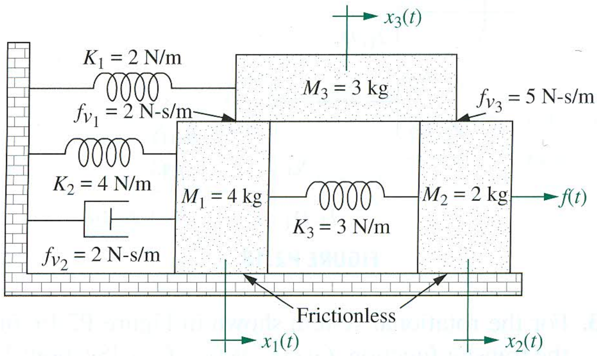


FIGURE P2.15

30. For each of the rotational mechanical systems shown in Figure P2.16, write, but do not solve, the equations of motion. [Section: 2.6]

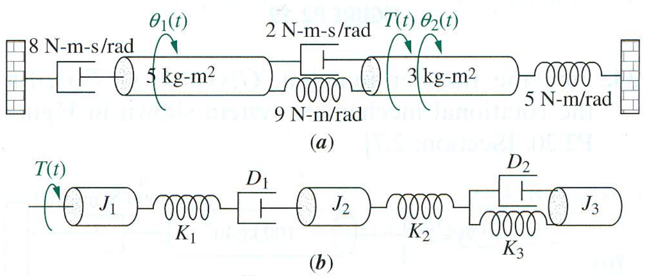


FIGURE P2.16

31. For the rotational mechanical system shown in Figure P2.17, find the transfer function $G(s) = \theta_2(s)/T(s)$ [Section: 2.6]

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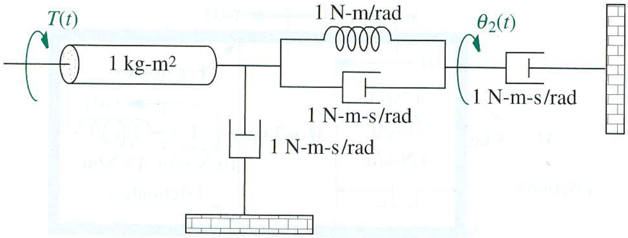

FIGURE P2.17

32. For the rotational mechanical system with gears shown in Figure P2.18, find the transfer function, $G(s) = \theta_3(s)/T(s)$. The gears have inertia and bearing friction as shown. [Section: 2.7]

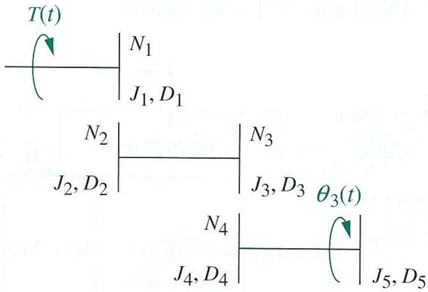

FIGURE P2.18

33. For the rotational system shown in Figure P2.19, find the transfer function, $G(s) = \theta_2(s)/T(s)$. [Section: 2.7]

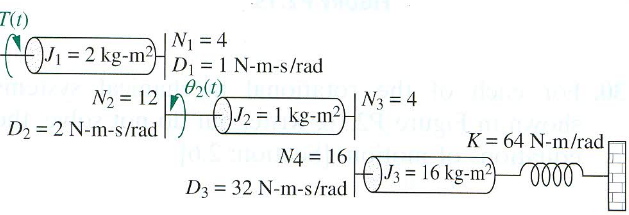

FIGURE P2.19

34. Find the transfer function, $G(s) = \theta_2(s)/T(s)$, for the rotational mechanical system shown in Figure P2.20. [Section: 2.7]

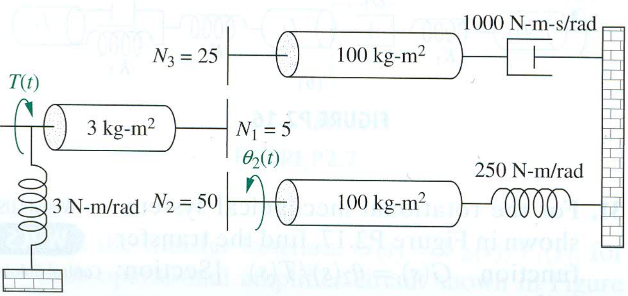

FIGURE P2.20

35. Find the transfer function, $G(s) = \theta_4(s)/T(s)$, for the rotational system shown in Figure P2.21. [Section: 2.7]

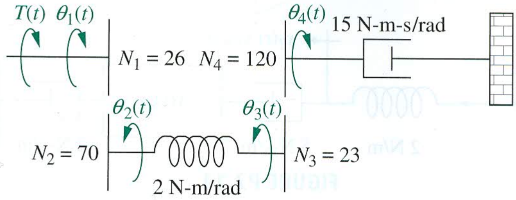

FIGURE P2.21

36. For the rotational system shown in Figure P2.22, find the transfer function, $G(s) = \theta_L(s)/T(s)$. [Section: 2.7]

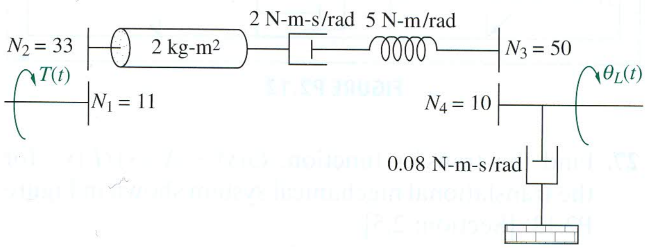

FIGURE P2.22

37. For the rotational system shown in Figure P2.23, write the equations of motion from which the transfer function, $G(s) = \theta_1(s)/T(s)$, can be found. [Section: 2.7]

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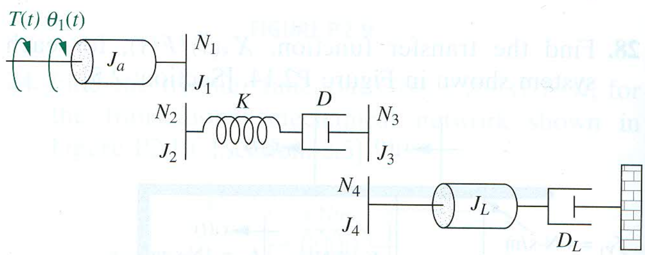

FIGURE P2.23

38. Given the rotational system shown in Figure P2.24, find the transfer function, $G(s) = \theta_6(s)/\theta_1(s)$. [Section: 2.7]

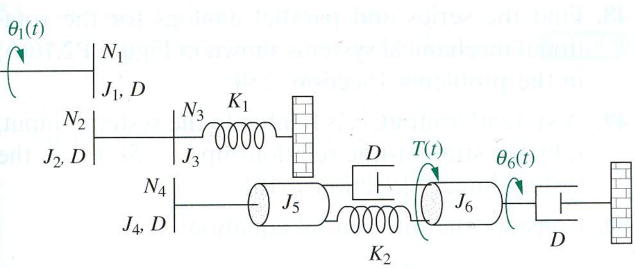

FIGURE P2.24

39. In the system shown in Figure P2.25, the inertia, J, of radius, r, is constrained to move only about the stationary axis A. A viscous damping force of translational value f_v exists between the bodies J and M. If an external force, $f(t)$, is applied to the mass, find the transfer function, $G(s) = \theta(s)/F(s)$. [Sections: 2.5; 2.6]

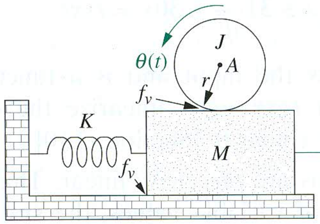

FIGURE P2.25

40. For the combined translational and rotational system shown in Figure P2.26, find the transfer function, $G(s) = X(s)/T(s)$. [Sections: 2.5; 2.6; 2.7]

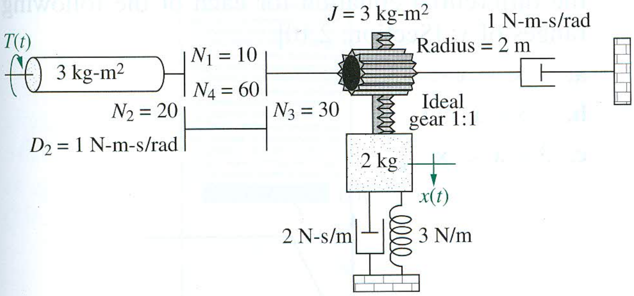

FIGURE P2.26

41. Given the combined translational and rotational system shown in Figure P2.27, find the transfer function, $G(s) = X(s)/T(s)$. [Sections: 2.5; 2.6]

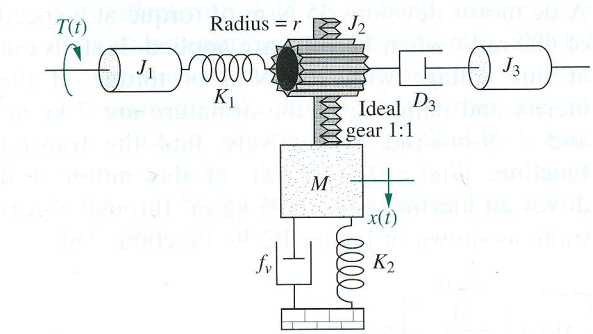

FIGURE P2.27

42. For the motor, load, and torque-speed curve shown in Figure P2.28, find the transfer function, $G(s) = \theta_L(s)/E_a(s)$. [Section: 2.8]

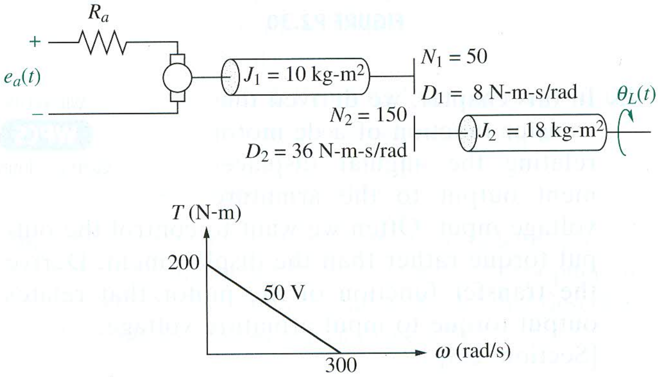

FIGURE P2.28

43. The motor whose torque-speed characteristics are shown in Figure P2.29 drives the load shown in the diagram. Some of the gears have inertia. Find the transfer function, $G(s) = \theta_2(s)/E_a(s)$. [Section: 2.8]

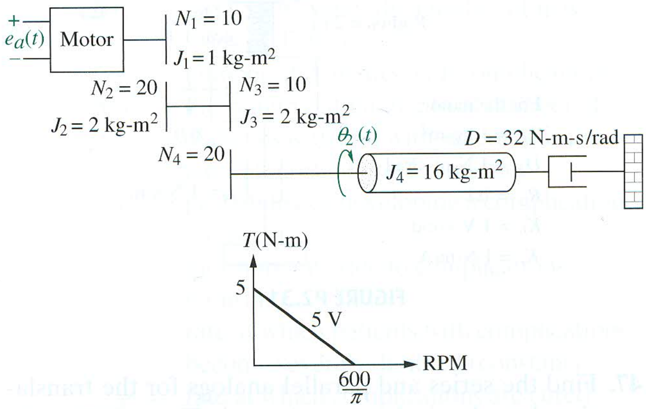

FIGURE P2.29

44. A dc motor develops 55 N-m of torque at a speed of 600 rad/s when 12 volts are applied. It stalls out at this voltage with 100 N-m of torque. If the inertia and damping of the armature are 7 kg-m^2 and 3 N-m-s/rad, respectively, find the transfer function, $G(s) = \theta_L(s)/E_a(s)$, of this motor if it drives an inertia load of 105 kg-m^2 through a gear train, as shown in Figure P2.30. [Section: 2.8]

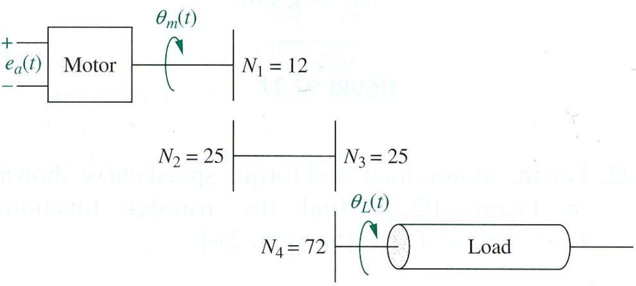

FIGURE P2.30

45. In this chapter, we derived the transfer function of a dc motor relating the angular displacement output to the armature voltage input. Often we want to control the output torque rather than the displacement. Derive the transfer function of the motor that relates output torque to input armature voltage. [Section: 2.8]

46. Find the transfer function, $G(s) = X(s)/E_a(s)$, for the system shown in Figure P2.31. [Sections: 2.5–2.8]

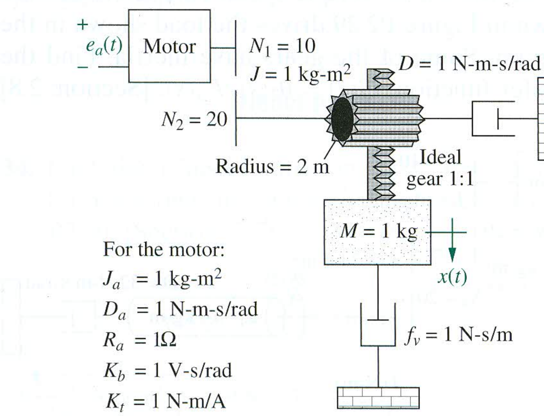

FIGURE P2.31

47. Find the series and parallel analogs for the translational mechanical system shown in Figure 2.20 in the text. [Section: 2.9]

48. Find the series and parallel analogs for the rotational mechanical systems shown in Figure P2.16(*b*) in the problems. [Section: 2.9]

49. A system's output, c, is related to the system's input, r, by the straight-line relationship, $c = 5r + 7$. Is the system linear? [Section: 2.10]

50. Consider the differential equation

$$\frac{d^2x}{dt^2} + 5\frac{dx}{dt} + 3x = f(x)$$

where $f(x)$ is the input and is a function of the output, x. If $f(x) = \sin x$, linearize the differential equation for small excursions. [Section: 2.10]

a. $x = 0$

b. $x = \pi$

51. Consider the differential equation

$$\frac{d^3x}{dt^3} + 10\frac{d^2x}{dt^2} + 31\frac{dx}{dt} + 30x = f(x)$$

where $f(x)$ is the input and is a function of the output, x. If $f(x) = e^{-x}$, linearize the differential equation for x near 0. [Section: 2.10]

52. Many systems are *piecewise* linear. That is, over a *large* range of variable values, the system can be described linearly. A system with amplifier saturation is one such example. Given the differential equation

$$\frac{d^2x}{dt^2} + 17\frac{dx}{dt} + 50x = f(x)$$

assume that $f(x)$ is as shown in Figure P2.32. Write the differential equation for each of the following ranges of x: [Section: 2.10]

a. $-\infty < x < -3$

b. $-3 < x < 3$

c. $3 < x < \infty$

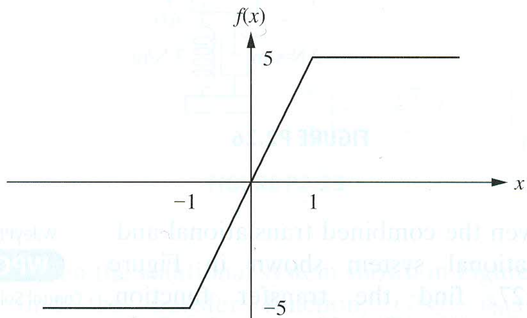

FIGURE P2.32