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]

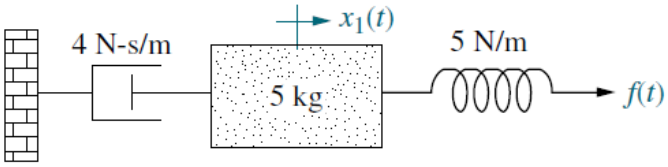

FIGURE P2.9

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]

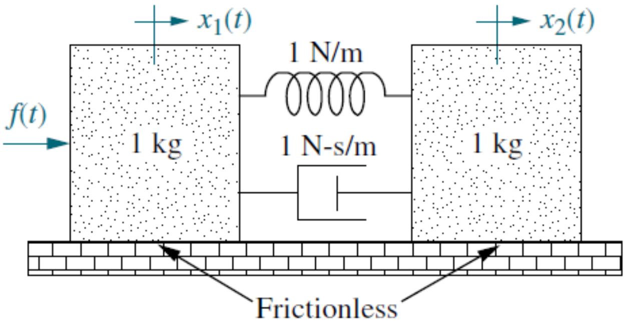

FIGURE P2.10

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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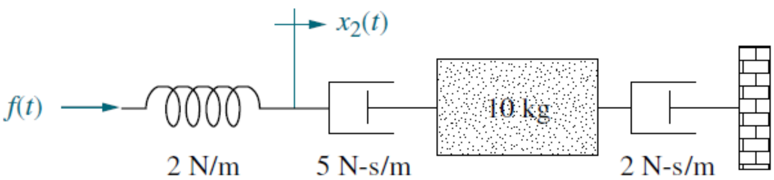

FIGURE P2.11

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]

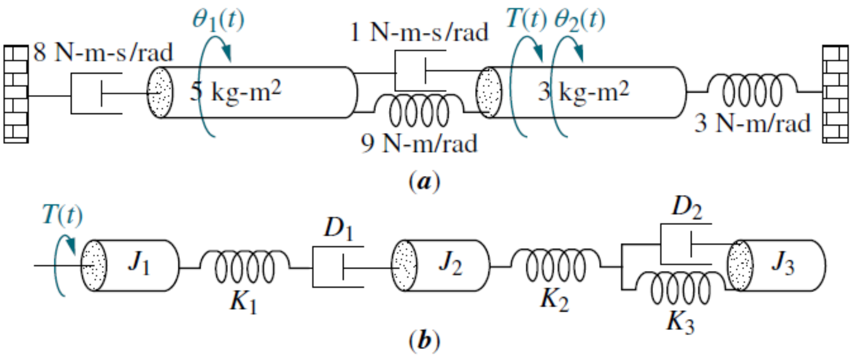

FIGURE P2.16

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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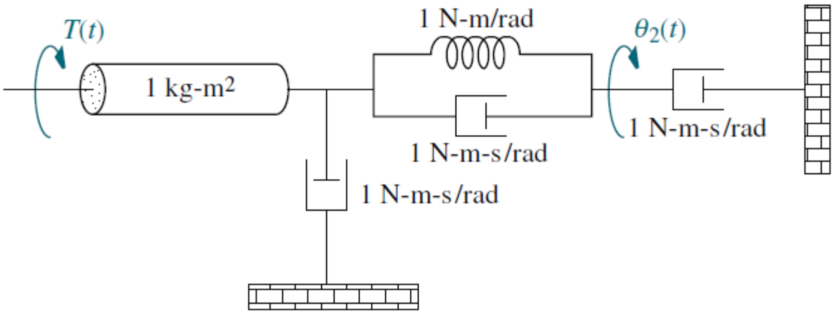

FIGURE P2.17

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

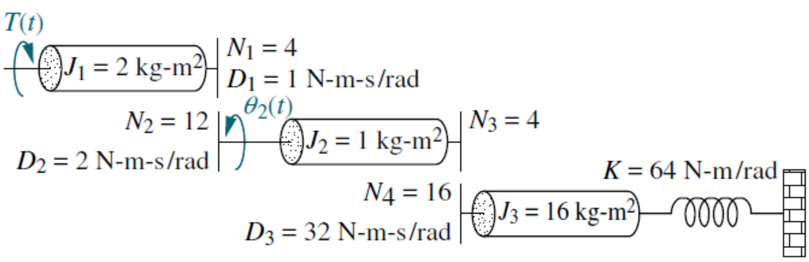

FIGURE P2.19

23.

Writing the equations of motion, where $x_2(t)$ is the displacement of the right member of springr,

$$(5s^2+4s+5)X_1(s) \ -5X_2(s) = 0$$

$$-5X_1(s) +5X_2(s) = F(s)$$

Adding the equations,

$$(5s^2+4s)X_1(s) \ = F(s)$$

From which, $\dfrac{X_1(s)}{F(s)} = \dfrac{1}{s(5s+4)} = \dfrac{1/5}{s(s+4/5)}$.

24.

Writing the equations of motion,

$$(s^2+s+1)X_1(s) - (s+1)X_2(s) = F(s)$$

$$-(s+1)X_1(s) + (s^2+s+1)X_2(s) = 0$$

Solving for $X_2(s)$,

$$X_2(s) = \frac{\begin{vmatrix} (s^2+s+1) & F(s) \\ -(s+1) & 0 \end{vmatrix}}{\begin{vmatrix} (s^2+s+1) & -(s+1) \\ -(s+1) & (s^2+s+1) \end{vmatrix}} = \frac{(s+1)F(s)}{s^2(s^2+2s+2)}$$

From which,

$$\frac{X_2(s)}{F(s)} = \frac{(s+1)}{s^2(s^2+2s+2)}.$$

25.

Let $X_1(s)$ be the displacement of the left member of the spring and $X_3(s)$ be the displacement of the mass.

Writing the equations of motion

$$2x_1(s) - 2x_2(s) = F(s)$$

$$-2X_1(s) + (5s+2)X_2(s) - 5sX_3(s) = 0$$

$$-5sX_2(s) + (10s^2 + 7s)X_3(s) = 0$$

Solving for $X_2(s)$,

$$X_2(s) = \frac{\begin{vmatrix} 5s^2+10 & F(s) \\ -10 & 0 \end{vmatrix}}{\begin{vmatrix} 5s^2+10 & -10 \\ -10 & \frac{1}{5}s+10 \end{vmatrix}} = \frac{10F(s)}{s(s^2+50s+2)}$$

$$\text{Thus,}\quad \frac{X_2(s)}{F(s)} = \frac{1}{10}\frac{(10s+7)}{s(5s+1)}$$

30.

a.

Writing the equations of motion,

$$(5s^2+9s+9)\theta_1(s) - (s+9)\theta_2(s) = 0$$
$$-(s+9)\theta_1(s) + (3s^2+s+12)\theta_2(s) = T(s)$$

b.

Defining

$\theta_1(s)$ = rotation of J_1

$\theta_2(s)$ = rotation between K_1 and D_1

$\theta_3(s)$ = rotation of J_3

$\theta_4(s)$ = rotation of right-hand side of K_2

the equations of motion are

$$(J_1s^2+K_1)\theta_1(s) - K_1\theta_2(s) = T(s)$$
$$-K_1\theta_1(s) + (D_1s+K_1)\theta_2(s) - D_1s\,\theta_3(s) = 0$$
$$-D_1s\,\theta_2(s) + (J_2s^2 + D_1s + K_2)\theta_3(s) - K_2\theta_4(s) = 0$$
$$-K_2\theta_3(s) + (D_2s + (K_2+K_3))\theta_4(s) = 0$$

31.

Writing the equations of motion,

$$(s^2+2s+1)\theta_1(s)-(s+1)\theta_2(s)=T(s)$$
$$-(s+1)\theta_1(s)+(2s+1)\theta_2(s)=0$$

Solving for $\theta_2(s)$

$$\theta_2(s)=\frac{\begin{vmatrix}(s^2+2s+1) & T(s)\\ -(s+1) & 0\end{vmatrix}}{\begin{vmatrix}(s^2+2s+1) & -(s+1)\\ -(s+1) & (2s+1)\end{vmatrix}}=\frac{T(s)}{2s(s+1)}$$

Hence,

$$\frac{\theta_2(s)}{T(s)}=\frac{1}{2s(s+1)}$$

33.

Reflecting all impedances to $\theta_2(s)$,

$$\left\{\left[J_2+J_1\left(\frac{N_2}{N_1}\right)^2+J_3\left(\frac{N3}{N4}\right)^2\right]s^2+\left[f_2+f_1\left(\frac{N_2}{N_1}\right)^2+f_3\left(\frac{N_3}{N_4}\right)^2\right]s+\left[K\left(\frac{N_3}{N_4}\right)^2\right]\right\}\theta_2(s)=T(s)\frac{N_2}{N_1}$$

Substituting values,

$$\left\{\left[1+2(3)^2+16\left(\frac{1}{4}\right)^2\right]s^2+\left[2+1(3)^2+32\left(\frac{1}{4}\right)^2\right]s+64\left(\frac{1}{4}\right)^2\right\}\theta_2(s)=T(s)(3)$$

Thus,

$$\frac{\theta_2(s)}{T(s)}=\frac{3}{20s^2+13s+4}$$