Problem 1:
(a) The impedance graph below may be reduced to a single impedance as shown:

The required transfer function is

\[ G(s) = \frac{V(s)}{F(s)} = Z_{eq} \]

It is more convenient to work with admittances (since there are a lot of parallel elements):

\[ Y_{eq} = \frac{1}{Z_{eq}} = Y_{m_1} + Y_{B_1} + Y_{K_1} + \frac{(Y_{K_2} + Y_{B_2})Y_{m_2}}{Y_{K_2} + Y_{B_2} + Y_{m_2}} \]

\[ = \frac{(Y_{m_1} + Y_{B_1} + Y_{K_1})(Y_{K_2} + Y_{B_2} + Y_{m_2}) + (Y_{K_2} + Y_{B_2})Y_{m_2}}{Y_{K_2} + Y_{B_2} + Y_{m_2}} \]

Then

\[ G(s) = \frac{1}{Y_{eq}} \]

\[ = \frac{Y_{K_2} + Y_{B_2} + Y_{m_2}}{m_2s + B_2 + K_2/s} \]

\[ = \frac{(m_1s + B_1 + K_1/s)(K_2/s + B_2 + m_2s) + (K_2/s + B_2)m_2s}{m_2s^3 + B_2s^2 + K_2s} \]

\[ = \frac{a_4s^4 + a_3s^3 + a_2s^2 + a_1s + a_0}{m_2s^3 + B_2s^2 + K_2s} \]
where \[ a_4 = m_1 m_2 \]
\[ a_3 = (m_1 + m_2) B_2 + m_2 B_1 \]
\[ a_2 = (m_1 + m_2) K_2 + m_2 K_1 + B_1 B_2 \]
\[ a_1 = K_1 B_2 + K_2 B_1 \]
\[ a_0 = K_1 K_2 \]

(b) Reduce the system graph to a reduced impedance graph as shown below:

\[
\begin{align*}
Y_1 &= \frac{1}{Z_1} = m_1 s + B_1 + \frac{K_1}{s} \\
Y_2 &= \frac{1}{Z_2} = B_2 + \frac{K_2}{s} \\
Y_3 &= \frac{1}{Z_3} = m_2 s
\end{align*}
\]

Use node equations:

At node (a) \[ F_{Z_1} + F_{Z_2} = F_{act} \]
At node (b) \[ F_{Z_2} - F_{Z_3} = F_{act} \]

Substitute admittances

\[
\begin{align*}
v_a Y_1 + (v_a - v_b) Y_2 &= F_{act} \\
(v_a - v_b) Y_2 - v_b Y_3 &= F_{act}
\end{align*}
\]

and express in matrix form

\[
\begin{bmatrix}
Y_1 + Y_2 & -Y_2 \\
Y_2 & -(Y_2 + Y_3)
\end{bmatrix}
\begin{bmatrix}
v_a \\
v_b
\end{bmatrix}
= \begin{bmatrix}
F_{act} \\
F_{act}
\end{bmatrix}
\]
Use Cramer’s Rule to solve for $v_a$:

$$
v_a = \frac{\begin{vmatrix} F_{\text{act}} & -Y_2 \\ F_{\text{act}} & -(Y_2 + Y_3) \end{vmatrix}}{\begin{vmatrix} Y_1 + Y_2 & -Y_2 \\ Y_2 & -(Y_2 + Y_3) \end{vmatrix}} = \frac{Y_3F_{\text{act}}}{Y_1Y_2 + Y_1Y_3 + Y_2Y_3}
$$

Substitution for the admittances gives

$$G(s) = \frac{v_a(s)}{F_{\text{act}}(s)} = \frac{m_2s^3}{a_4s^4 + a_3s^3 + a_2s^2 + a_1s + a_0}$$

where

- $a_4 = m_1m_2$
- $a_3 = (m_1 + m_2)B_2 + m_2B_1$
- $a_2 = (m_1 + m_2)K_2 + m_2K_1 + B_1B_2$
- $a_1 = K_1B_2 + K_2B_1$
- $a_0 = K_1K_2$

and we note that the denominator is the same as in (a) above.

**Problem 2:** Nise Problem 4-23 (p. 207).

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**Problem 3:** Nise Problem 4-29 (p. 208).

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**Problem 4:** Nise Problem 4-55 (p. 212).

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**Problem 5:** Nise Problem 4-62 (p. 214).

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Both responses are indistinguishable.

**Problem 6:** Nise Problem 4-67 (p. 215).

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