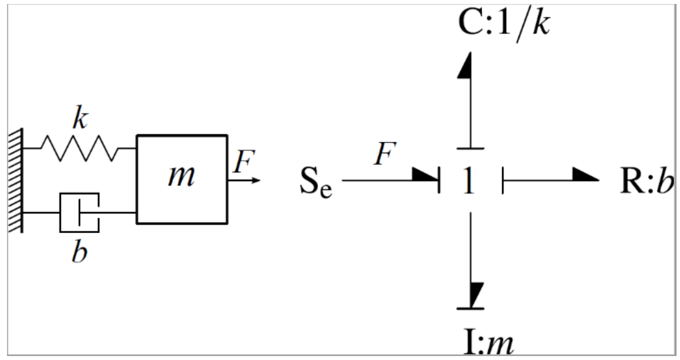
Example 6.1

Take for Example the simple mass-spring-damper depicted in Figure 6.2. Derive the transfer functions for the system.

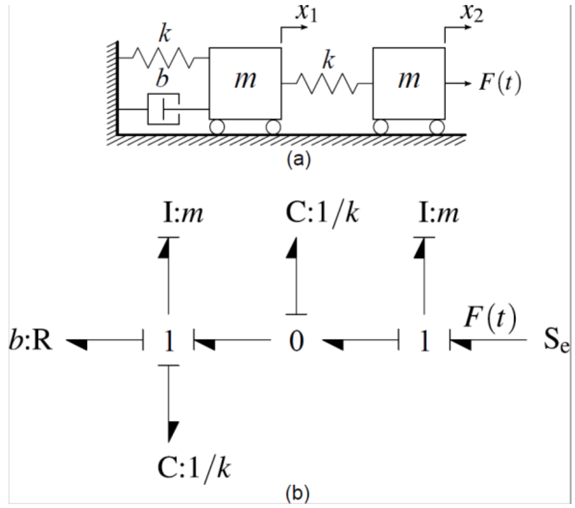
$$\begin{bmatrix} \dot{x} \\ \dot{p} \end{bmatrix} = \begin{bmatrix} 0 & 1/m \\ -k & -b/m \end{bmatrix} \begin{bmatrix} x \\ p \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} F(t)$$

$$y = x = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ p \end{bmatrix} + 0 \cdot F(t)$$



Example 6.2

Remember the mass-spring-damper system from Example 3.11. Figure 6.2(b) shows four energy storing elements in integral causality. The output of interest are the positions of the two masses, x_1 and x_2. Convert the state-space models to transfer functions relating each of the displacement to the input force.

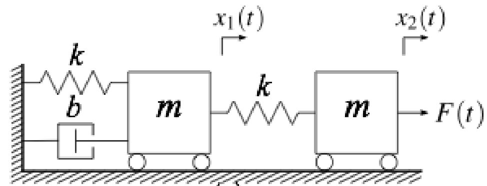


$$\begin{bmatrix} \dot{x}_1 \\ \dot{p}_1 \\ \dot{\delta} \\ \dot{p}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1/m & 0 & 0 \\ -k & -b/m & k & 0 \\ 0 & -1/m & 0 & 1/m \\ 0 & 0 & -k & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ p_1 \\ \delta \\ p_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} F(t)$$

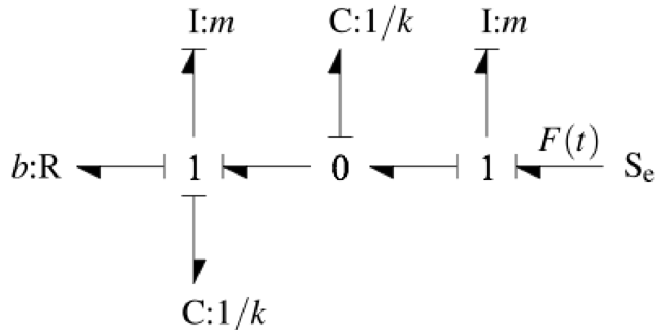
$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ p_1 \\ \delta \\ p_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} F(t)$$

Example 6.3

Recall the mass-spring-damper problem from Example 6.2. Generate the impedance bond graph for this system.



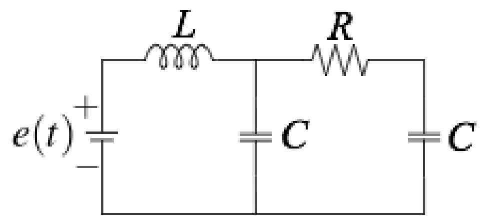
(a)



(b)

Example 6.4

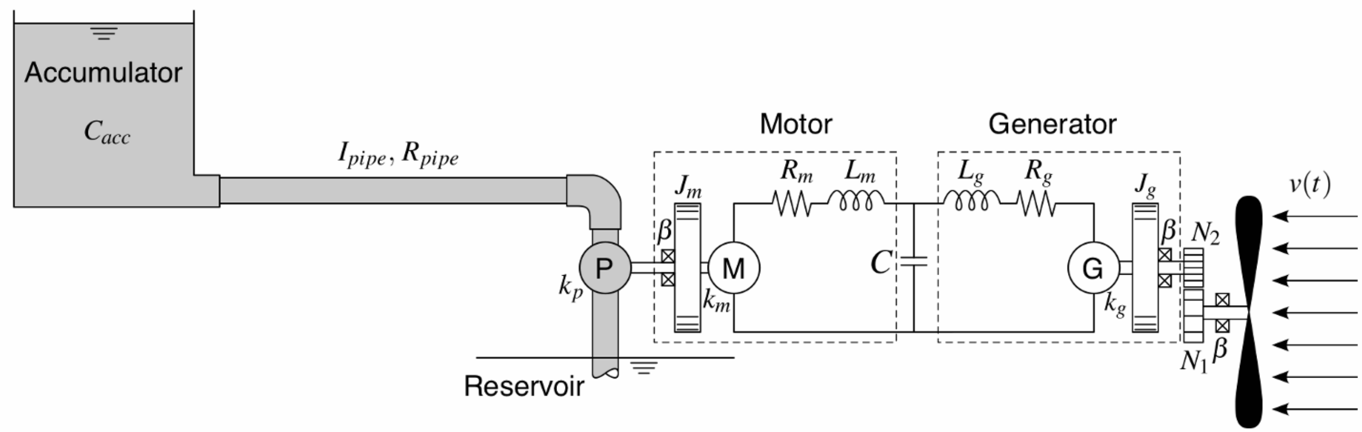
Recall the circuit for Example 3.5. Create a regular bond graph and compare to an impedance bond graph.



(a)

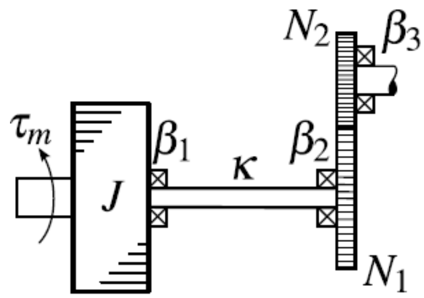
Challenge Problem

Recall the bond graph for the challenge problem. Convert the bond graph to an impedance bond graph.

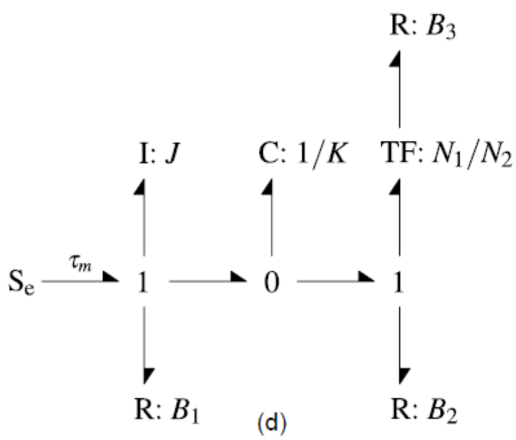


Example 1

Generate an impedance bond graph. Reduce the resulting impedance bond graph to a single power bond.



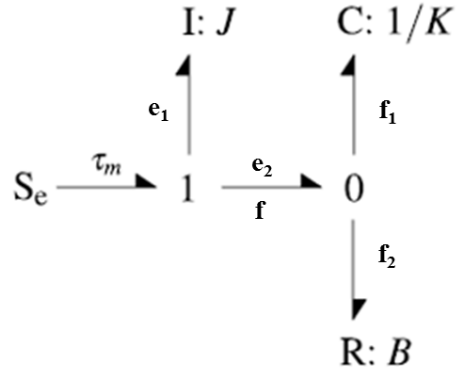
(a)



(d)

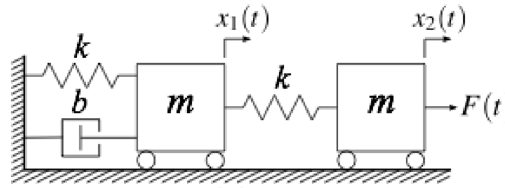
Example 2

Convert the following bond graph to an impedance bond graph. Determine the transfer functions for the following relationships: $\frac{f_1}{f}, \frac{f_2}{f}, \frac{e_1}{\tau_m}, \frac{e_2}{\tau_m}$.



Example 6.5

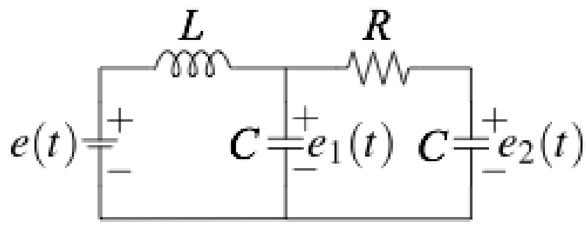
Derive a transfer function relating the displacements of the masses to the input force using an impedance bond graph.



(a)

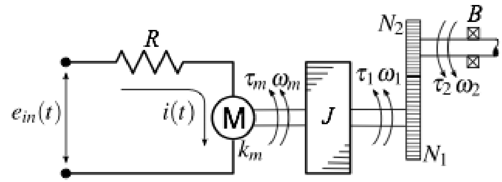
Example 6.6

Derive the transfer functions relating the voltages $e_1(s)$ and $e_2(s)$ to the input voltage e(t).



(a)

Example 6.7

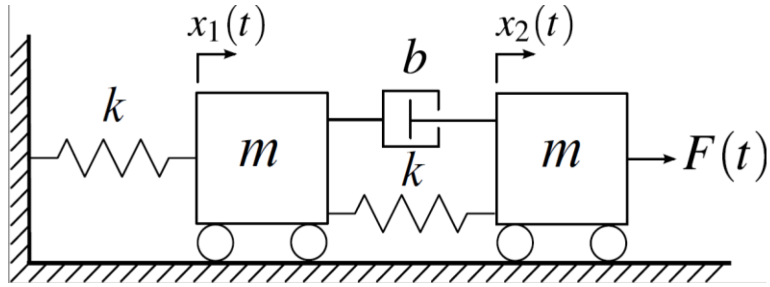


(a)

Derive a transfer function using an impedance bond graph to determine the response of the output torque, $\tau_2(t)$, relative to the input voltage, $e_{in}(t)$.

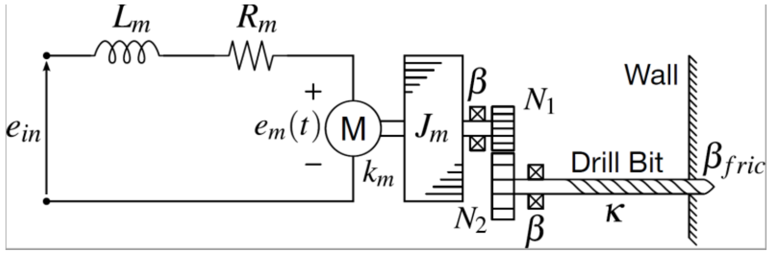
Review Problem 1

Recall the bond graph synthesized in Chapter 3 for the given system. Derive transfer functions relating the displacements of both masses to the input force F(t).



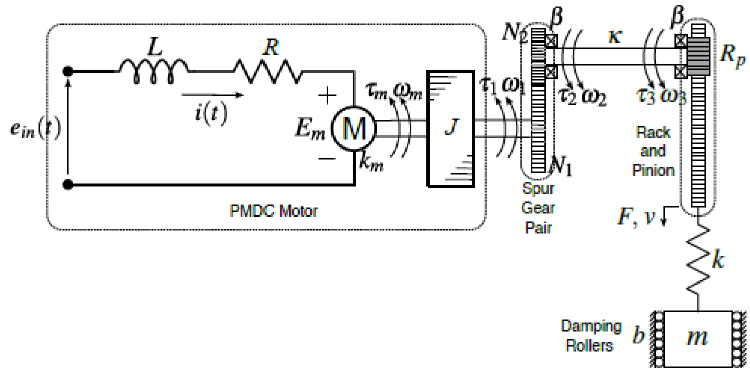
Review Problem 2

Recall the bond graph synthesized in Chapter 3 for the given system. Derive the transfer functions relating output angular velocity to the input voltage, $e_{in}(t)$.



Review Problem 3

Recall the bond graph synthesized in Chapter 3 for the given system. Derive the transfer function relating the displacement of the mass to the input voltage, $e_{in}(t)$.



Challenge Problem