2nd Midterm - Solution

- 2.1 Electrical Circuit
- 2.2 Mechanical System
- 2.3 Hydraulic System

2.1 Electrical Circuit I

- Create a bond graph for the electrical circuit to the left. Choose the same direction for the harpoons as for the currents.
- Add causality strokes, and determine whether or not this circuit contains any algebraic loops and/or structural singularities.
- Draw the dual bond graph.
- Read a horizontally sorted set of simulation equations out of the dual bond graph.
Electrical Circuit II

- The dual bond graph is not the same as a dual circuit. It represents the same circuit as before.
- You get sort of a dual circuit by starting out with the dual bond graph, then interpreting each current as a voltage (or potential), and each voltage (or potential) as a current.
- Draw a circuit diagram for the so-obtained dual circuit.
2.2 Cervical Syndrome

- Create a bond graph for the human upper body shown on the left.
- Use the diamond property to simplify the bond graph.
- Add causality strokes to the modified bond graph.
- Read a horizontally sorted set of simulation equations out of the modified bond graph.
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Diamonds

Original model

Simplified model

\[ Fv_4 = v_4 + F_{k3} + F_{b3} \]

\[ F = f(t) \]

\[ \frac{dF_{k3}}{dt} = k_3 \cdot (v_4 - v_2) \]

\[ F_{b3} = b_3 \cdot (v_4 - v_2) \]

\[ \frac{dv_2}{dt} = \frac{FI_2}{M_2} \]

\[ FI_2 = (F_{k3} + F_{b3}) - (F_{k2} + F_{b2}) \]

\[ \frac{dv_3}{dt} = \frac{FI_3}{M_3} \]

\[ FI_3 = F_{k2} + F_{b2} \]

\[ \frac{dv_1}{dt} = \frac{FI_1}{M_1} \]

\[ FI_1 = F_{k1} + F_{b1} \]

\[ \frac{dF_{k1}}{dt} = k_1 \cdot (v_2 - v_1) \]

\[ F_{b1} = b_1 \cdot (v_2 - v_1) \]

\[ \frac{dv_4}{dt} = \frac{FI_4}{M_4} \]

\[ FI_4 = F - (F_{k3} + F_{b3}) \]
2.3 Hydraulic System I

- Create a bond graph for the hydraulic motor with servo valve shown on the left.
- The hydraulic motor is here a hydraulic cylinder, i.e., it generates a translational rather than rotational motion. Both the internal and external leakage flows are ignored.
- The servo valve is also different from the one shown in the lecture notes.

Hydraulic System II

- You may assume that the \( m\text{Hydro-element} \) is available.
- You don’t need to model the control of the tongue of the servo valve. Assume \( x \) to be the input signal, and \( y \) the output signal.
- Use appropriate modulated sources and sensor elements to convert the input signal to the bond graph, and to sense the output signal from the bond graph.
The equations for the two servo valves are exactly the same, except that the modulation signals have reversed signs.

Hydraulic Cylinder

- The model of the hydraulic cylinder is also exactly the same as for the hydraulic motor, except that the leakage flows were said to be negligible (eliminate the corresponding bonds and R-elements), and that the flux, $\psi$, is now the surface area of the piston, $A$. 