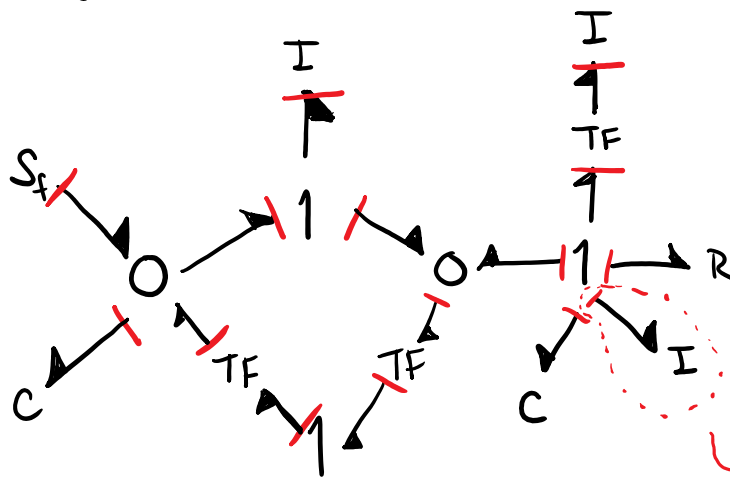
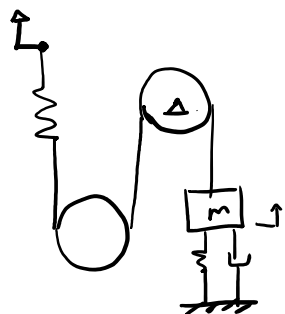
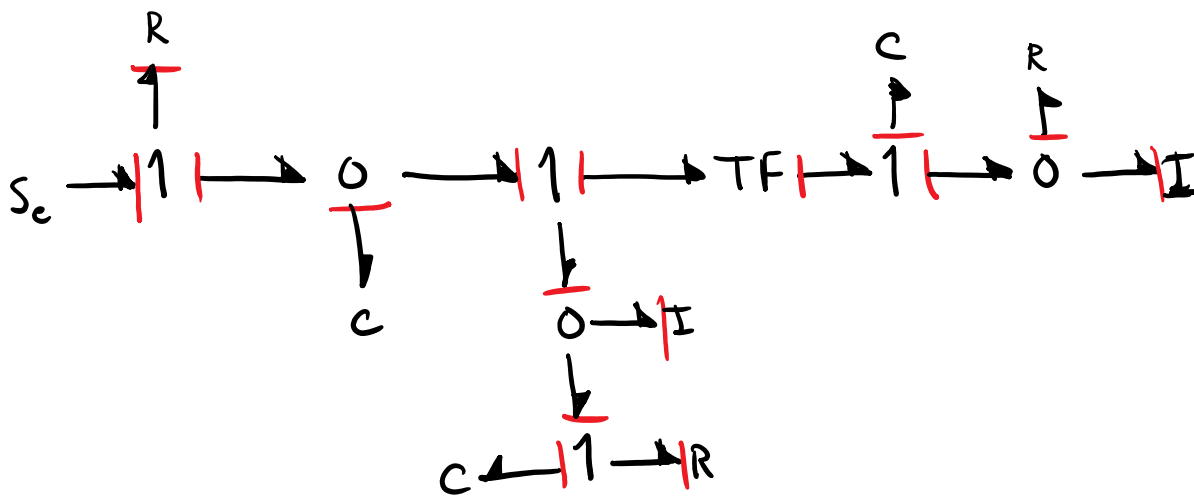
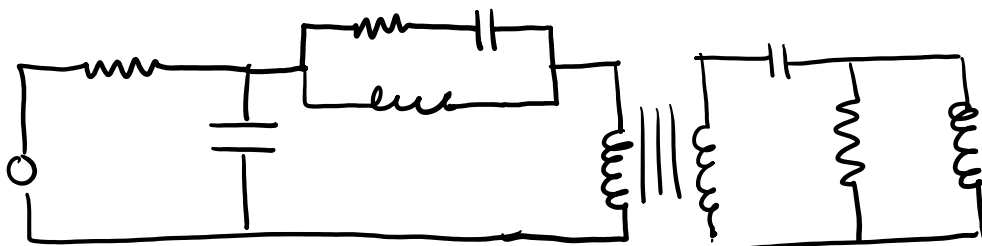


Exercise : assign causality

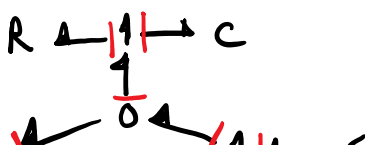


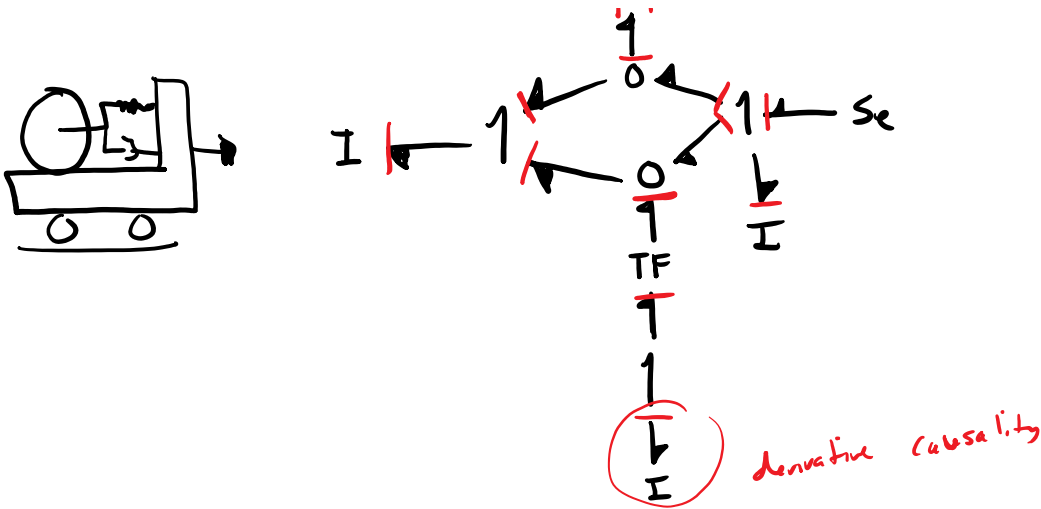
derivative causality

Exercise



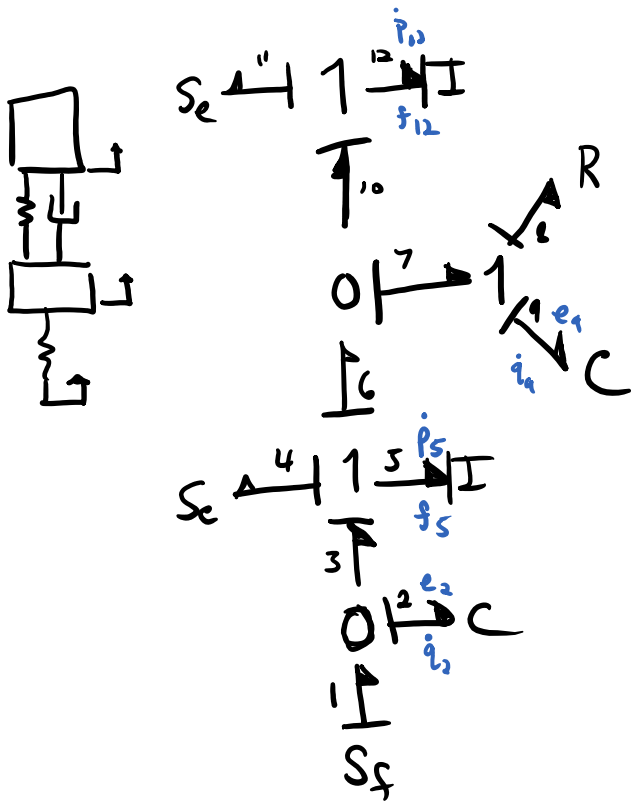
Example





Forming System Equations

1. number the bonds
2. define state variables: p 's and q 's of I and C ports with integral causality
3. write \dot{p}, f and \dot{q}, e for each I and C
4. start with lowest # bond I and C and write $\dot{p} = e$ or $\dot{q} = f$
5. following causality for e or f to I, C, R 's
6. write constitutive relationships for non-state variables



State variables: q_2, p_5, q_9, p_{12}

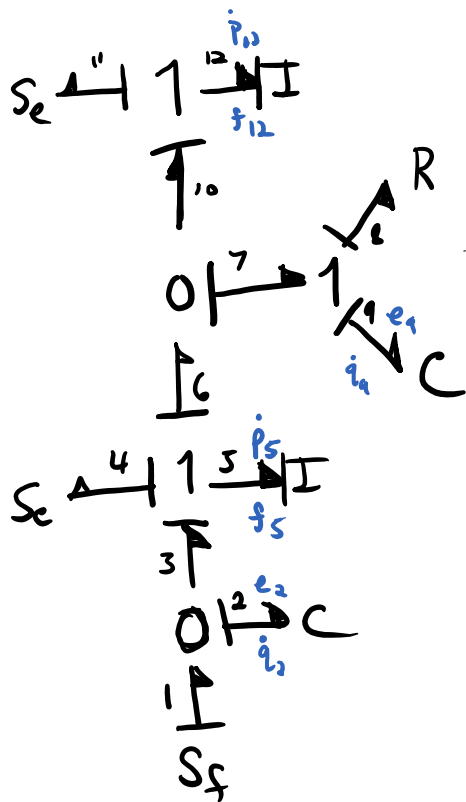
Inputs: S_{f1}, S_{e4}, S_{e11}

① $\dot{q}_2 = f_2$

② $\dot{p}_5 = e_5$

③ $\dot{q}_9 = f_9$

④ $\dot{p}_{12} = e_{12}$



① $\dot{q}_2 = f_2 = f_1 - f_3 = S_{f1} - f_5 = S_{f1} - \frac{p_5}{I_5}$

$$\dot{q}_2 = S_{f1} - \frac{p_5}{I_5}$$

② $\dot{p}_5 = e_5 = e_3 - e_4 - e_6 = e_2 - S_{e4} - e_7$

$$\dot{p}_5 = \frac{q_2}{c_2} - S_{e4} - (e_9 + e_8)$$

$$\dot{p}_5 = \frac{q_2}{c_2} - S_{e4} - \left(\frac{q_9}{c_9} + R_8 f_8 \right)$$

$$\dot{p}_5 = \frac{q_2}{c_2} - S_{e4} - \left(\frac{q_9}{c_9} + R_8 (f_c - f_{10}) \right)$$

$$\dot{p}_5 = \frac{q_2}{c_2} - S_{e4} - \left(\frac{q_9}{c_9} + R_8 \left(\frac{p_5}{I_5} - \frac{p_{12}}{I_{12}} \right) \right)$$