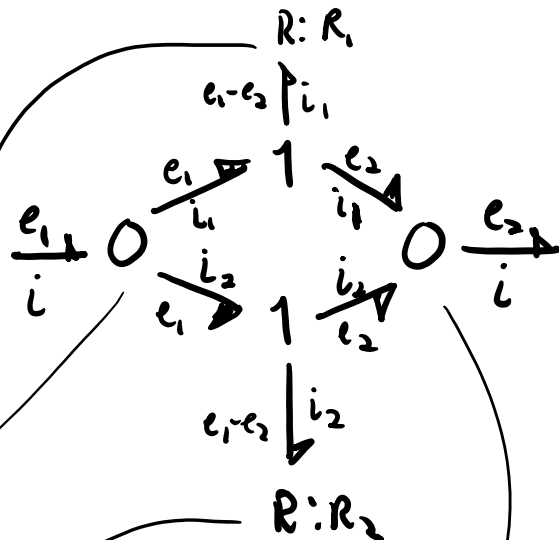
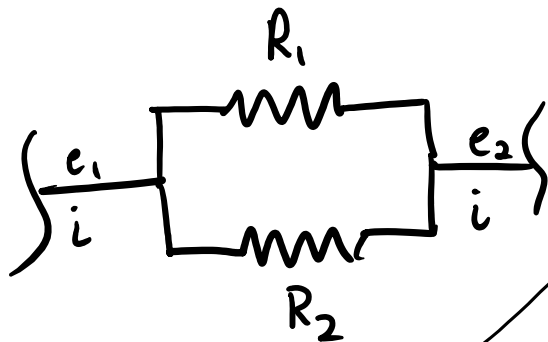
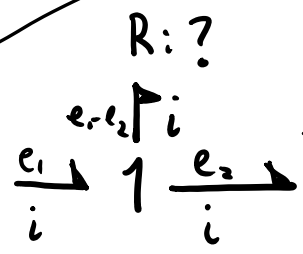


- HW 4 due Monday (electrical networks & intro mechanical)
- Lab 2 due Fri. Feb. 7
- Midterm Tuesday, Feb 11
- Midterm review Thurs. Feb. 6

Parallel and Series Circuits



- ① $e_1 - e_2 = R_1 i_1$
- ② $e_1 - e_2 = R_2 i_2$
- ③ $i = i_1 + i_2$
- $i = i_1 + i_2$



$e_1 - e_2 = ? i$

③ $i = i_1 + i_2$

$$i = \frac{e_1 - e_2}{R_1} + \frac{e_1 - e_2}{R_2}$$

$$i = (e_1 - e_2) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

$$e_1 - e_2 = \left(\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \right) i$$

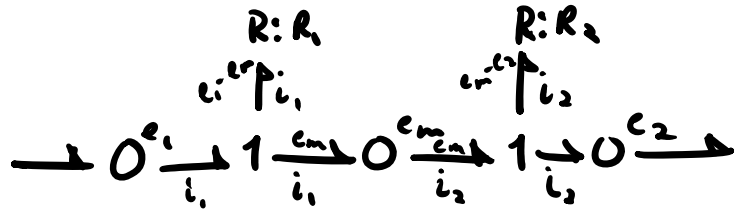
$$e_1 - e_2 = \left(\frac{R_1 R_2}{R_1 + R_2} \right) i$$

equivalent resistance for parallel resistors

equivalent

resist

Series

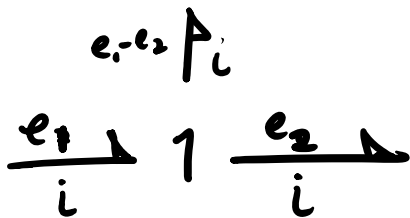


(1) $e_1 - e_m = R_1 i_1$

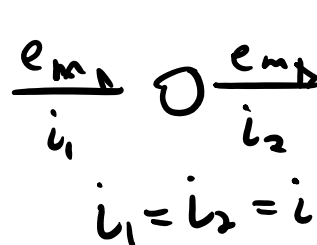
(2) $e_m - e_2 = R_2 i_2$

(1)+(2) $e_1 - e_2 = R_1 i_1 + R_2 i_2$

$R: ? = R_1 + R_2$

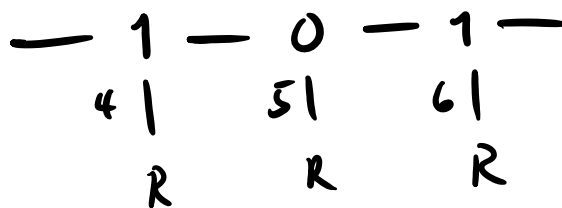
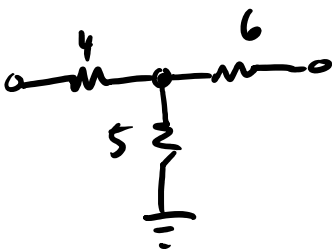
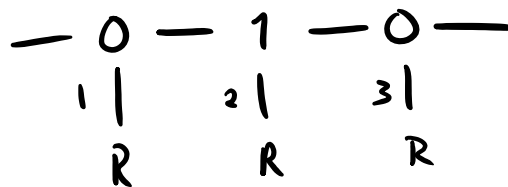
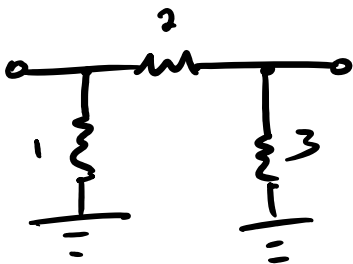


$e_1 - e_2 = ? i$



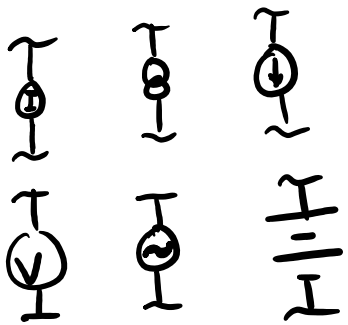
$e_1 - e_2 = (R_1 + R_2) i$
equivalent resistance

Patterns emerge in the bond graphs:

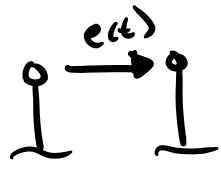


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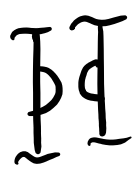


Current sources



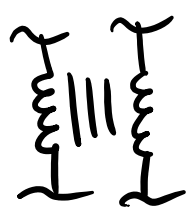
Voltage source

"Auditor"



resistance

gyrator



transformer

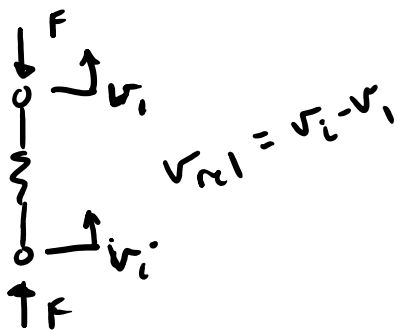
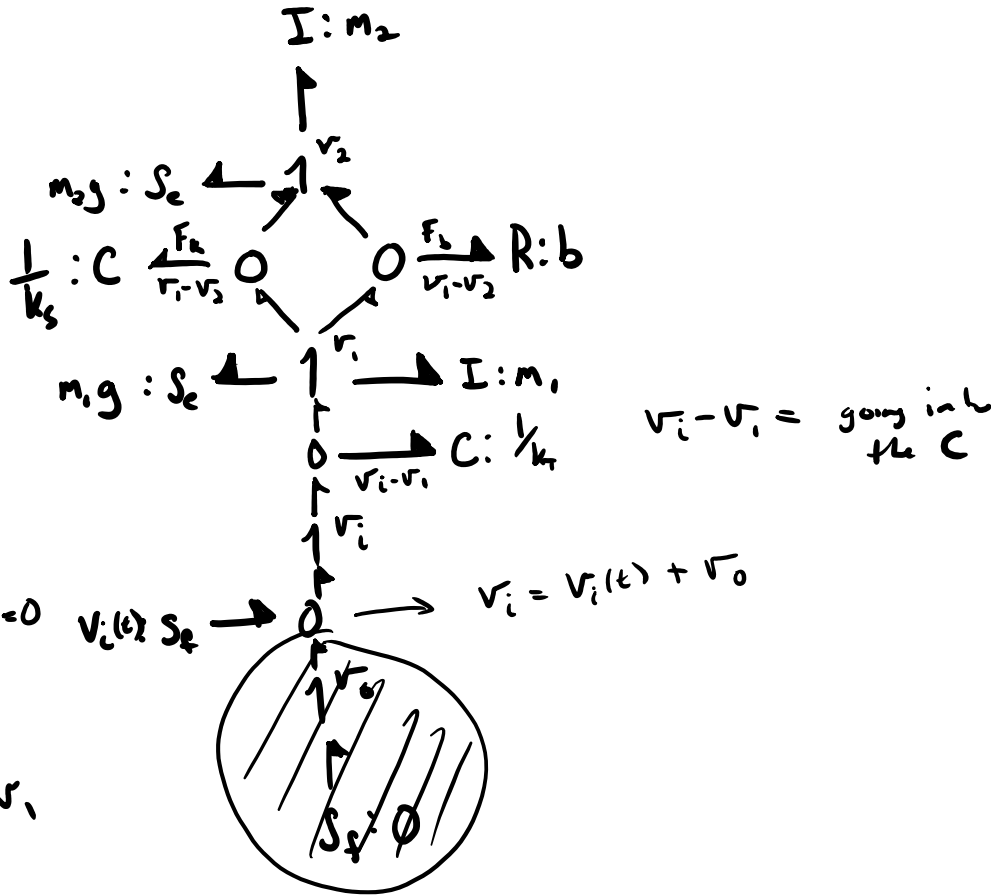
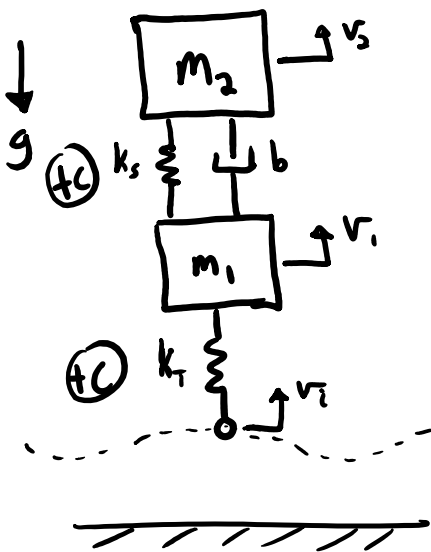
Mechanical Systems

masses, springs, dampers, levers, flywheels, gears, shafts, etc

Steps

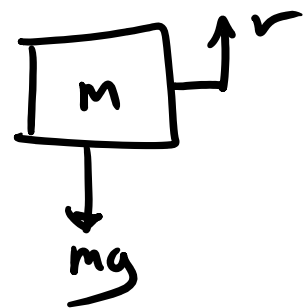
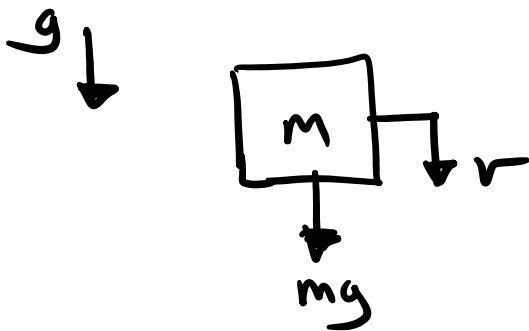
1. Create a free body diagram and specify positive absolute velocity directions and whether tension or compression is a positive force.
2. Use 1 junctions to represent all velocities.
3. Attach to each 1-junction any element that relates to the absolute velocity (I, C, R, S_c, S_f)
4. Use 0 junctions establish relative velocities and associated parts.
5. Eliminate bonds with zero absolute velocity.
6. Simplify the bond graph.

Example



Sign conventions

gravitational forces (on earth constant force generators)



$mg \downarrow \quad \vec{p} = m\vec{v} \rightarrow T \cdot m$

$mg \downarrow \quad \vec{p} = m\vec{v} \rightarrow I : m$

$$mg: Se \xrightarrow{mg} 1 \xrightarrow{\dot{p} = m\dot{v}} I: m$$

$$m\dot{v} = \dot{p} = \Sigma F = mg$$

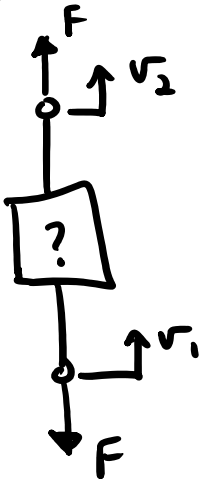
$$m\dot{v} - mg = 0$$

$$mg: Se \xleftarrow{mg} 1 \xrightarrow{m\dot{v}} I: m$$

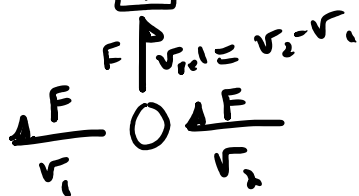
$$M\dot{v} = -mg$$

$$M\dot{v} + mg = 0$$

Compression & tension



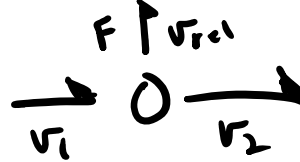
(+T)



$$v_{rel} = v_2 - v_1$$

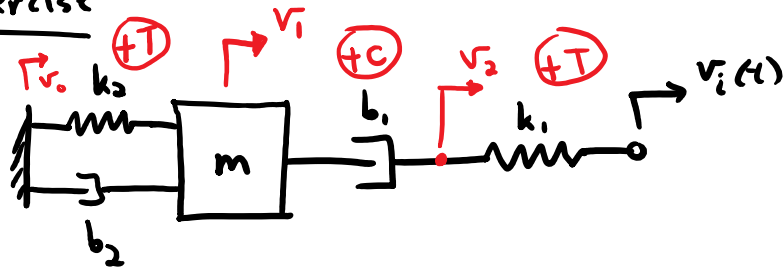


(+C)



$$v_{rel} = v_1 - v_2$$

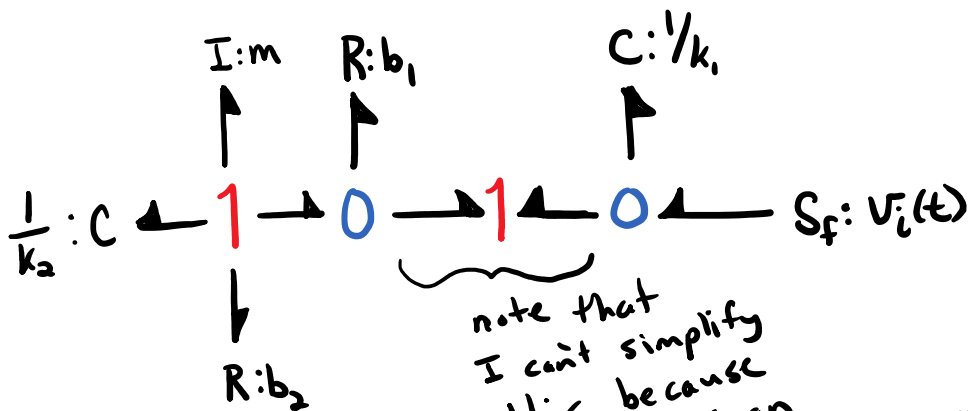
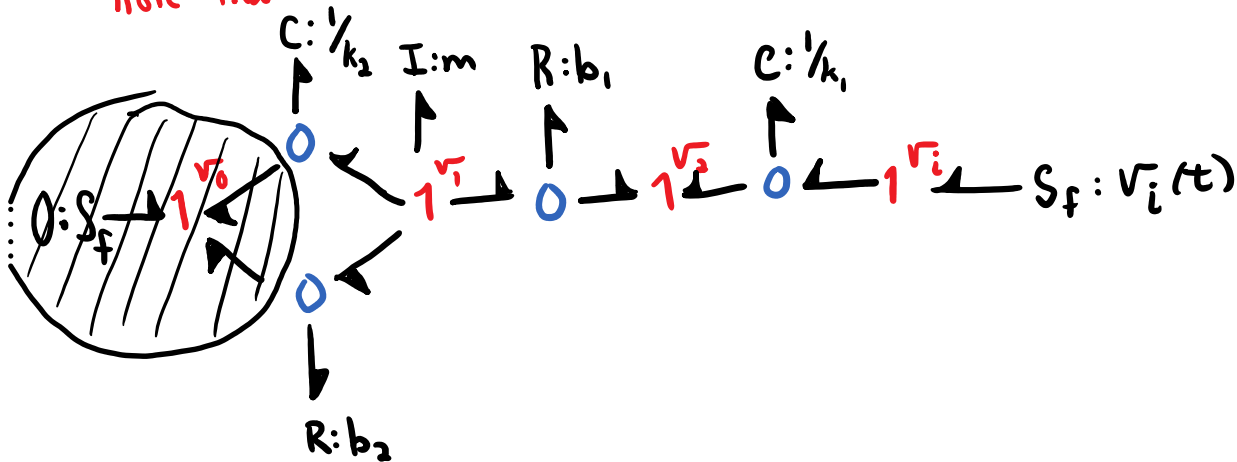
Exercise



linear springs and dampers

hint: need 3 non-zero velocities

note that I choose both tension and compression to show both



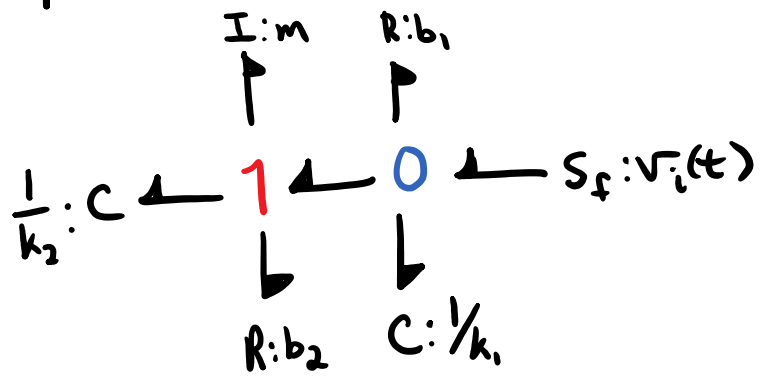
note that I can't simplify this because it defines an effort sign change due to my choice of effort sign conventions

If I had selected (+T) for all components the bond graph would simplify to:



1 1 1 are

graph with outer simplifying ...



both graphs are valid, the only difference is the sign conventions