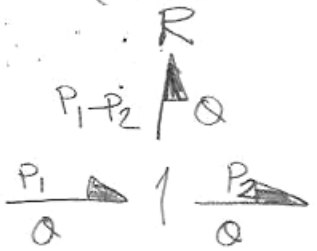
MCE503/403 Midterm 1 solution

In-class

1.a. The port variables are specified as the pressure differential and the flowrate (effort and flow). Therefore X is a resistor.

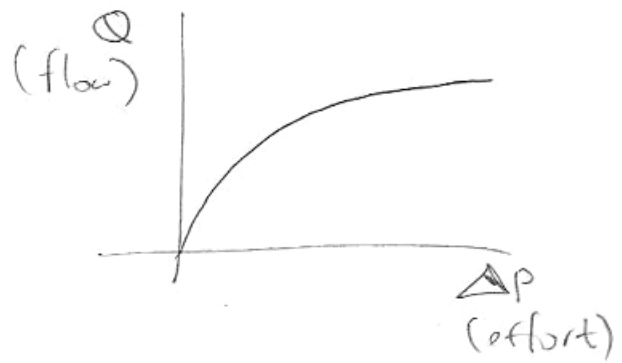


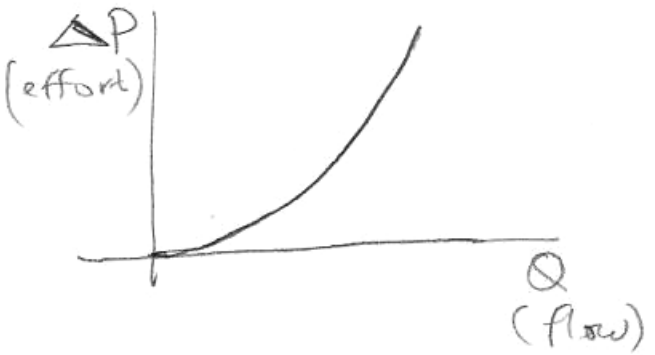
The flowrate is $Q = A_2 V_2 = A_2\sqrt{\frac{2(P_1-P_2)}{\rho}}$ for $P_1 \geq P_2$.

that is, $Q = A_2\sqrt{\frac{2\Delta P}{\rho}}$ or, solving for ΔP:

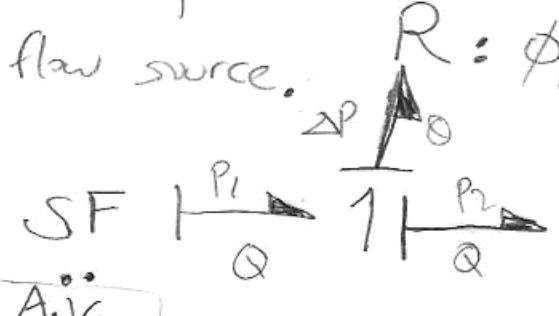
$$\Delta P = \frac{\rho}{2}\left(\frac{Q}{A_2}\right)^2$$ (constitutive equation in effort or flow form)

The graphs for each case look like:



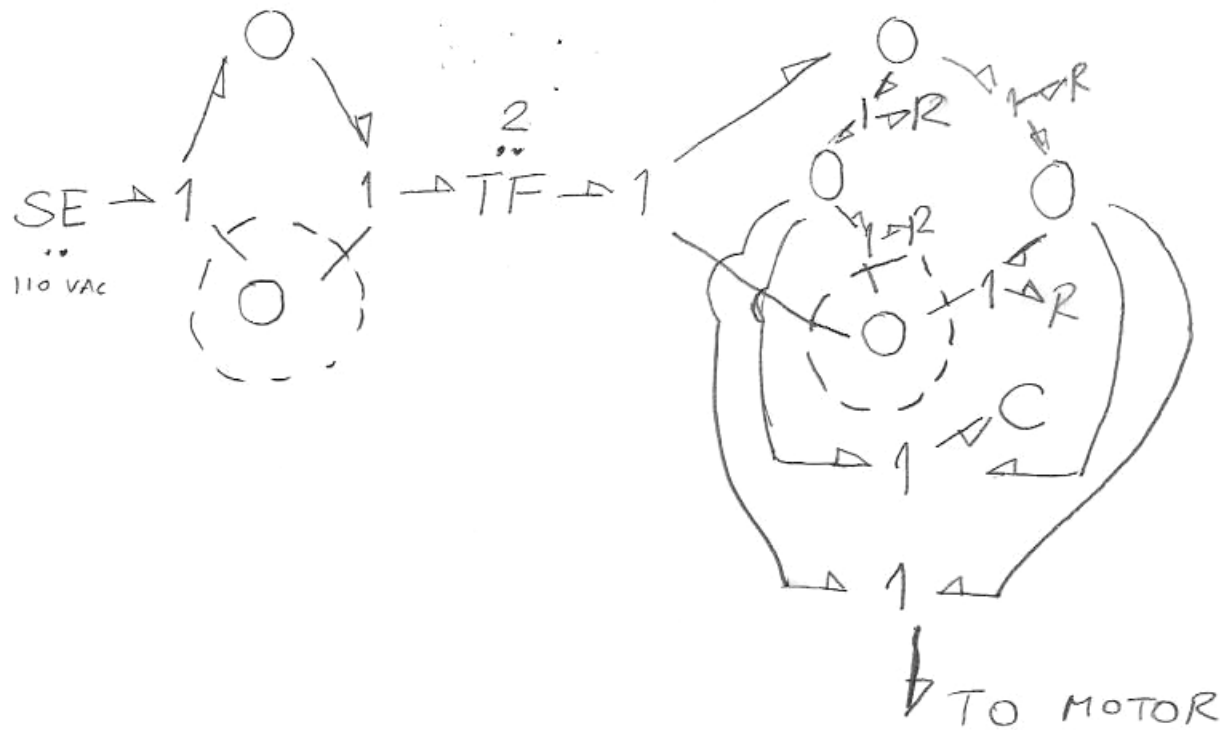


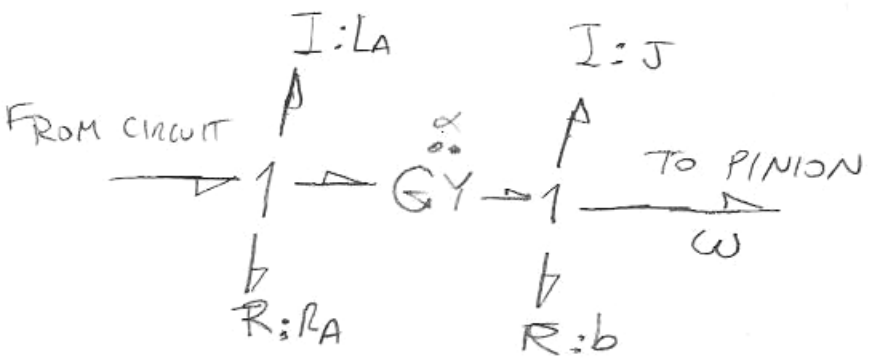
b. If the piston moves at prescribed velocity, it acts as a flow source.

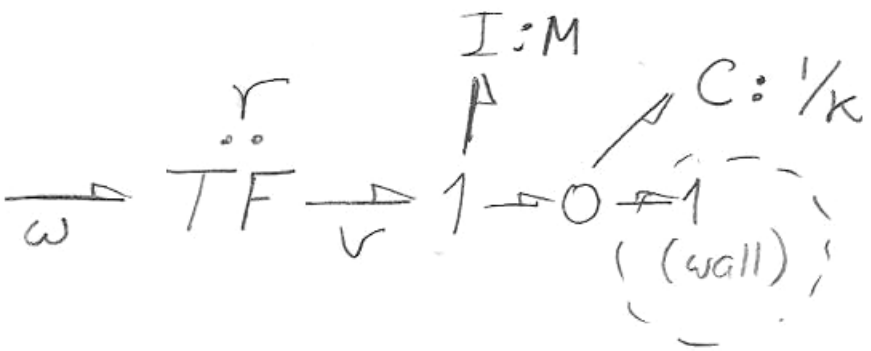


2. The overall BG needs to be constructed by sections:

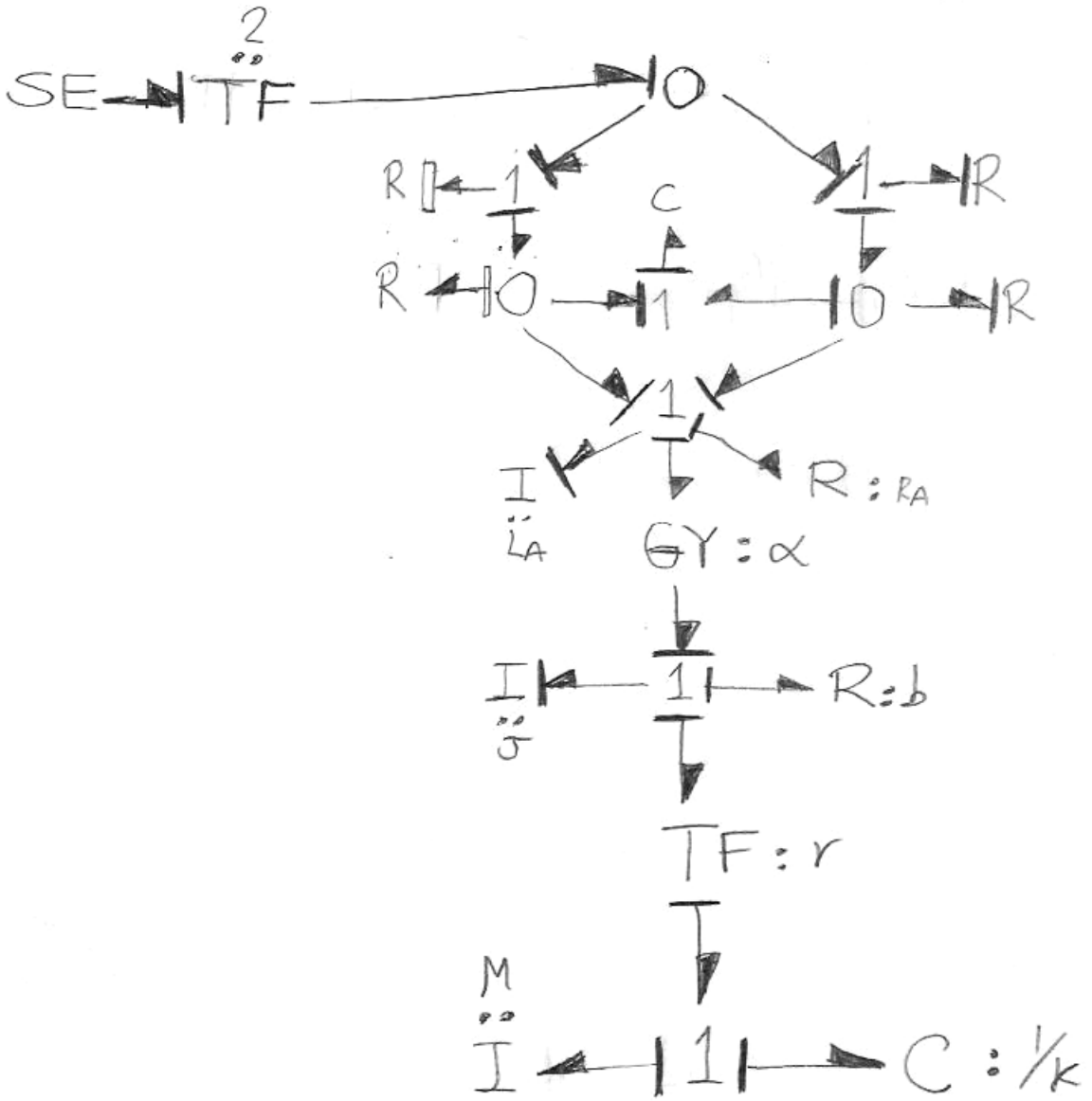
Between AC source and motor:





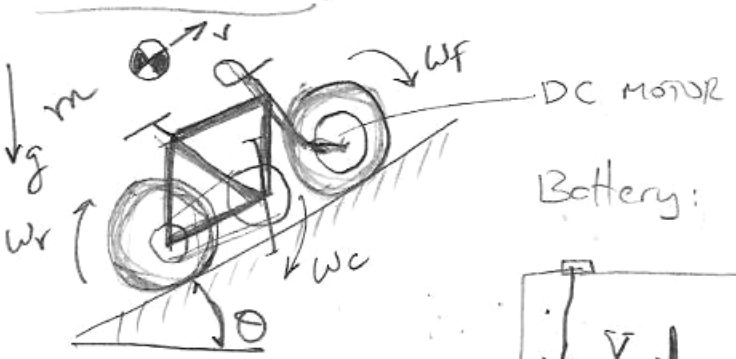


Carrying simplifications and completing causality:

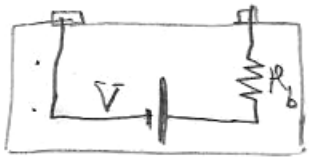


Several valid solutions exist for causality assignment, depending on which (I or C) elements receive preferred causality and which R's are chosen for arbitrary assignment.

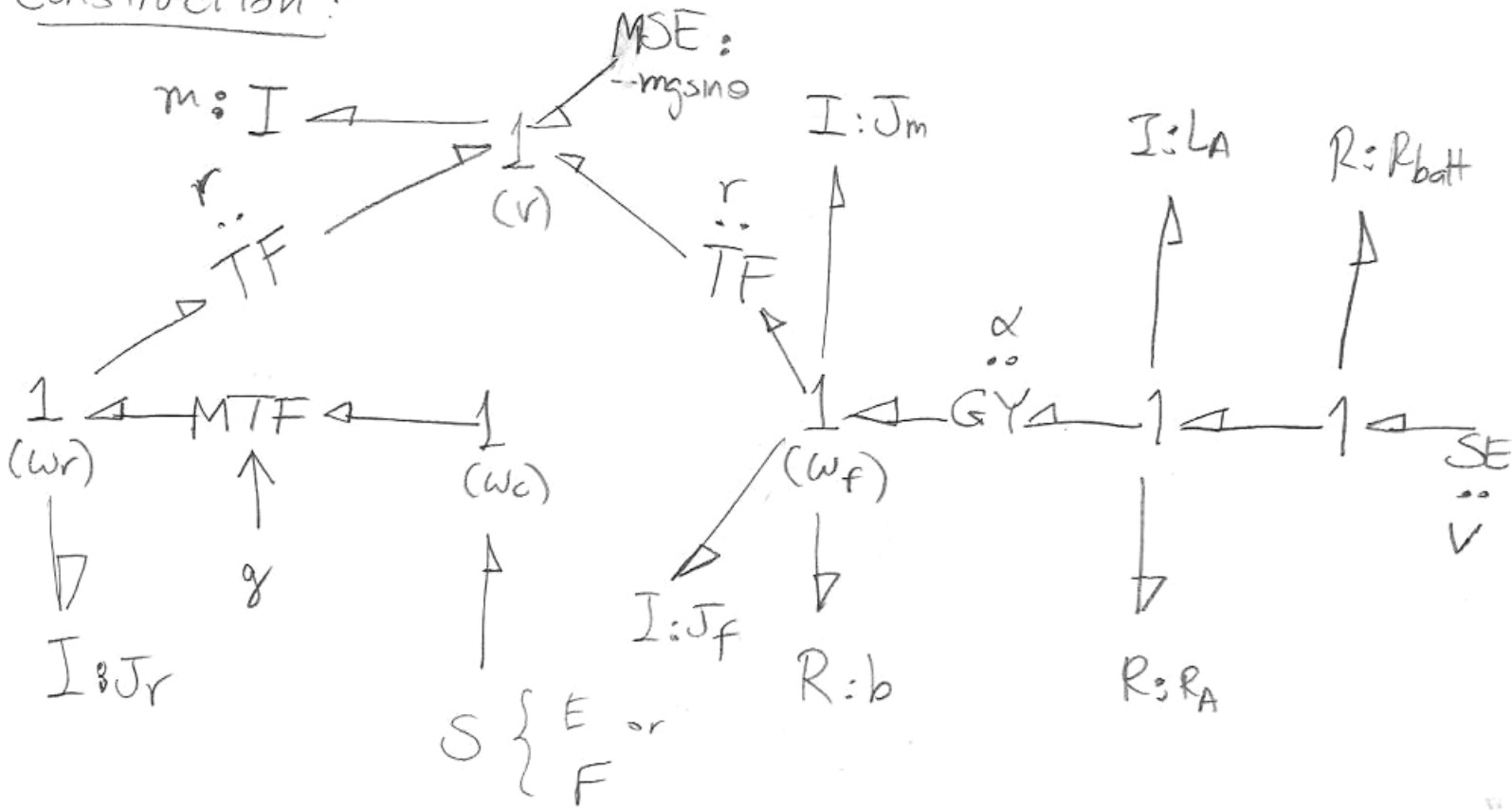
Take-home:



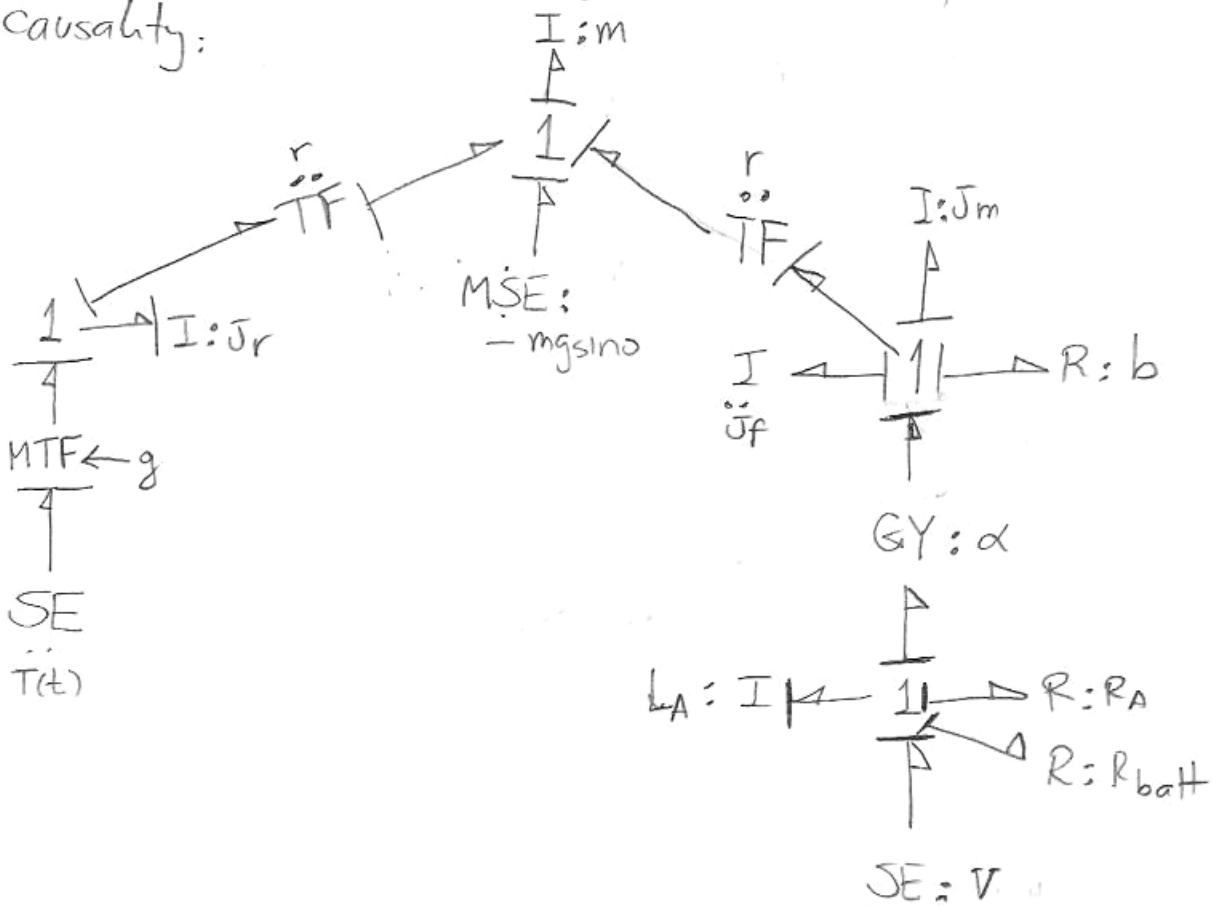
Battery:



Construction:



MCE403: Simplifying, using SE at the pedals and assigning causality:

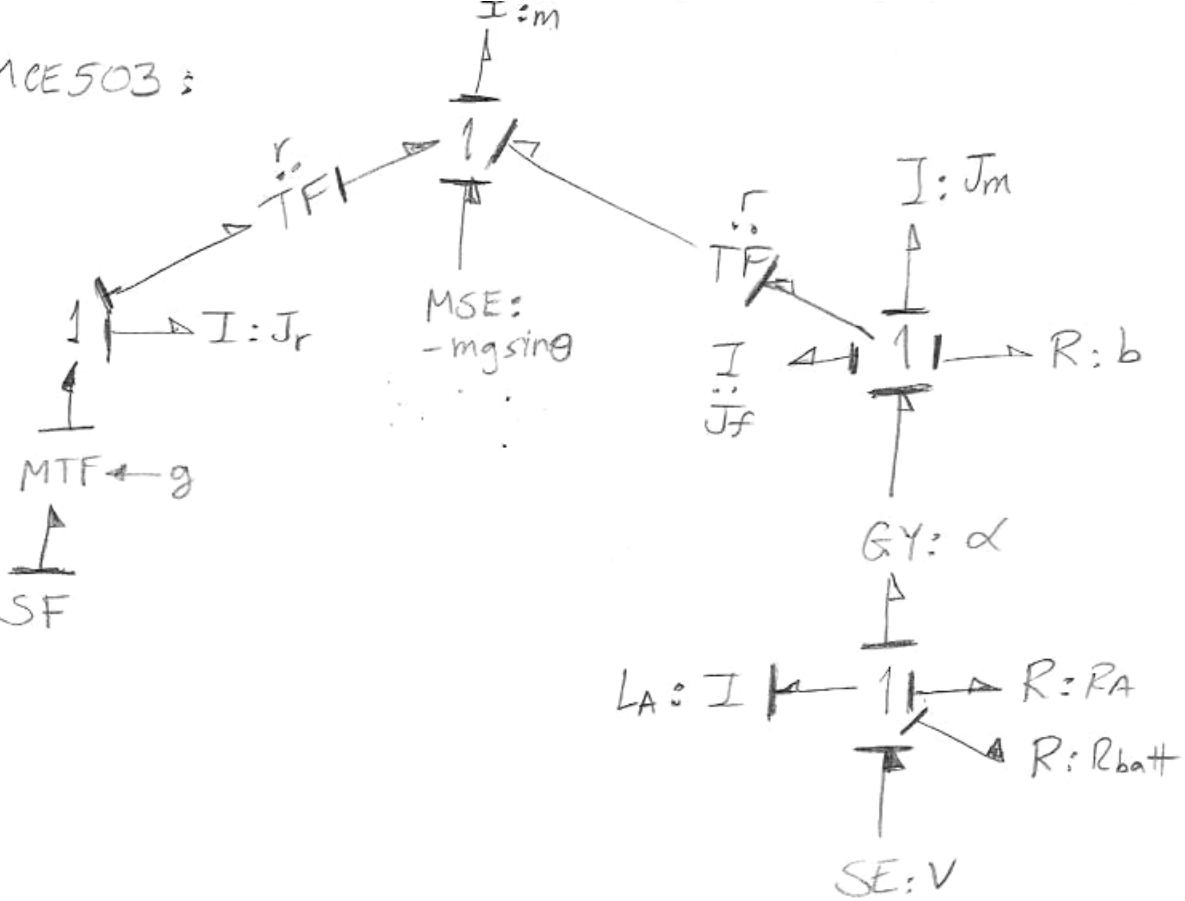


Observations:

- There are 5 'I' elements. Only 2 receive integral (preferred) causality.
- There are no undetermined causalities at R elements
- There are no causality conflicts (no mechanical inconsistency)

Note that the velocities are propagated through the system, forcing the pedals to rotate at certain speed (can't be changed if T(t) is to be met).

MCE503:



Observations:

- There are 5 'I' elements, but only 1 has integral (preferred) causality (the motor inductance).
- There are no undetermined causalities at R elements
- There are no causality conflicts. The flow source must provide whatever torque is necessary to maintain pedaling cadence (this may imply driving the motor, reversing current flow at the battery (charging))