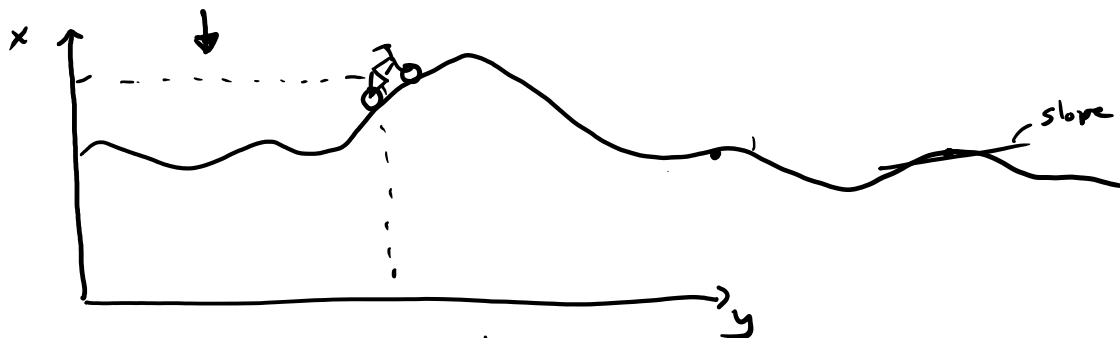


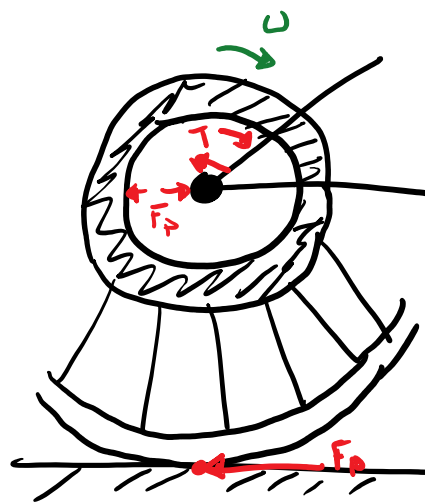
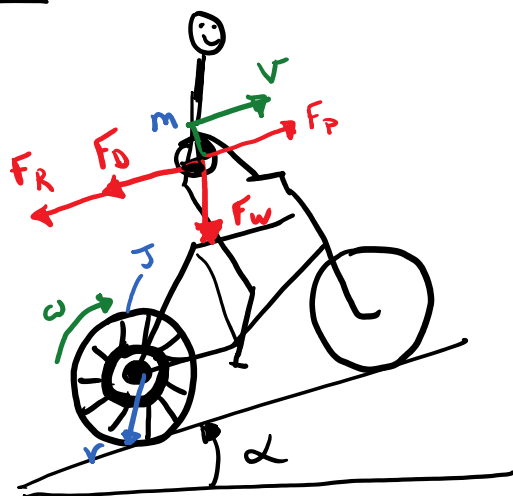
Electric Bicycle over 2D Profile

Question: How much energy is required to traverse some elevation profile?



Assumptions & Modeling Decisions

FBD

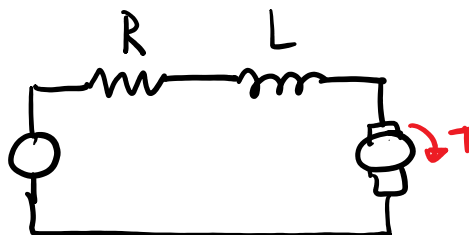


$$F_D = \frac{1}{2} \rho A v^2 \text{ Drag}$$

$$F_R = C_R F_N = C_R mg \cos \alpha$$

$$F_w = mg \sin \alpha \text{ weight}$$

Rolling resist $\propto(t)$



Newton's Laws

$$(1) m \dot{v} = F_N - F_D - F_R - F_w$$

Kinematics

$$(3) \dot{\theta} = \omega$$

Kirchoff's Voltage Law

Law

$$\textcircled{1} \quad m\dot{v} = F_p - F_D - F_R - F_w$$

Euler's Laws

$$\textcircled{2} \quad 2J\dot{\omega} = T_{\text{motor}} - T_{\text{fric}}$$

$$\textcircled{3} \quad \dot{\theta} = \omega$$

$$\textcircled{4} \quad \dot{x} = v \cos \alpha$$

$$\textcircled{5} \quad v = \omega r$$

8 equations!

Law

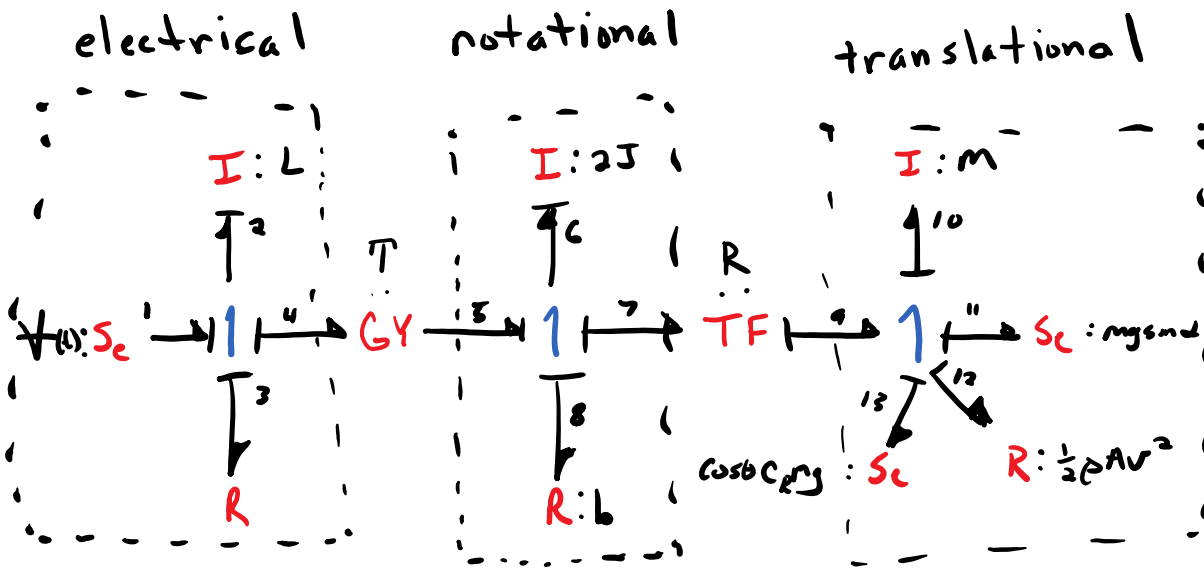
$$\textcircled{6} \quad L \frac{di}{dt} = V(t) - Ri - e_{\text{emf}}$$

$$\textcircled{7} \quad e_{\text{emf}} = T\omega$$

$$\textcircled{8} \quad T_{\text{motor}} = Ti$$

} DC motor model

Bond Graph Of Electric Bicycle Model



Two ordinary differential equations can be generated from the bond graph.

$$\textcircled{1} \dot{P}_2 = S_{e,1} - R_3 \frac{P_2}{I_2} - T \frac{P_6}{I_6}$$

$$\textcircled{2} \dot{P}_6 = \frac{T \frac{R_2}{I_2} - R_9 \frac{P_6}{I_6} - R(S_{e,11} + R_{12} + S_{e,13})}{1 + \frac{I_{10}}{I_6} R^2}$$



$T_{L t_1}$ is $x @ t_1$

✓