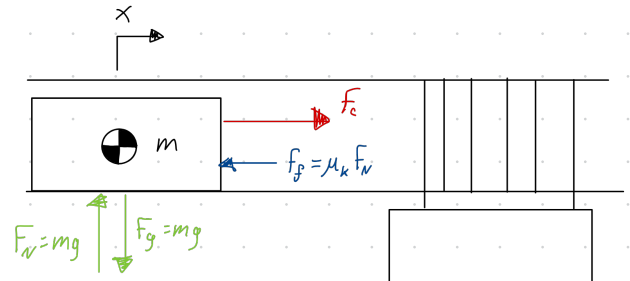
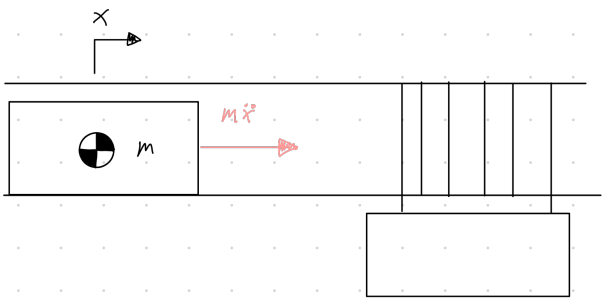
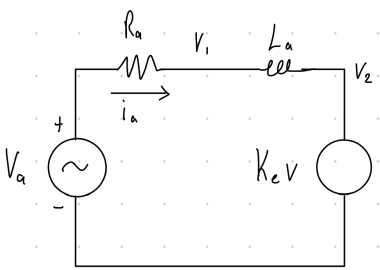


Neglect air resistance



$\Sigma F = m\ddot{x}$

$\Rightarrow F_c - f_f = m\ddot{x} \Rightarrow F_c - \mu_k mg = m\ddot{x}$



$i_a = \frac{V_a - V_1}{R_a} \Rightarrow V_1 = V_a - R_a i_a$

$S i_a = \frac{1}{L_a}(V_1 - V_2)$

$V_2 = K_e V$

$S i_a = \frac{1}{L_a}(V_1 - V_2) = \frac{1}{L_a}(V_a - R_a i_a - V_2) = \frac{1}{L_a}(V_a - R_a i_a - K_e V)$

$F_c = K_f i_a$

$\frac{di_a}{dt} = \frac{1}{L_a}(V_a - R_a i_a - K_e \dot{x}) \Rightarrow \frac{di_a}{dt} L_a = (V_a - R_a i_a - K_e \dot{x}) \Rightarrow \frac{di_a}{dt} L_a - V_a + R_a i_a = -K_e \dot{x} \Rightarrow \dot{x} =$

$m\ddot{x} = K_f i_a - \mu_k mg$

$\vec{x} = \begin{bmatrix} i_a \\ x \\ \dot{x} \end{bmatrix} \rightarrow \dot{\vec{x}} = \begin{bmatrix} \frac{di_a}{dt} \\ \dot{x} \\ \ddot{x} \end{bmatrix}$

$\frac{1}{L_a}(V_a - R i_a - K_e \dot{x})$

$\dot{x}$

$\frac{1}{m}(K_f i_a - \mu_K mg)$

$$\begin{bmatrix} -\frac{R}{L_a} & 0 & -\frac{K_e}{L_a} \\ 0 & 0 & 1 \\ \frac{K_f}{m} & 0 & 0 \end{bmatrix} \begin{bmatrix} i_a \\ x \\ \dot{x} \end{bmatrix} + \begin{bmatrix} \frac{V_a}{L_a} \\ 0 \\ \mu_K g \end{bmatrix} = \begin{bmatrix} \frac{di_a}{dt} \\ \dot{x} \\ \ddot{x} \end{bmatrix}$$