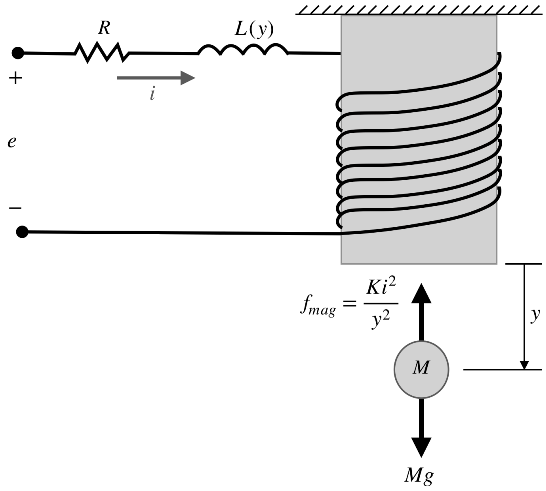
A maglev system has been shown here where the goal is to keep the metal ball levitated at the nominal equilibrium position by controlling the current of the electromagnet with the voltage $e(t)$. The resistance of the coil is R and the inductance is $L(y) = L/y(t)$, where L is a constant. The electromagnet force is $f_{mag} = Ki^2/y^2$.



$$R = 2(\Omega)$$
$$L = 0.001(H.mm)$$
$$K = 10(N.mm^2/A^2)$$
$$M = 20(gram)$$

Important: *Maximum input voltage of 12 volts (control signal) can not be exceeded during system operation.*

Part A : Modeling

- Define the states and find the nonlinear state equations.
- Linearize the state equations about the equilibrium point, $y^* = 10mm$ to obtain the linear state space equations.
- Use a sample time of $T = 0.001$ sec, to discretize the state-space equations.
- Obtain the discrete transfer function of the system.

Part B : Frequency-Domain Design

- Design a digital controller using direct design techniques to stabilize the system and achieve $MP = 5\%$ and $t_r = 0.1$ sec.
- Simulate the whole system comprising the discrete transfer function of the plant and the digital controller using simulink and show the response of the system to initial conditions: $y(0) = 12mm$ and $\dot{y}(0) = 0$ by plotting voltage, $e(t)$, current, $i(t)$, displacement, $y(t)$ and the error signal. (Note: Make necessary adjustment to the controller so that the maximum voltage supply limit is not exceeded.)
- Repeat the previous task by replacing the discrete transfer function of the plant with nonlinear continuous state-space equations of the plant and compare the results.

Part C: Time-Domain Design

- Put the state-space equations in normal form and check the controllability and observability of the system.
- Design a state-feedback system to achieve $MP = 5\,\%$ and $t_r = 0.1\,\text{sec}$.
- Design a full-order observer with deadbeat performance.
- Simulate the whole system comprising the discrete state-space equations of the plant, state feedback gain and the observer using simulink and show the response of the system to initial conditions: $y(0) = 12mm$ and $\dot{y}(0) = 0$ by plotting voltage, $e(t)$, current, $i(t)$, displacement, $y(t)$ and the error signal. (Note: Make necessary adjustment to the controller so that the maximum voltage supply limit is not exceeded.)
- Repeat the previous task by replacing the discrete state-space equations with nonlinear continuous state-space equations of the plant and compare the results.
- Add a white noise to the sensor (displacement signal) and study the impact of eigenvalues of the observer on the overall system performance.

Part D: Sinusoidal Disturbance Rejection

Assuming a $10-Hz$ sinusoidal force disturbance with the magnitude of $0.02\ N$ is being exerted on the steel ball:

- Repeat the simulation of Part C and show the impact of this disturbance on ball position.
- Design an observer to estimate the disturbance and compensate the system to remove its impact.
- Perform a complete system simulation and compare the results with the system without disturbance compensation.

Deliverables:

- **The report** comprising all design, calculations, description, snapshots of simulink models, and simulation results in the form of a single PDF file. (Note: The whole report must be typed. The hand-written reports will not be graded)
- All **Matlab/Simulink Files** in the form of a single zip file. (Note: Make sure the model can be easily run and validated without any problem)