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Lab 5 Magnetic Levitation Controller I

Figure 1 shows a magnetic levitation system. In this and the next lab, we will design and construct a feedback controller for this system so that the steel ball can be levitated at a fix distance from the electromagnet. In this lab, we will develop a model for the open-loop system, which will be linearized for use in the design of a feedback controller for the next lab.

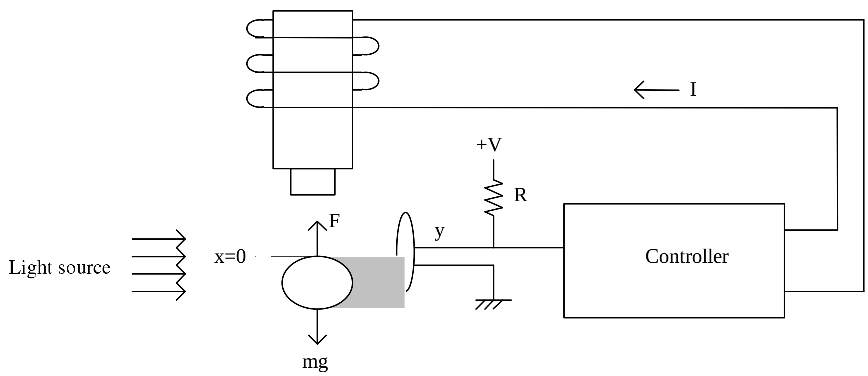

Figure 1

The equation of motion of the ball is:

$$m*a = f(I,x) - m*g$$
$$y = h(x)$$

where a: acceleration of the ball (m/s^2),
m: mass of the ball (kg),
g: gravitational constant (m/s^2),
I: current in Amperes (A),
x: ball position in meters (m).
f(I,x): magnetic force (N) as a nonlinear function of x and I,
y(x): output voltage (V) as a nonlinear function of the position x.

The objective of this lab is to determine the nonlinear function f(I,x) and y(x) and to derive a linearized model.

Procedure:

The x=0 position should be set at about 6mm from the bottom of the electromagnet.

Measure the range of variation of the resistance of the photo-resistor as the ball's shadow covers from none to all of the resistor surface. Using this data, determine a suitable resistor R to use in series with the photo resistor as shown in Figure 1. Also determine if V=15V is too high to apply to this circuit. Note: the photo-resistor power dissipation is rated at 250mW.

Move the ball over the entire range (shadowing from none to the entire photo-resistor surface). Record the voltage output y versus ball position x. Plot the data and find the slope of the curve at x=0.

To determine f(i,x), take force readings (make sure to convert gram to Newton) over the entire x range and from 0.0 A to 5.0 A for the current i. Plot the function f(i,x) as a 3D plot.

Linearize the system equation at x=0 and I=Io where Io is the current that renders zero net force at x=0. In other words, f(Io,0)=mg and (x=0 and I=Io) is an equilibrium point of the system.

Repeat the above step for $x=x_{top}$ and $x=x_{bottom}$ where x_{top} is the position at which the photo-resistor is completely covered by the ball's shadow and x_{bottom} is the other extreme.

Based on the linearized system model and considering I as the input and y as the output, determine the transfer function of the system and find the poles of the system. Sketch the root locus of the system. Is the system stable for a value of the feedback gain K?