MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.007 – Electromagnetic Energy: From Motors to Lasers
Spring 2011

Lab 2 Pre-Lab: Coil Gun
Due at beginning of lab, March 1/March 2, 2011

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1 Simulated Data for Height of Magnet on Mars

We have provided simulated data in a file named `marsvoltage.csv`, with data similar to what you would obtain if you performed your lab measurements on Mars. For the prelab, you should download this file and walk through the lab with this simulated data. Separately you need to know that the length of the four-coil back emf test tube was 0.5 m long. The coil centers were at $y_1 = 0.1$ m, $y_2 = 0.2$ m, $y_3 = 0.3$ m, and $y_4 = 0.4$ m.

1.1 Analyze Voltage Data

- **Import your data into MATLAB using** `File → Import Data...`. It will prompt you for a file; select your downloaded `marsvoltage.csv` file. The Import Wizard window will appear. You want to select "Comma" as the column separator and "1" as the number of text header lines. Click Next. Here you want to select "Create vectors from each column using column names." Click Finish. The data has been loaded into `V1`, `V2`, `V3`, `V4`, and `t`.

- **Plot V_{Bemf} as a function of t. The zeros of the voltage waveform correspond to times when the coil was in the center of the coil.** Plot this by executing the command `plot(t, V1, t, V2, t, V3, t, V4)`. Remember that variable names in MATLAB are case sensitive. Your plot should have four voltage spikes corresponding to the four coils.

- **Using your plot or looking through the data, find t_1 through t_4.** These are the times when the voltage reverses across a coil, corresponding to when the magnet is exactly passing through the center of the coil. Record your four times in variables `t1`, `t2`, `t3`, and `t4`. [Hint: you can use the "Data Cursor" tool to look at individual data points on a MATLAB plot. This is the icon that looks like a Post-It note attached to a plus sign.

- **Plot y as a function of t. You should have four points on this curve. The derivative of this curve is velocity.** The easiest way to do this is put your y measurements (given above) into MATLAB `y1` through `y4`, and then run the command `plot([t1 t2 t3 t4], [y1 y2 y3 y4])`. It should look parabolic.

- **Find the constant of acceleration, a, such that $y = at^2/2$.** This is purely a mathematical exercise and can be done in many ways. For those of you interested in a MATLAB function to relieve you of having to remember how to fit parabolas, try the following: `c = polyfit([t1 t2 t3 t4],[y1 y2 y3 y4],2)`. (Use `help polyfit` to learn more.) The result is three numbers, c_1, c_2, and c_3, corresponding to the coefficients of $c_1 t^2 + c_2 t + c_3 = y$. Comparing this to the expected function of $y = at^2/2 + v_o t + y_o$, we can identify $a/2 = c_1$. What is the acceleration, a? [Hint: Mars' gravity is one-third of Earth's, but there may also be air resistance.]

- **Use $v = dy/dt$ to find $v(t)$.** We can now find the velocity of our magnet as it moves through the test station. Note that $v(t) = dy/dt = at + v_o = 2c_1 t + c_2$. Create the velocity data by executing `v = 2*c(1)*t+c(2);`, where `c(1)` and `c(2)` are the coefficients that you found above. The result is rather unexciting; you have a new variable called `v` in your workspace.

- **Divide $V_{\text{Bemf}}(t)$ by $v(t)$ to find $d\lambda/dy$.** Here you'll have to pick one of the four voltage wave forms to use as your back emf (or you can try them all). Say you pick the first one stored in `V1`. To find

$d\lambda/dy$, use `dldy1=V1./v`. You may see a Divide by zero warning, which you can ignore because it only applies to the first point when $v_0 = 0$.

- **Plot $d\lambda/dy$ as a function of y.** While we have $d\lambda/dy$, we actually never got a y vector. To create y, use $y = c_1 t^2 + c_2 t + c_3$: `y=c(1)*t.^2+c(2)*t+c(3);`. To create the plot, use `plot(y, dldy1)`. To see all of the curves, use `plot(y, dldy1, y, dldy2, y, dldy3, y, dldy4)`. The divide by zero has messed up the vertical scale. We can correct this by changing the bounds of the axes using the command `axis([xmin xmax ymin ymax])`. (You should pick bounds that make your graph look good.)

2 Analyze Current Data

We're over halfway done. Now let's find the average current. A typical current output is shown as the green curve in the figure below. Using the right scale, estimate the average current through the solenoid while the magnet is inside. The magnet has effectively left the solenoid when i reaches a local minimum around 5 ms. Record this value for i_{avg} in MATLAB as `i_avg`. It should be approximately 16A.
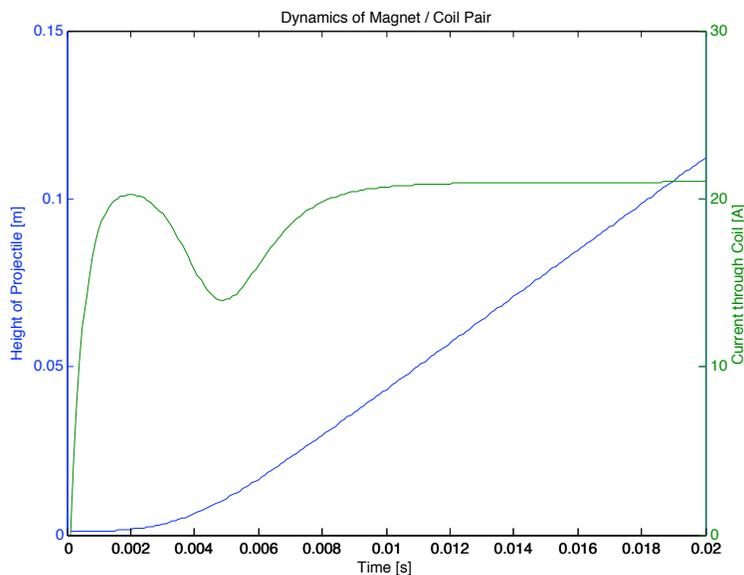
3 Calculate Height

We are now ready to calculate the height. Assume $m = 10$ g (it may be different in lab) and recall:

$$mgh = \int_0^d f(y) \cdot dy = \int_0^d (i_{\text{avg}}) \left(\frac{d\lambda}{dy} \right) dy = i_{\text{avg}} \int_0^d \left(\frac{d\lambda}{dy} \right) dy \tag{1}$$

First of all, the bounds on this integral go from 0 to d. If we look at our plot for $d\lambda/dy$ vs. y, we only want to use the right half of one pulse. Using the "Data Cursor" tool, we can find the values where the curve is above zero. There is no reverse lookup in MATLAB, but we can look through the vector to find the indices over which to integrate.

Now we'll use the `trapz` function to integrate. Type `help trapz` for more information. The integration is simply performed as `i_avg*trapz(y(694:754),dldy2(694:754))`. The answer returned is in Joules. Note that in lab it will probably be best to use data from the third or fourth coil.

Recalling that you are on Mars with $g \approx 3.3$ m/s^2 how high will the magnet fly? _____ **[m].**

- Make sure to bring all of your prelab plots to the lab!

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