Cavendish Experiment: Measuring G

In this experiment you will measure the gravitational constant using an apparatus like that used by Henry Cavendish. We have the Pasco AP-8215 Gravitational Torsion Balance. You will use python code to fit the oscillation of the torsion pendulum to extract the period and the equilibrium positions, ultimately finding G.

Prelab Presentation. Your presentation should answer the following questions.
The answers can be found in the Pasco AP-8215 Instruction Manual pp 1-18). We are using method 2 as described in the manual.

- What is G?
- Explain the parts of your apparatus. What do they do?
- Explain the procedure. How is G calculated? Explain the correction? Don't derive the equations, just explain the basic physics behind them.
- What do you need to measure?
- What classical mathematical model will you use for fitting? What adjustable parameters will you need in the fit?
- What is the accepted value of G and its uncertainty?

The experiment.

You will need to set up the experiment. (See the manual, pp 1-13.)

You will measure G using method 2. The laser projects the deflection of the torsion pendulum bob onto the backboard at the far end of the lab. You can measure the deflection by reading the position from a scale every 15 s. Some students take a video and extract the position with software. The tricky part is making sure the bob is twisting freely without hitting a stop or other part of the structure. If it does, you can be fooled. The hallmark of that problem is sudden acceleration of the bob. Too large an amplitude will obviously do this too. Make sure the bob is undergoing uniform oscillation before investing time on collecting data. Then take some preliminary data and graph it. Verify that you are observing a damped sine wave. For your analysis you will fit the data to your model. Make sure you have included the appropriate number adjustable parameters to account for the phase offset and the equilibrium position.

A word of caution that will save you time. Typically, the apparatus is close to proper alignment. Familiarize yourself with it and the operation before you perform drastic adjustments. DO NOT LEAN ON THE TABLE when preparing to make measurements. That will cause the bob to swing. (How many types of vibration does the bob exhibit? Which one is useful in this experiment?) The zero adjust knob does not work properly so you need to turn the brass ribbon directly. That is extremely sensitive.

EXTREME CAUTION: The torsion ribbon is very fragile! The cost of $50 each.

Your python code needs to do the following:

- **Read in your datafiles.** I recommend entering your data into excel or some other spreadsheet program and then saving them as a comma or tab delimited text file format or a csv format. These will be straight forward to read with Python. It is appropriate to use a spreadsheet program to graph your data as you take it. However, further analysis needs to be done in Python.
- **Fit the data to your model.** Initially you should perform fits on each decaying oscillation individually. Plot the data and the best fit curve for comparison.
- **Fit your data groups simultaneously.** You will notice that the period should be the same for all your measurements. You can fit the measurements for the two different equilibrium positions simultaneously. To do that you need to combine the two fitting operations so that the period parameter is linked. Be careful, the other fit parameters will need to be independent. Experiment with this. Always compare the fit to the data. Repeat for additional sets of measurements.
- **Final plot.** The final graph for your write up should show the data (with error bars), the best fit function for each of the two equilibrium positions, and lines showing the best fit equilibrium positions. This will look like Fig 18 in the manual, but the traces for the two sets of oscillations will not be joined. You will need to adjust the plot order, colors, and transparency for readability. I recommend color coding the data and fit by the slit.
- **Report your result.** The value of G with uncertainty and compare it to the known value.