27.6: Sample proposal (Measuring g using a pendulum)

27.6.1: Summary and Goal

One can measure the gravitational constant, g, by measuring the period of a pendulum of a known length, requiring only a string, mass, ruler and timer. Because the experimental design can be easily adjusted and the experiment is simple, the experiment has a high chance of success.

27.6.2: Method and equipment

The period of a pendulum of length L is easily shown to be given by:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Thus, by measuring the period, T, of a pendulum as well as its length, one can determine the value of g:

$$g = \frac{4\pi^2 L}{T^2}$$

One can carry out the experiment using the following materials:

- a mass
- inextensible string
- a meter stick
- stand to attach string
- cell-phone with timer and slow-motion camera

The materials listed above are all inexpensive and can be easily obtained. It is recommended that the experiment be completed indoors at room temperature, in order to minimize any environmental effects.

One should tie the string to the mass at one end and the stand at the other, and measure the length, L, of the string from the point on the stand to the center of mass of the mass.

The period of the pendulum is measured by timing how long it takes the pendulum to complete 20 oscillations and dividing that time by 20. This will be more precise than trying to time the period of a single oscillation.

The pendulum should be released from 90°. When releasing the pendulum, the string should be pulled taught, and the team member's eye that is measuring the angle should be situated parallel to the measuring device.

A slow-motion video will be taken of the pendulum to track the time of the oscillation in order to minimize error due to reaction time. The team member in charge of taking the video will start the video shortly before the pendulum is released. After releasing the pendulum, the team should record 20 oscillations before stopping the pendulum and the video. Data from the video should be entered into a Jupyter Notebook. It is recommended that this measurement be repeated at least 5 times.

The uncertainty in the time should be taken as half of the smallest division of the cell-phone timer, and the uncertainty in the length of the pendulum as half the smallest division of the meter stick used to measure the length of the pendulum.

Foreseeable issues in this experiment may arise when trying to find a string that is optimally inextensible, as any extensibility will cause error in the results. Additionally, being able to measure exactly 90 as the drop-angle for the pendulum could be difficult. In order to correct for this, the team member who is dropping the pendulum must stand directly parallel to the measuring device, minimizing parallax error.

The measure of success will be determined by the uncertainty and precision of the measured value of g. If the measured value of g has a relative uncertainty that is less than 10 %, and is consistent with the accepted value, then one can consider the experiment to have been carried out successfully.

27.6.3: Team and timeline

One should be able to complete the experiment and analysis in approximately 1 hour and 30 minutes with the data being collected in the first 30 minutes. The remainder of the time should be spent processing the data and writing the experimental report.

Following the strengths of the members of the team, the following people should be responsible for leading the following tasks, while everyone participates:

- Alice: building the pendulum
- Brice: taking the measurements
- Chloë: analyzing the data
- Dennis: writing and formatting
