27.8: Sample lab report (Measuring g using a pendulum)

27.8.1: Abstract

In this experiment, we measured g by measuring the period of a pendulum of a known length. We measured $g = 7.65 \pm 0.378 \mathrm{m/s}^2$. This correspond to a relative difference of 22% with the accepted value ($9.8 \mathrm{m/s}^2$), and our result is not consistent with the accepted value.

27.8.2: Theory

A pendulum exhibits simple harmonic motion (SHM), which allowed us to measure the gravitational constant by measuring the period of the pendulum. The period, T, of a pendulum of length L undergoing simple harmonic motion is given by:

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

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

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

We assumed that the frequency and period of the pendulum depend on the length of the pendulum string, rather than the angle from which it was dropped.

27.8.3: Predictions

We built the pendulum with a length $L = 1.0000 \pm 0.0005 \mathrm{m}$ that was measured with a ruler with $1 \mathrm{mm}$ graduations (thus a negligible uncertainty in L). We plan to measure the period of one oscillation by measuring the time to it takes the pendulum to go through 20 oscillations and dividing that by 20. The period for one oscillation, based on our value of L and the accepted value for g, is expected to be $T = 2.0 \mathrm{s}$. We expect that we can measure the time for 20 oscillations with an uncertainty of $0.5 \mathrm{s}$. We thus expect to measure one oscillation with an uncertainty of $0.025 \mathrm{s}$ (about 1% relative uncertainty on the period). We thus expect that we should be able to measure g with a relative uncertainty of the order of 1%

27.8.4: Procedure

The experiment was conducted in a laboratory indoors.

1. Construction of the pendulum

We constructed the pendulum by attaching a inextensible string to a stand on one end and to a mass on the other end. The mass, string and stand were attached together with knots. We adjusted the knots so that the length of the pendulum was $1.0000 \pm 0.0005 \mathrm{m}$ The uncertainty is given by half of the smallest division of the ruler that we used.

2. Measurement of the period

The pendulum was released from 90 and its period was measured by filming the pendulum with a cell-phone camera and using the phone's built-in time. In order to minimize the uncertainty in the period, we measured the time for the pendulum to make 20 oscillations, and divided that time by 20. We repeated this measurement five times. We transcribed the measurements from the cell-phone into a Jupyter Notebook.

27.8.5: Data and Analysis

Using a $100 \mathrm{g}$ mass and $1.0 \mathrm{m}$ ruler stick, the period of 20 oscillations was measured over 5 trials. The corresponding value of g for each of these trials was calculated. The following data for each trial and corresponding value of g are shown in the table below.

Trial	Angle (Degrees)	Measured Period (s)	Value of g m/s^2
1	90	2.24	7.87
2	90	2.37	7.03

Trial	Angle (Degrees)	Measured Period (s)	Value of g m/s^2
3	90	2.28	7.59
4	90	2.26	7.73
5	90	2.22	8.01

Table A3.8.1

Our final measured value of g is $(7.65 \pm 0.378)\mathrm{m/s}^2$. This was calculated using the mean of the values of g from the last column and the corresponding standard deviation. The relative uncertainty on our measured value of g is 4.9% and the relative difference with the accepted value of $9.8\mathrm{m/s}^2$ is 22%, well above our relative uncertainty.

27.8.6: Discussion and Conclusion

In this experiment, we measured $g = (7.65 \pm 0.378)\mathrm{m/s}^2$. This has a relative difference of 22% with the accepted value and our measured value is not consistent with the accepted value. All of our measured values were systematically lower than expected, as our measured periods were all systematically higher than the $\S 2.0\mathrm{s}$ that we expected from our prediction. We also found that our measurement of g had a much larger uncertainty (as determined from the spread in values that we obtained), compared to the 1% relative uncertainty that we predicted.

We suspect that by using 20 oscillations, the pendulum slowed down due to friction, and this resulted in a deviation from simple harmonic motion. This is consistent with the fact that our measured periods are systematically higher. We also worry that we were not able to accurately measure the angle from which the pendulum was released, as we did not use a protractor.

If this experiment could be redone, measuring 10 oscillations of the pendulum, rather than 20 oscillations, could provide a more precise value of g. Additionally, a protractor could be taped to the top of the pendulum stand, with the ruler taped to the protractor. This way, the pendulum could be dropped from a near-perfect 90° rather than a rough estimate.