Lab 1

Period of a Pendulum

Physical Models: Simple Harmonic Oscillator

Analysis Tools: Mean, Standard Deviation, Standard Deviation of the Mean, t-score

Experimental Systems: PASCO Pendulum Setup, Hanging Clip

Equipment: Stopwatch, Photogate, Cell Phone Holder, Tape Measure, Protractor, Scissors

Safety Concerns: Careful not to allow your pendulum to swing and hit people and, correspondingly, watch out for swinging pendulums while walking around the room!

Introduction

The goal of lab this week and next will revolve around investigating the period of a pendulum. In the Prelab Activity for this week, you were introduced to a model that predicted that the period obeys the relation:

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{1.1}$$

Where T is the period, l is the length (from the pivot to the hanging object's center of mass), $g \approx 9.81$ N/kg is the strength of the Earth's gravitation field. Most importantly the amplitude, θ, doesn't show up anywhere in the formula and therefore according to the model has no effect on the period.

This means that according to the model, the period of a given pendulum is the same regardless of the size of a pendulum's "swing". It's this aspect of the model we'll seek to test. We will emphasize obtaining as precise a test of this as possible.

Part 1. Period vs. Amplitude

First you'll need to set up a pendulum to experiment with. You're welcome to choose any length of string and any of the four hanging masses. Just make sure to record which of the hanging masses you choose and the length l of the pendulum for later reference.

Quick Check: Once your pendulum is set up, try displacing the pendulum a bit, letting it go, and watching it oscillate a few times. Are you able to do this? Ask your TA if you're having trouble with your setup. Try a few different amplitudes (different sized displacements). Does it *seem* like there's any difference in the period?

Designing Your Experiment: Now, write down a plan for a high-precision measurement of the period of your pendulum for 4 different amplitudes of your choice. Make sure to include at least one amplitude $\leq 10°$ and at least one $\geq 30°$ Use last week's lessons on measurement with the stopwatch and statistical uncertainty to inform your decisions. Plan to use the t-score criteria described by your TA to compare results from different amplitudes. Compare all 4 results pairwise (6 total comparisons).

Check in with Another Group: Briefly discuss your plans with another group. They may provide you with additional ideas and feedback. Note one similarity and one difference between your approaches.

Conducting Your Experiment: Go ahead and give it a shot. You can change your method around while you're at it, you don't need to treat your previous decisions as a contract. Make sure all your data is labeled clearly with units, and that you keep track of uncertainty and try to minimize it.

Forming a Conclusion: Does your data support the model that the period is independent of amplitude?

Check in with Another Group: Check back in with the same group you discussed things with before. How do your results compare? Note two similarities and/or differences between what you found, and use this to inform your proposals for future iterations.

Part 2. Period vs. Amplitude Redux

Options for Improvement: Regardless of what you found in Part 1, your goal will be to improve your confidence in your measurements so that you can correspondingly increase your confidence in your conclusions.

How you improve the precision of your measurements will depend on whether the limiting factor in your Part 1 was systematic error or random error. Make an assessment of which was larger. Then consider the following. Pick the option which makes the most sense given your assessment:

- According to the manufacturer the stopwatch systematic uncertainty is actually *much lower* than the digital display leads you to believe. Rather than .01 seconds, it's actually accurate to within .01 %. So whereas normally there would be no value in taking additional measurements once $\sigma/\sqrt{(N)} < .01$ second, you actually can keep reducing $\sigma/\sqrt{(N)}$ all the way down to $.0001 \times \bar{x}$. For example if your mean value is 5 seconds you can keep taking additional measurements until the uncertainty is .0005 seconds. This is a good option to reduce systematic uncertainty if it was the limiting factor in Part 1 (if you got the standard deviation of the mean down to, or below, .01s in most of your measurements in Part 1).

- On your table you have a PASCO photogate. You may use this to measure time instead of the stopwatch. This is a good option if you'd like to reduce random uncertainty associated with e.g. your reaction times or if your standard deviation of the mean was larger than .01s for nearly all measurements in Part 1. To use the photogate, first make sure the PASCO interface is on. Then go to "Desktop/PHY105M/" and move PhotogatePeriod.cap" to the desktop. Then open Capstone from the bottom menu. After Capstone is open, select "open experiment" from the menu and open "Desktop/PHY105M/PhotogatePeriod.cap". Then, all you need to to is hit "record" But ask your TA if you need help. (If you don't see the folder, log out then log in again and make sure to select "Yes" when prompted about connecting to the server).
- In the Prelab, you were introduced to the app Phyphox. This has a "Pendulum" setting (under "Mechanics") which allows you to use your phone as a pendulum. You may use this along with a phone mount obtained from your TA. Just make sure to record any changes in l. This is also a good way to reduce random uncertainty.
- You can try recording a video of the pendulum using your cell phone and determining the period that way. Which kind of uncertainty could this eliminate? Make sure to explain.

Pick the measurement tool you think has the best chance of improving upon your results from Part 1.

Quick Check: Try it out and make sure your method works.

Designing Your Experiment: Design an experiment like in Part 1 but using your new method. Record your plan.

Check in with Another Group: Briefly discuss your plans with another group. They may provide you with additional ideas and feedback. Note one similarity and one difference between your approaches.

Conducting Your Experiment: Conduct the experiment as planned. (Note: it might turn out that your new method is no better than the old one, that's perfectly fine, just try to be as precise as you can).

Check in with Another Group: Check back in with the same group you discussed things with before. How do your results compare? Note two similarities and/or differences between what you found, and use this to inform your proposals for future iterations.
Forming a Conclusion: What did your new method reveal about the dependence of a pendulum's period on the amplitude of the swing? Did it agree with what you found in Part 1? Which method, Part 1 or Part 2, was more precise? How confident are you in your conclusion?

Writing Up Your Lab Notes for Submission

Write up your notes for Part 1 and Part 2 in an organized way according to the rubric provided.