Lab 2

Period of a Pendulum Continued

Physical Models: Anharmonic Oscillator, Physical Pendulum

Analysis Tools: Mean, Standard Deviation, Standard Deviation of the Mean, t-score, Regime of Validity, Scatter plots with uncertainty bars

Experimental Systems: PASCO Pendulum Setup, Hanging Clips, Weights

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

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

Last week we investigated the following model for the period of a pendulum::

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{2.1}$$

Where T is the period, l is the length (from the pivot to the 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. But (if you measured precisely enough) you found that in at least some cases the model was falsified! Now what?

Your TA will begin lab by leading a discussion of possible explanations for the discrepancy. After contributing your own point of view and hearing others, you'll need to decide which you think is mostly likely and and determine a way to investigate it.

Part 1. Explaining and Investigating

Like last time, you'll need to set up a pendulum to experiment with. Configure it as closely as possible to the way you had it last week. Record which mass you chose and the length l of the pendulum for later reference.

Deciding on a New Hypothesis: To further help you formulate a new prediction, here are some examples of new hypotheses students came up with last semester and how they investigated them.

- Some students thought that the model is accurate only for some ranges of data and not others. Based off their data from last week, they made a precise statement which could be tested by e.g. collecting new data both inside and outside of the range to see if the pattern continued.
- Some students thought the model is simply incorrect, and proposed a different model, for example $T = 2\pi\sqrt{l/g}\theta^2$ or $T = 2\pi\sqrt{l/g}(1+\theta)$. Students used e.g. excel to find a best fit function to provide a new prediction, then collected additional data and checked if the new model predicted the results accurately.
- Some students thought that the issue was an extra dissipative force (like friction or air resistance) that's unaccounted for in the model. They performed new trials that would be expected to increase/decrease these effects and checked if it increased/decreased the descrepancy.
- Some students thought the mass of the pendulum, or shape, or material, played a role, or that the length mattered. They changed these variables around and tested if this increased/decreased the discrepancy.
- There were many other, completely different and good, ideas. These are just examples!

Last week we compared data for different amplitudes pairwise. This week, depending on how you approach things, you may need to compare data to a model directly (like $T = 2\pi\sqrt{l/g}$). But how do you determine the uncertainty in the model? We'll learn more about this next week, for this week you can treat $\delta T_{model} = 0$.

Check in with your TA: BEFORE PROCEEDING, check in with your TA to discuss your proposal. They may offer you some additional ideas or feedback.

Designing Your Experiment: Now, write out a plan for a high-precision test of your hypothesis. You should plan on collecting at least as much data as last week, all entirely new (so different amplitudes or for different pendulum configurations etc. as appropriate).

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 or hypotheses.

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. Just make sure to record any changes. Make sure all your data is labeled clearly with units, and that you keep track of uncertainty and try to minimize it. Keep working until you're confident in your conclusion.

Forming a Conclusion: What did you find? Was your prediction for the cause of discrepancy borne out? List a few improvements you could make, or alternative explanation you could investigate, for a next iteration.

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. Were either of your hypotheses able to account for the discrepancy?

Part 2. Exploring Alternatives, New Systems or Other Variables

Any investigation we complete, whether we falsify a given model or not, can be continued simply by comparing the model to new systems or by exploring other aspects of the model.

Your approach to Part 2 will depend on what you found in Part 1. If in Part 1 you identified the cause of the discrepancy with the model to your satisfaction, proceed with the instructions below. If not, follow the instructions for Part 1 a second time for a new possible explanation.

Either option is worth full points as long as its logical given your results and conclusions thus far. Think of the process as following the flowchart provided in the module.

Deciding on a New Hypothesis: If you now have a reasonable account of the pendulum for at least some range of data, consider the following options for a next iteration of your investigation:

- Perhaps the model works better for some values of l than others?
- Perhaps the period actually depends on the mass m of the pendulum, even though the model says it doesn't?
- Perhaps the discrepancy in the model came from the type of pendulum we used, and would be more accurate for a different one? Configure a different pendulum type and compare with the original model $T = 2\pi\sqrt{l/g}$. Make sure you have a well thought out reason for trying this though.
- Something else you're interested in? Discuss with your TA.

Designing Your Experiment: Design an experiment to test your new hypothesis.

Conducting Your Experiment: Conduct the experiment as planned.

Forming a Conclusion: What did you find? How could you improve your experiment?

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.