**Period of a Pendulum**

**(Three weeks, In-Person)**

# Notes:

1. This is a three-week long lab with multiple parts that will require you to do the experimental design and data collection in the campus lab.
2. We urge you stay on task in the lab and complete the activity that is required during each week.
3. You must prepare a draft report on what you did during each week and get feedback from TA before starting the report for next week. The drafts must have as many elements as feasible that a final report would have.
4. Turning in your report:
   1. Collaborate with your partner(s) on data collection, analysis and report.
   2. When working in a group, turn in only one report and make sure it lists all group members as authors.
   3. Lab reports should be uploaded to Canvas by the deadline in the course calendar.
   4. Do not include your raw spreadsheets in the final report. You may want to use figures generated from the spreadsheet(s) in your report.
5. Getting help:
   1. Your lab TA can answer questions by email or during their office hours listed in the syllabus.
   2. You can also ask advice from lab partner(s) and/or other students.

# Objectives of this lab:

In this experiment, you explore how the period of a physical pendulum depends on a couple of its properties. The pendulum you will use consists of metal rod with holes at varying points along its length. The rod, suspended from the support, will be your pendulum. Pulling it to one side and letting it go will cause the pendulum to oscillate about the point at which it is suspended. The pendulum has two attributes that you can vary to study the effect of each attribute on the period of the pendulum, (i) length of the pendulum, and (ii) the initial amplitude of the pendulum, i.e. the angle between the displaced rod and the vertical. You will vary each of these, one at a time, to investigate the effect of each on the period of the pendulum.

These are things you will do:

1. You will use the equipment provided to construct a pendulum, and use the photogate to measure the period of the pendulum
2. You will gather data and transfer to Excel for analysis.
3. Identify the errors that can occur in your experiment.

# What you will learn:

Please review the learning goals for the semester in lab in the handout from the first week. In addition, this lab has several specific goals:

1. You will practice keeping lab notes in a paper notebook, computer file, or other format.
2. You will enhance the data analysis skills you learned previously, by applying them to real data.
3. You will learn to distinguish between two types of errors that occur in data: systematic errors and random errors.
4. You will enhance your understanding of how noise arises in data, and how to account for that noise when interpreting experimental results.
5. You will practice scientific communication skills by preparing graphs and writing a formal lab report.

## What goes in my lab notes, and what about my report?

The purpose of lab notes is to enable you or a colleague to reconstruct what was done and why.

* They don’t have to be neat, in complete sentences, etc., but they do have to be useful.
* In a case like this, they should include things like what as the setup for measuring acceleration and what you did while recording data.
* Did you try different setups (pulley vs dropping phone on bed), or take multiple data sets for same setup?
* If you store multiple files, record what filenames correspond to what conditions.

The purpose of a **report** is to explain what you learned and how you learned it. The sorts of things that belong here are

* A description of each step you did as part of the activities.
* Graphs to show to your results.
* Explain differences between calculated and the actual measured values.
* Your conclusions about any relevant and useful information you were able to extract from the data.
* An analysis of the errors of the in your experiment including an explanation of how calculated average acceleration, found the standard deviation, and determined the standard error.

# EQUIPMENT

* Metal rod with holes, pendulum support, photogates
* Excel, Numbers, or other graphing software
* Word or other word processor to prepare your report

**DOs & DON’Ts**

* ***Do*** decide which quantity (length of pendulum, angle of displacement) you wish to vary first. Keep the other quantity a constant.
* ***Do*** cover the range of angles from 0 to 80 degrees. Measure period for as many angles as you need to definitively answer the question, “How does the period vary with angle?”.
* ***Do*** use your imagination and have fun.
* ***Don’t*** hurt yourself by allowing the rod to swing violently, and don’t give the rod a push. You must pull the rod to one side and then release it, not push it.

# ACTIVITY 1 (Week 1): Measure *period of pendulum*

* This activity is intended for you to set up your experiment and measure the period of a pendulum as accurately as possible.
* Form a pendulum by suspending the metal rod from one of the holes, and measure distance from bottom of pendulum to the suspension point.
* Pull pendulum to one side and release it, starting its oscillation.
* Set up photogate such that the oscillating pendulum intersects the detector in the photogate.
* You may have to play with the height of the photogate to get the detector to register the passage of the pendulum.
* Transfer output of photogate to Excel.
* Think about what the data means and how to extract period from the data. Talk to your TA and get advice.
* Use the timer app in your phone to measure the period of the pendulum. How does it compare with you get from the photogate?

What is the standard deviation and uncertainty in your measurement? Your write-up should explain what you are analyzing, why you think that is justified, and what it means.

**NOTE: Before continuing to Activity 2, STOP and make sure that your measured period agrees with your theoretically predicted period.**

# ACTIVITY 2 (Week 1): Measure *period vs angle*

* + - This week, you will measure variations in the period of the pendulum as a function of the angle to which you displace the pendulum.
    - Carefully record the angles you use and the periods you measure.
    - Cover the range from 5 to 80 degrees.

**Write a draft report on what you did during week 1 and submit to TA before lab of week 2. TA will give you feedback which you must incorporate in your report submission at the end of week 2. The draft you submit must have almost all of the elements mentioned in the handout “Lab Overview”. A portion of that is reproduced here: “…………***your report should be typed, in essay form (not bulleted lists), and contain the following sections: title, abstract, introduction, theoretical background, experimental procedure (including any re-design or refinements), data (in tabular form or a format that makes sense for that lab), analysis of data including errors, your interpretation of the results,…….”.*

# ACTIVITY 3 (Weeks 2, 3): Measure *period vs length*

* + - This week, you will measure variations in the period of the pendulum as a function of the length of the pendulum.
    - Length can be varied by suspending the rod from holes at different heights.
    - For a given length, try to measure the period for the same angle of displacement so that you are not varying two quantities at the same time.

**Note: At the end of this, submit a final report describing the complete lab.**

# ACTIVITY 4 (Weeks 2, 3): OPEN ACTIVITY

Did you see a variation in the period of the pendulum with length and angle? If yes, explain why these changes occur. If no, then explain why the period does not depend on these quantities.

**Write a draft report on what you did during week 2 and submit to TA before lab of week 3. TA will give you feedback which you must incorporate in your final report submission at the end of week 2. The draft you submit must have almost all of the elements mentioned in the handout “Lab Overview”. A portion of that is reproduced here: “…………***your report should be typed, in essay form (not bulleted lists), and contain the following sections: title, abstract, introduction, theoretical background, experimental procedure (including any re-design or refinements), data (in tabular form or a format that makes sense for that lab), analysis of data including errors, your interpretation of the results,…….”.*