Pendulum Lab—Open Investigation PH 220

In this lab, there will be more emphasis on using the Scientific Method for yourself. You will discuss your findings and logic in a brief report. Before starting, think about how you would go about investigating the system if you had no lab handout or instructor to guide you.

Key elements of any scientific investigation include:

1. A testable hypothesis: this is an informed guess about how the measurable quantities depend on each other. The hypothesis is an equation to be tested using experimental data.
2. Clear definitions of all symbols used in the documents, so that the report makes sense to the reader. It should be clear which variables are being held constant (controls), which are varied by choice (independent variables), and which will be measured from the apparatus (dependent variables).
3. One or more tables of measured data for each investigation, with proper headings, units, etc.
4. One or more graphs showing the data and revealing the relationship between the variables
5. Analysis based on the quantities extracted from the graphs. For straight-line graphs, the only quantities extracted would be the slope and the intercept found from the best-fit line.
6. A clear report, with an emphasis on logical reasoning. Full sentences with correct spelling, punctuation, and grammar are expected.

Forming a hypothesis for the simple pendulum

First, note that there are three things you can vary:
(1) the length l, (2) the mass m of the bob, (3) the initial release angle θ

The fourth measurable quantity is the period T, and is the time it takes for the pendulum to complete a full cycle (returning to the same spot and moving in the same direction).

The first three variables are 'independent' because they can be set freely by the experimenter. The period, however, is 'dependent' because it is determined by letting the swing. As a scientist, the goal is to find an **equation** that models the dependent variable T correctly.

Experiment: A good investigation is varying the length l and measuring the period T (while keeping m, θ fixed). To find an equation for T, consider several hypotheses:

a. Linear hypothesis: $[T] = a\,[l]$ a linear relationship between T and l
b. Quadratic hypothesis: $[T] = b\,[l^2]$ a power-law with l to the 2nd power
c. Another one: $[T] = c\,[\sqrt{l}\,]$ here, the power of l is one half

In theory, plots of the square-bracketed quantities versus each other will give a straight line each time. However, the **experiment** has to be performed to find out which one actually is a straight line.
So, tabulate T for a full range of lengths l, make each graph, and decide which one best follows the trend of a straight line. Then, compare the trendline equation with the corresponding theory equation to find the value of the constant (a, b, or c) for the case that matches.

Other options: There other hypotheses one could look at:
For example, varying only the mass m, hypothesize that the period T satisfies $T = k_1\, m + r_1$, where k_1 and r_1 are constants to be found by the experiment (from the slope and intercept).
Alternatively, vary only the initial angle of release θ, and hypothesize that the period satisfies $T = k_2\, \theta + r_2$, where k_2, r_2 are constants to be determined by the experiment.

Cover page: PH 220 Simple Pendulum Investigation NAME: ____________________

Partners: ____________________

Instructions:
This cover page should be the first page, with your report attached after that.
Each person must write their own report, which must be word processed.
Use the section headings: **1. Question, 2. Method, 3. Analysis, and 4. Discussion.**
Your work will also be assessed based on critical thinking skills:
Evidence: base your conclusions on the experimental evidence you found.
Integration: combine information from different parts of the experiment logically.
Evaluation: Draw rational conclusions based on your experiment.

Grading Rubric: (Leave this for your instructor to fill in)

1. **Question**. State the hypothesis equations you are investigating. Discuss the quantities in the equations – which are the independent variables, which are the dependent variables? A clear, labelled diagram is a good idea. Based on the hypothesis equations, explain what quantities will go on the axes for each graph, and how you will identify which hypothesis best fits the data. Provide enough detail so that someone not familiar with the experiment can understand what you are interested in finding out. Write a clear paragraph, in full sentences.

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2. **Method**. Discuss details of each measurement in the experiment. Mention anything that needs particular care. Discuss how many significant digits can be justified for each measurement. The measurements you took are the evidence upon which you draw your conclusions. Provide a critical discussion of how reliable they are.

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3. **Analysis**. Show the table with your measured quantities, and write a brief explanation of what is included in each column. Show the graphs you have made to test your hypotheses. For each, discuss whether the experimental data follows a linear trend, and thus whether it is consistent with the hypothesis. If this is the case, extract the values of the constants and report them clearly. Make sure quality standards are met for tables and graphs. Correct use of units and significant figures is expected. **Refer to the handout from the first graphing lab** to review details of how graphs are used to find experimental results. Integrate the information you found from your tables, graphs, and calculations to form a logical sequence.

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4. **Discussion**. Discuss whether your data is consistent with, or in conflict with, your original hypothesis equations. Give quantitative conclusions. Justify your claims by referencing the evidence you found in the experiment. Evaluate your results critically. This should include a discussion of weaknesses in your experiment and how you might change things in future.

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Use full sentences and clear language throughout. A person that was not in the lab ought to be able to read your report and understand reasonably well what you did.