

UNIT I: Scientific Thinking in Experimental Settings

Instructional Goals

1. Experimental design

Build a qualitative model

Identify and classify variables

Make tentative qualitative predictions about the relationship between variables

2. Data Collection

Select appropriate measuring devices

Consider accuracy of measuring device and significant figures

Maximize range of data

3. Mathematical Modeling

Learn to use *Graphical Analysis* (Vernier) software

Develop linear relationships

Relate mathematical and graphical expressions.

Validate pendulum model

4. Lab Report

Present and defend interpretations.

Write a coherent report (See Appendix for suggested format.)

Lab Notes and Instructional Comments

Pendulum lab

Apparatus

3 masses for bobs (same size and shape, different masses- you can use metal spheres or film canisters filled with "BBs".)
string
pendulum support and clamp (or equivalent)
stop watches
balance for mass measurement
Graphical Analysis (optional)

Pre-lab discussion

- ¥ Set up a support stand from which at least two pendula are swinging. Ask for observations. Request a list of factors that might have an impact on the behavior of the pendula. Accept all suggestions at first; cull from this list those factors which are not quantifiable (shape of bob or material) or over which you have little or no control (room temperature, gravity). Ask which observations are related in order to isolate dependent and independent variables.
- ¥ The *dependent variable* is the period of swing (T). Use period rather than frequency to simplify the data analysis, since $T \propto \sqrt{l}$ and $f \propto \frac{1}{\sqrt{l}}$. The dependent variable will be graphed on the vertical axis.
- ¥ The *independent variables* are:
 - length (l).
 - mass (m). You should draw a distinction between mass and weight.
 - amplitude (A). You can measure as an angle or a distance from the rest point.
- ¥ Ask the students to make tentative predictions about how changes in the independent variables will affect the period.

Lab performance notes

- ¥ This is a teacher-directed activity. Each student, however, will produce a separate lab report. Try to involve every student in the class by assigning various tasks.
- ¥ Pass out stopwatches to as many students as possible to increase involvement and quantity of data. Have all students with stopwatches time each trial.
- ¥ Select a "data recorder" to work at the board.
- ¥ Emphasize that there must be separate experimental designs for each independent variable.
- ¥ Use at least three pendulums of different mass, keeping the shape and size identical if possible.
- ¥ Record data involving each variable separately. This is the time to introduce and discuss uncertainty and significant digits. Use SI units only.
- ¥ PERIOD VS MASS: avoid the term "weight". Emphasize the recording of mass in kilograms. (See Figure 1.)
- ¥ PERIOD VS AMPLITUDE: record amplitude in meters or degrees. Carefully select amplitudes to avoid large angles. (See Figure 2.)
- ¥ PERIOD VS LENGTH: record length in meters. Select a wide range of values for length. *Be sure to collect enough data at short lengths where the curve changes the most.* Otherwise, students might conclude that the relationship is linear. It is appropriate to pose the question, "What would the period be if the length were zero?" (See Figure 3.)

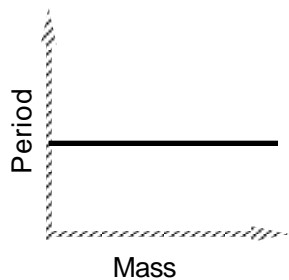


Fig. 1

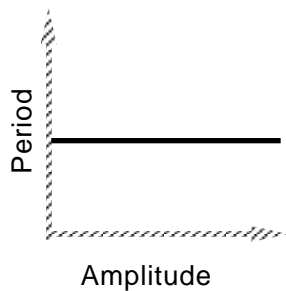


Fig. 2

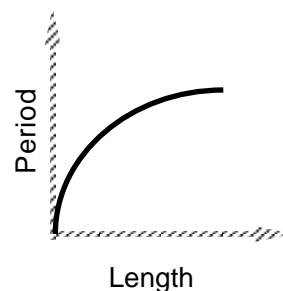


Fig. 3

Analysis of Data

This is the appropriate time to review graphical methods with your students. You could have the students graph the data in the three experiments by hand as a way to determine their weaknesses and provide remediation. This approach makes students appreciative of the power of graphical analysis software. Or, you could introduce Graphical Analysis right away. If you do so, then on this first set of experiments, *do not* select regression line for the T vs m , T vs a and T vs l graphs. GA will scale the vertical axis in such a way as to make it appear that the regression line has a slight slope. Instead, have the students sketch the lines (and curve) by hand. On the T vs l data, you will have to point out that on GA, you need to select <raise to a power> and make the exponent 0.5 in order to obtain the square root of l .

Post-lab discussion

- ¥ Focus discussion on the scientific method.
- ¥ Emphasize need to have adequate data quantity and adequate data ranges to get good graphs and to make conclusions.
- ¥ Discuss graphical versus mathematical models. Show samples of curve fitting. Discuss the five-percent rule for intercepts. Derive the mathematical model from the graphical representation.
- ¥ Reiterate the concepts of dependent and independent variables.
- ¥ Redefine the terms: period, frequency, weight, mass.
- ¥ Avoid introducing the formal pendulum equation (using "g" and „). It is not the purpose of this lab to derive this relationship.
- ¥ Discuss and demonstrate proper lab report format.

Types of Graphs Suite of labs (Optional)

Depending on the availability of equipment and the abilities of your students, you might choose to perform this set of labs in order to give your students more opportunity to relate the five basic types of graphical relationships to real lab phenomena. In the interest of time and logistics, have each group perform two different experiments (one linear, one curve) and evaluate the data. In the post-lab discussion, students can compare results and learn about the phenomena they didn't directly examine.

Reading: Graphical Methods

Worksheet 1

Quiz 1

Reading: Significant Figures

Worksheet 2

Quiz 2

Review

Test