1.3 Inquiry, Experimentation, and Measurements

SECTION OUTCOMES

- Select and use appropriate equipment to accurately collect scientific data.
- Design and conduct experiments that control major variables.
- Hypothesize, predict, and test phenomena based on scientific models.

KEY TERMS

- period
- frequency
- percent difference
- percent deviation

Analyzing "real" world phenomena, as you will be doing throughout this course, requires the ability to take measurements — from very small to very large. It also requires that you be able to visualize the data in various ways, and to determine how accurately current models can predict actual events. In this section you will do two experiments that give you an opportunity to start having experience at measuring actual events, and analyzing the data generated in the experiments.

In the first investigation, you will design your own experiment to investigate the variables that determine the rate of the swing of a pendulum. In the second investigation, you will compare your experimental results from the first investigation to an existing model that predicts how the swing rate of a pendulum is controlled. You will then have the opportunity to practise using some of the mathematical tools of a physicist, comparing your data with the predictions of a mathematical model.

Before you conduct the investigations on the next two pages, think about the motion of a swing, like the one shown in Figure 1.10. See if you can apply the terms that follow the photograph to the child's motion.

Figure 1.10 A swing is an excellent example of periodic motion.

The time required for one complete oscillation is called the **period**.

Period = time interval / 1 cycle

The SI unit for period, T, is seconds (s).

The number of oscillations in a specific time interval is called the **frequency**.

frequency = number of oscillations / time interval

The SI unit for frequency, f, is 1/s or Hertz (Hz)

INVESTIGATION 1-A

Analyzing a Pendulum

TARGET SKILLS

- Hypothesizing
- Predicting
- Identifying variables
- Performing and recording
- Analyzing and interpreting
- Communicating results

Grandfather clocks are not merely timepieces, they are also works of art. A key feature of a grandfather clock is the ornate pendulum that swings back and forth.

Problem

Part 1: What factors affect the period of oscillation of a pendulum?

Part 2: Compare your results with your predictions.

Hypothesis

Formulate a hypothesis listing variables that will affect the period of oscillation of a pendulum. Predict how each variable will affect the period of oscillation.

Equipment

- various masses (50 g to 100 g)
- string (1 m)
- stopwatch
- retort stand

Procedure

1. With a partner, design an experiment to determine variables that will affect the period of oscillation of a pendulum. Investigate a minimum of three variables.
2. Provide step-by-step procedures.
3. Predict and record the effect of each variable, and have your teacher initial each prediction.
4. Following your school's safety rules, carry out the experiment and record your observations.

Analyze and Conclude

1. How many oscillations did you use to determine the period of the pendulum?
2. How many trials did you run before changing variables? Was this enough? Explain.
3. Did your hypothesis include length as a variable? If so, why? If not, why not? Explain your choice of variables.
4. Determine the uncertainty *within* your data by calculating the **percent difference** between your maximum and minimum values for the period of oscillation for each controlled variable. Refer to Skill Set 1 for an explanation of percent difference.
5. According to your results, what variables affect the period of oscillation of a pendulum? Explain, providing as much detail as possible.

INVESTIGATION 1-B

Analyzing Pendulum Data

TARGET SKILLS

- Hypothesizing
- Performing and recording
- Analyzing and interpreting
- Communicating results

Physicists and clock designers have used results from experiments like the previous one to develop a relationship between the period of oscillation of a pendulum and its length. The mathematical model for this relationship is approximated by the following equation:

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

where: T = period of oscillation
l = pendulum length
$g = 9.81\ \text{m/s}^2$ (acceleration due to gravity near Earth's surface)

Problem

How should experimental data be analyzed to test for (a) error within the data set and (b) accuracy when compared to a theoretical value?

Hypothesis

Formulate a hypothesis predicting how closely your experimental results from Investigation 1A will match the mathematical model shown above.

Procedure

1. Set up a table identical to the one shown.
2. Use the theoretical equation and the data you collected in the previous investigation to complete the table. Refer to Skill Set 1 for an explanation of **percent deviation**.
3. If length was not one of the variables that you and your partner tested, borrow data from tests carried out by your classmates.

Analyze and Conclude

1. Generate the following graphs on one set of axes:
   (a) $T_{\text{Experimental}}$ vs. l
   (b) $T_{\text{Theoretical}}$ vs. l
2. Analyze the graph. Is it possible to qualitatively determine whether your experimental data were similar to the results predicted by the theory?
3. Do the percent deviation values allow you to quantitatively determine whether your experimental data were similar to the results predicted by the theory? Again, refer to Appendix B for an explanation of percent deviation.
4. Suggest a method of determining whether the experimental deviation of your data is within acceptable parameters.
5. Suggest techniques to reduce the experimental deviation between your data and the theoretical period values.
6. Explain the difference between percent deviation and percent difference. When should each one be used?

Trial	Length (m)	Experimental results		Theoretical results $\left(T = 2\pi\sqrt{\frac{l}{g}}\right)$	Percent deviation
		Time 5 cycles (s)	Time 1 cycle (s)		
Sample 1	0.80 m	1.0×10^1 s	2.0 s	$T = 2\pi\sqrt{\frac{0.80\ \text{m}}{9.81\ \text{m/s}^2}} = 1.8$ s	11 %
Sample 2					

Physics: an Active Endeavour

Understanding physics concepts requires making good observations and analyses. Thus, this book provides numerous active investigations, less formal Multi-Labs, Quick Labs that require few materials to carry them out, and marginal Try This activities that are just that — actions that won't take much time to do, but will help make concepts clearer. Watch for the following designations throughout the text:

INVESTIGATION 1-B
Analyzing Pendulum Data

TARGET SKILLS
- Hypothesizing
- Performing and recording
- Analyzing and interpreting
- Communicating results

MULTI LAB
Winning the Race

TARGET SKILLS
- Identifying variables
- Performing and recording
- Analyzing and interpreting

QUICK LAB
Bend a Wall

TARGET SKILLS
- Modelling concepts
- Communicating Results

TRY THIS...

1.3 Section Review

1. K/U When should percent deviation be used to analyze experimental data?
2. K/U When should percent difference be used to analyze experimental data?
3. I A group of science students hypothesize that the ratio of red jellybeans to green jellybeans is the same in packages with the same brand name, regardless of size. Their results are provided in Table 3.

Table 3 Jellybean data

Package	1	2	3	4	5
Red	23	18	50	62	19
Green	35	24	2	81	23

(a) Compute a red-to-green jellybean ratio for each package.
(b) Is there a general trend in the data?
(c) Is there a data set that, while properly recorded, should not be considered when looking for a trend? Explain.