2.2 Experiments and Variables

An **experiment** is a situation specifically set up to investigate something. For example, you could do an experiment in your class to investigate how fast a car moves as it travels down a ramp (Figure 2.6). An experiment is designed around a **system**, or a group of variables that are related in some way.

Experiments

Experiments tell us how variables are related

The goal of any experiment is to understand the relationship between variables. For example, what is the relationship between the speed of the car and the angle of the ramp? To answer the question, you set up the experiment with the ramp attached to different holes in the stand. Each hole sets the ramp at a different angle. You measure all the variables that affect the speed of the car and see how (and if) they change when the angle is changed. A **variable** is a factor that affects how an experiment works.

Changing one variable at a time

In a simple, ideal experiment *only one variable is changed at a time*. You can assume that any changes you see in other variables were caused by the one variable you changed. If you change more than one variable, it's hard to tell which one caused the changes in the others. The experiment will probably still *work*, you just won't learn much from the results!

The experimental variable

The variable you change in an experiment is called the **experimental variable**. This is usually the variable that you can freely manipulate. For the experiment with a car on a ramp, the angle of the ramp is the experimental variable.

Control variables

The variables you keep the same are called **control variables**. If you are changing the angle of the ramp, you want to keep the mass of the car the same each time you roll the car. Mass is a control variable. You also want to keep the position of the photogate the same. Photogate position is also a control variable. You will also want to have the same release technique for the car each time it rolls down the ramp. If you want to test different angles, the ramp angle should be the *only* variable you change.

VOCABULARY

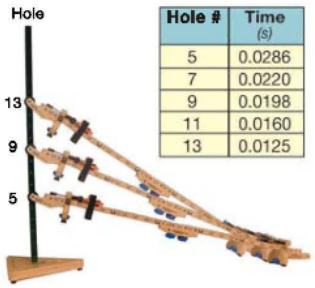
experiment - a situation specifically set up to investigate relationships between variables.

system - a group of variables that are related.

variable - a factor that affects how an experiment works.

experimental variable - the variable you change in an experiment.

control variable - a variable that is kept constant (the same) in an experiment.



Hole #	Time (s)
5	0.0286
7	0.0220
9	0.0198
11	0.0160
13	0.0125

Figure 2.6: *A car rolling downhill can be an experiment.*

Experimental techniques

Experiments often have several trials

Many experiments are done over and over with only one variable changed. For example, you might roll a car down a ramp 10 times, each time with the ramp at a different angle. Each time you run the experiment is called a **trial**. To be sure of your results, each trial must be as similar as possible to all the others. The only change should be the one variable you are testing.

Experimental technique

Your **experimental technique** is how you actually do the experiment. For example, you might release the car using one finger on top. If this is your technique, you want to do it the same way every time. When you place the photogate on the track, you make sure the gate is always perpendicular to the track. By developing a good technique, you make sure your results accurately show the effects of changing your experimental variable. If your technique is sloppy, you might not be able to determine if your results are due to technique or changing your variable.

Procedures

The **procedure** is a collection of all the techniques you use to do an experiment. Your procedure for testing the ramp angle might have several steps. Good scientists keep careful track of their procedures so they can come back another time and repeat their experiments. Writing the procedures down in a lab notebook is a good way to keep track (Figure 2.7).

Scientific results must always be repeatable

Scientific discoveries and inventions must always be testable by someone other than you. If other people can follow your procedure and get the same results, then most scientists would accept your results as being true. Writing good procedures is the best way to ensure that others can repeat and verify your experiments. This is a good thing to keep in mind when you write your own procedure for an experiment. Write it with enough detail that someone else could follow the procedure and do the experiment exactly the way you did it.

Communicating your results

A *lab report* is a good way to communicate the results of an experiment to others. It should contain your research question, hypothesis, experiment procedures and data, and your conclusion. If you give an oral report to your class, colorful charts and graphs are a good way to show your data. This is how scientists present the results of their experiments to other scientists.

VOCABULARY

trial - each time an experiment is tried.

experimental technique - the exact procedure that is followed each time an experiment is repeated.

procedure - a collection of all the techniques you use to do an experiment.

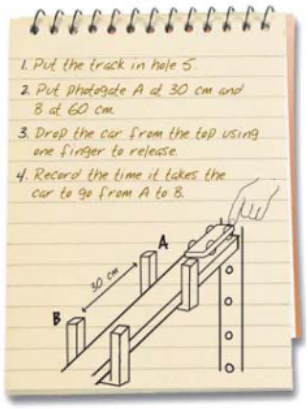


Figure 2.7: *A notebook keeps your observations and procedures from getting lost or being forgotten.*

Experiments: Then and now

Electricity and magnetism in the 1800s

Michael Faraday, a British scientist, made some important discoveries while experimenting with electricity and magnets. This is a great example of how one experiment often leads to another. Faraday's original question was, "How are electricity and magnetism related?"

The original experiment

Faraday designed a controlled experiment with a loop of wire and a magnet. When he moved the magnet through the loop of wire, an electric current was produced in the wire. In previous experiments, he had generated electricity by using homemade batteries, but the magnet experiment was different. Moving a magnet through the wire loop was enough to produce an electric current in the wire, without using the chemical reactions of his homemade batteries. The opposite was also true. When Faraday rotated a wire through a magnetic field, an electric current was produced in the wire (Figure 2.8).

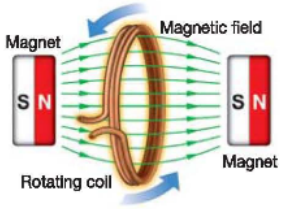


Figure 2.8: *Electric current is created when a coil rotates in a magnetic field.*

A new experiment based on the old one

NASA (National Aeronautics and Space Administration) has conducted a modern version of Faraday's electromagnetism experiments. In simple terms, Earth is like a giant magnet. Magnetic field lines extend out from Earth into space. What would happen if Faraday's experiment were performed in space? What if you dragged a wire through Earth's magnetic field? Could an electric current be produced in the wire? This became an important mission for the space shuttle in 1996 (Figure 2.9).

The world's most amazing electricity generator

NASA scientists worked with Italian scientists to design equipment for the experiment. They made a special satellite and connected it to the space shuttle with over 20 kilometers of a special insulated copper cable. As the shuttle orbited Earth, scientists released the tethered satellite and conducted 12 different experiments while dragging the cable through Earth's magnetic field at speeds over 15,000 mph! The satellite was equipped with many instruments to study the electricity generated in the cable. As the cable cut through Earth's magnetic field, 3,500 volts of electricity was produced, and a current of 0.5 amperes was generated. Faraday's experiment worked in outer space! Unfortunately, the tether broke during the experiment and the satellite was lost, but not before scientists gathered enormous amounts of interesting data.

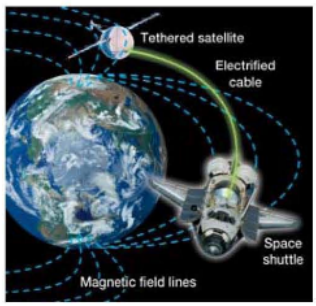


Figure 2.9: *NASA's tethered satellite experiment from shuttle mission STS-75. An electric current was created when the cable was dragged through Earth's magnetic field.*

Section 2.2 Review

1. Why is experimentation so important to science?
2. Why is it important, in an ideal, simple experiment, to change only one variable from trial to trial?
3. What is the difference between an experimental variable and a control variable? Give an example to explain your answer.
4. You are planning an experiment to find out which detergent is the best at removing grass stains from cotton fabric. Think about how you might do this experiment and what kinds of variables are involved. Make a list of two variables that would be a part of the experimental system and two variables that would not be a part of this system.
5. Suppose you have three drinking cups that are identical except for the material they are made of. One is made of plastic, one of foam, and one of paper. You want to find out which cup will keep your hot cocoa hot for the longest time.
   a. Phrase a formal question for this experiment.
   b. What is your hypothesis?
   c. What is the experimental variable?
   d. What are three important control variables?
   e. What type of evidence will you collect to test your hypothesis?
   f. Challenge: Conduct your experiment and summarize your findings.
6. Think of an experiment you did in a past science class.
   a. Describe the experiment.
   b. What was the experimental variable?
   c. What were two control variables?
   d. What was the outcome of the experiment?
7. Water in an open container will eventually evaporate. Do all liquids evaporate at the same rate? Suppose you conduct an experiment to see how quickly water, rubbing alcohol, and nail polish remover evaporate. Describe three important techniques you will have to follow to make sure your experimental procedure is repeatable and objective.

CHALLENGE

Science and Serendipity

Not all discoveries in science are made using the scientific method! In fact, many important new discoveries and inventions happen by trial and error, a lucky experiment, or by accident. The word *serendipity* describes an event during which a valuable discovery is made by accident.

1. Describe a situation in which you made a serendipitous discovery.
2. Think about an object that you use every day. Find out how it was invented. Was this invention the result of serendipity? Why or why not?

SOLVE IT!

For Question 5, predict what a graph or graphs of the data you collect would look like. Sketch the graph or graphs. The graph(s) should support the hypothesis you made in 5b.