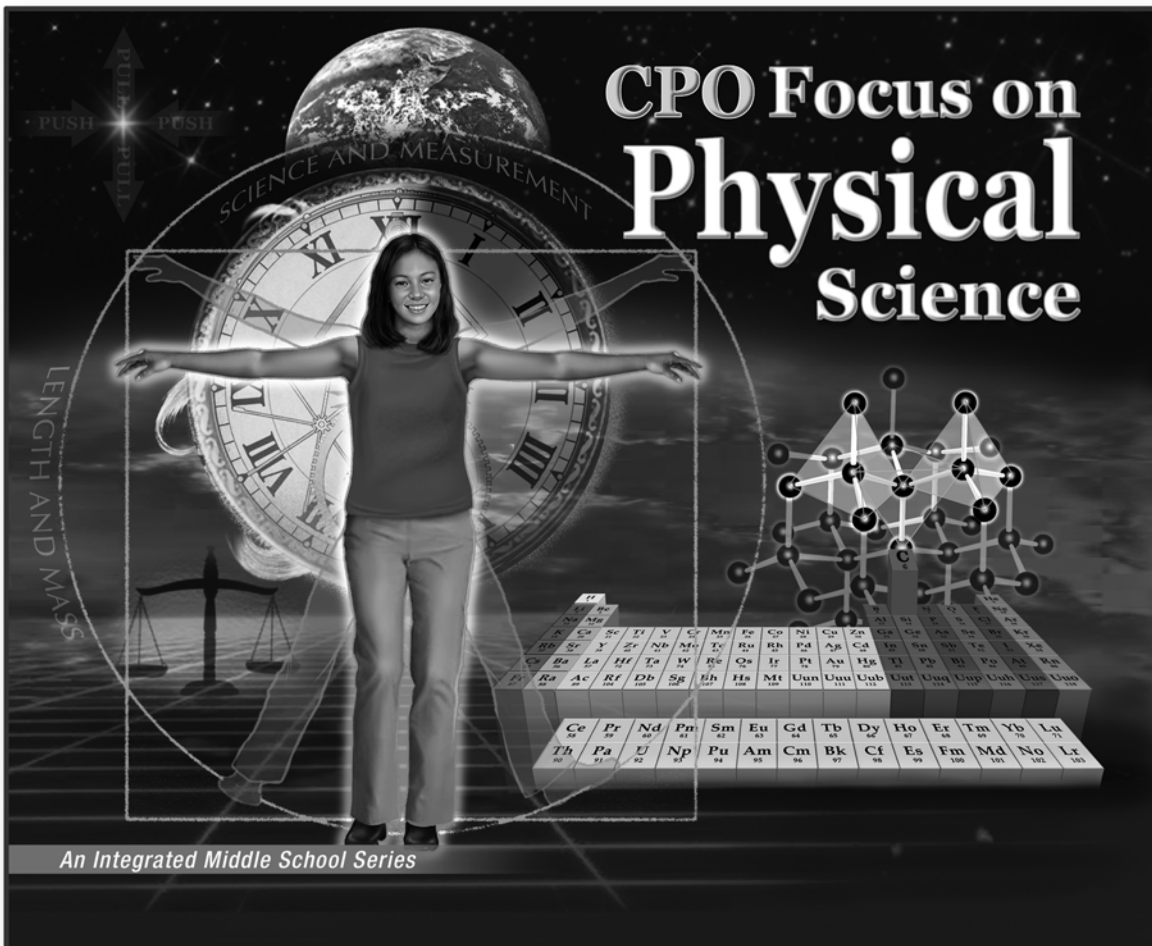
Blackline Answer Sheets



cpo science

CPO Focus on Physical Science
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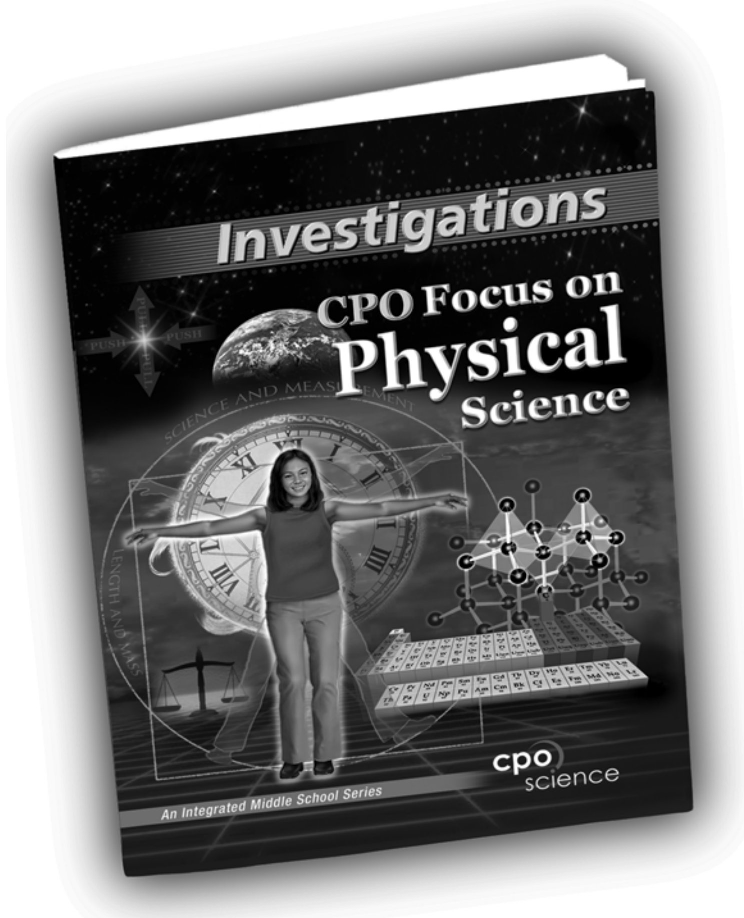

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Blackline Answer Sheets

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Investigation Skills

1A Inquiry and Scientific Evidence

How do scientists discover things that they may not see or touch?

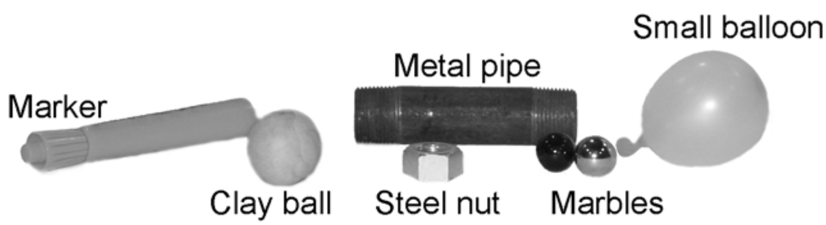
In solving a crime mystery, you cannot actually go back in time to see what happened. Instead, you search for clues that help you think of a hypothesis for what happened. You then collect evidence to see if your hypothesis is correct. Your hypothesis is potentially correct if it agrees with all the evidence. Scientists learn about the mysteries of nature in a similar way. In this investigation, you will try to solve a simple mystery using the tools of inquiry, hypothesis, and scientific evidence.

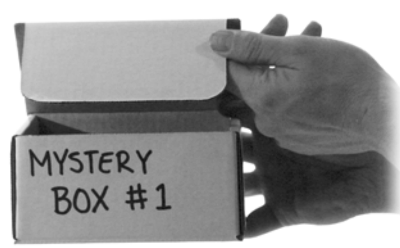
Materials

- A small cardboard box which may be closed and sealed.
- A selection of objects that may be placed in the box.

1 Setting up

Some objects that might be in the box





This investigation is about solving a scientific mystery using the same processes that scientists use to discover new things. The mystery is the identity of the object, or objects in the box. You have to determine what these objects are without being able to open the box.

1. Write down at least one thing you know about the object before even touching the box.

2. Before picking up the box, write down at least 3 different observations you could make that might help you figure out what is inside. Assume you can hold the box and do it anything (in your classroom) except open it or damage it in any way.

2 Conducting your inquiry

A scientific inquiry is an investigation that seeks to find the answer to question. Your question is “what is in the box”. The inquiry includes all the things you do, and all the thinking you do to figure it out.

1. Try doing the things you suggested in part one above. Write down the results as carefully as you can.

Table 1: Results of your inquiry

What you did	What you observed

3 Your hypothesis

As they try to explain what they see, scientists think of one or more hypotheses. A hypothesis is a possible explanation. At the start of the inquiry you may think of each hypothesis as an educated guess at the explanation. None may be the correct solution, but each should be a solution that fits with at least some of the observations you have made so far. Use the following questions to help write down your first hypothesis.

1. What do you think is in the box? (your hypothesis)

2. What specific things did you observe that caused you to think this hypothesis may be correct?

3. Were there things that you did NOT see which also cause you to think your hypothesis might be correct?

4 Testing your hypothesis

As part of the scientific method, all hypotheses must be testable. That means the hypothesis must make a prediction that can be tested with an experiment. For example, suppose your hypothesis is that there is a steel nail in the box. You might predict that a magnet will stick to the box. This is a prediction that can be tested.

1. Assume your hypothesis is right. Write down one additional test you could make to confirm that you do indeed have the right object. This test should be something you have not done before.

2. Do the test and write down what you observe.

3. Try any other ways that you can think of to examine the box.

5 Stop and think

A correct hypothesis agrees with ALL of the observations. If the hypothesis disagrees with even one observation, it cannot be completely correct.

a. Write down your hypothesis for what is in the box based on all your observations.

b. Write down at least four observations that you made.

c. Next to each observation, write down whether it supports or does not support your hypothesis.

d. Ask your teacher what is really in the box. Was your hypothesis right? If not, is there another test you could suggest that might have provided a clue to the correct hypothesis?

6 Exploring on your own

Go home and make your own mystery box using things you find around the house. The box should contain at most three objects but may contain only one. Write down at least four tests that would allow someone to solve your mystery.

1B Measuring Time and Distance

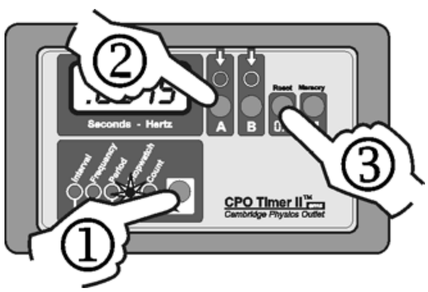
How are time and distance measured and described in physical science?

We describe the universe with measurements. A measurement includes a unit and the quantity. For example, 3 seconds is a measurement of time that includes a unit (seconds) and a quantity (3). This investigation will explore the measurement and units for time and distance.

Materials

- CPO Timer and 2 photogates.
- Metric tape, centimeter ruler or meter stick with millimeter gradations
- Several different books, preferably made with different types of paper.

1 Using the timer as a stopwatch



1. Set the timer to **stopwatch**.
2. Start and stop using the "**A**" button.
3. Reset the stopwatch to zero with the "**O**" button.

The photogate timer allows you to make accurate, precise measurements of time. The timer does different functions and the first one to try is **stopwatch**. Use the button (1) to move the light under the word stopwatch.

A stopwatch measures a **time interval**. The stopwatch is started and stopped with the "**A**" button (2). The display shows time in seconds up to 60 seconds, then changes to show **min:sec** for times longer than one minute.

2 Observing reaction time

The time it takes a signal from your brain to move a muscle is called **reaction time**.

1. This experiment takes two people. One person (the watcher) watches the stopwatch and the other person pushes the buttons. The watcher should think of a number between 5 and 10 seconds and keep the number secret.
2. The second person starts (and stops) the stopwatch *without looking at the display*. The watcher looks at the display and says STOP at the secret number. For example, if the secret number is 6 they should say STOP when the display reaches 6.00 seconds.
3. Repeat the experiment several times and estimate reaction time.

3 Mixed units for time

Time is often given in mixed units including hours, minutes, and seconds. Convert (a) and (b) to seconds then arrange the three measurements from smallest to largest:

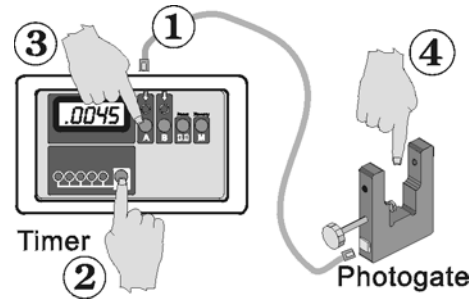
a. 16,000 seconds ______________________________

b. 250 minutes ______________________________

c. 4 hours, 23 minutes and 15 seconds (4:23:15) ______________________________

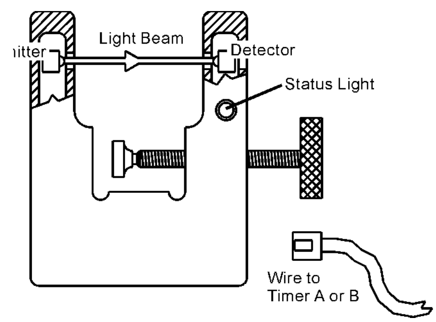
4 Using the photogates

A photogate allows us to use a light beam to start and stop the timer. When the timer is in interval mode, it uses photogates to control the clock.



1. Connect a single photogate to the "**A**" input with a cord.
2. Select **interval** on the timer.
3. Push the "**A**" button and the "**A**" light should come on and stay on.
4. Try blocking the light beam with your finger and observe what happens to the timer.

Try your own experiments until you can answer the following questions. Be very specific in your answer. Someone who has never used the timer before should be able to read your answer and know what to do with the light beam to make the clock start and stop.



a. Question: How do you start the clock?

____

____

____

b. Question: How do you stop the clock?

____

____

____

c. Question: What time interval has the clock measured?

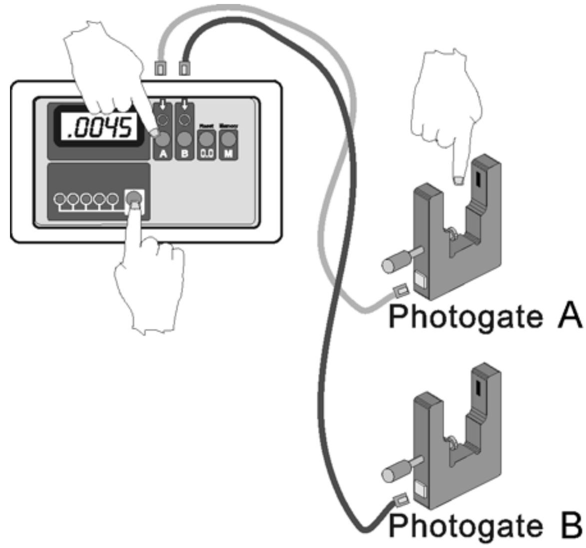
____

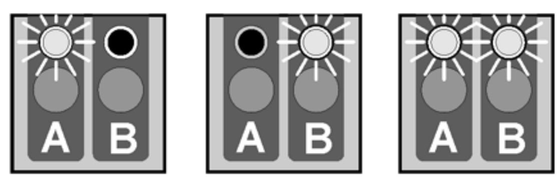
____

____

5 Using the timer with two photogates

1. Connect a second photogate to the socket behind the B button (input B). You should now have two photogates connected to the Timer.
2. Make sure the light on each photogate is green and press the reset button. Pressing reset clears the clocks and also tells the timer to look at its inputs to see which photogates are connected.
3. Use the A and B buttons to turn the A and B lights on and off. The timer does something slightly different for each combination of lights shown in Table 1.
4. Do your own experiments and fill in the rest of Table 1.





What starts and stops the displayed time for each setting of the A and B lights?

Table 1: Timer and photogate rules

A light	B light	How do you start the clock?	How do you stop the clock?	What time interval does the clock measure?
On	Off			
Off	On			
On	On			
Off	Off			

6 Another test to try

If you block the light beam several times in a row, does the time add or does the timer start at zero every time you break the beam? Write a one-sentence answer that also gives the reasons for what you say. For example, "the timer does _____ because_____."

___

___

___

7 Measuring small distances

In science, length is usually measured in units based on the meter. For example, one millimeter is 0.001 meters (or 1/1000 meter). A millimeter may be small, but there are many things in science that are smaller still. Scientists have to measure these things even though they are so small that they cannot be measured directly with the ruler.

1. Describe a way to measure the thickness of a single sheet of paper using a ruler that can measure to a precision of one millimeter.

2. Collect several books and use your technique to measure the thickness of paper in each book.

8 Converting between the metric units of distance

Use the conversion factors below to help you convert your measurement of paper thickness into kilometers, meters, and centimeters. (Converting from mm to km requires 2 steps).

$$\frac{1\text{ m}}{1000\text{ mm}} = 1 \qquad \frac{1\text{ km}}{1000\text{ m}} = 1 \qquad \frac{1\text{ cm}}{10\text{ mm}} = 1$$

9 Measuring distances in different units

1. Measure the length and width of your desk or lab table in centimeters.
2. Measure the length and width of your desk or lab table in millimeters.
3. Measure the length and width of your desk or lab table in inches.

a. Explain why the length measurements have different numerical values even though you were measuring the exact same length.

b. Calculate the width to length ratio (in cm) by dividing the width (cm) by the length (cm). What is the ratio in the other units (mm and inches)? Why are all the answers the same?

2A Systems and Variables

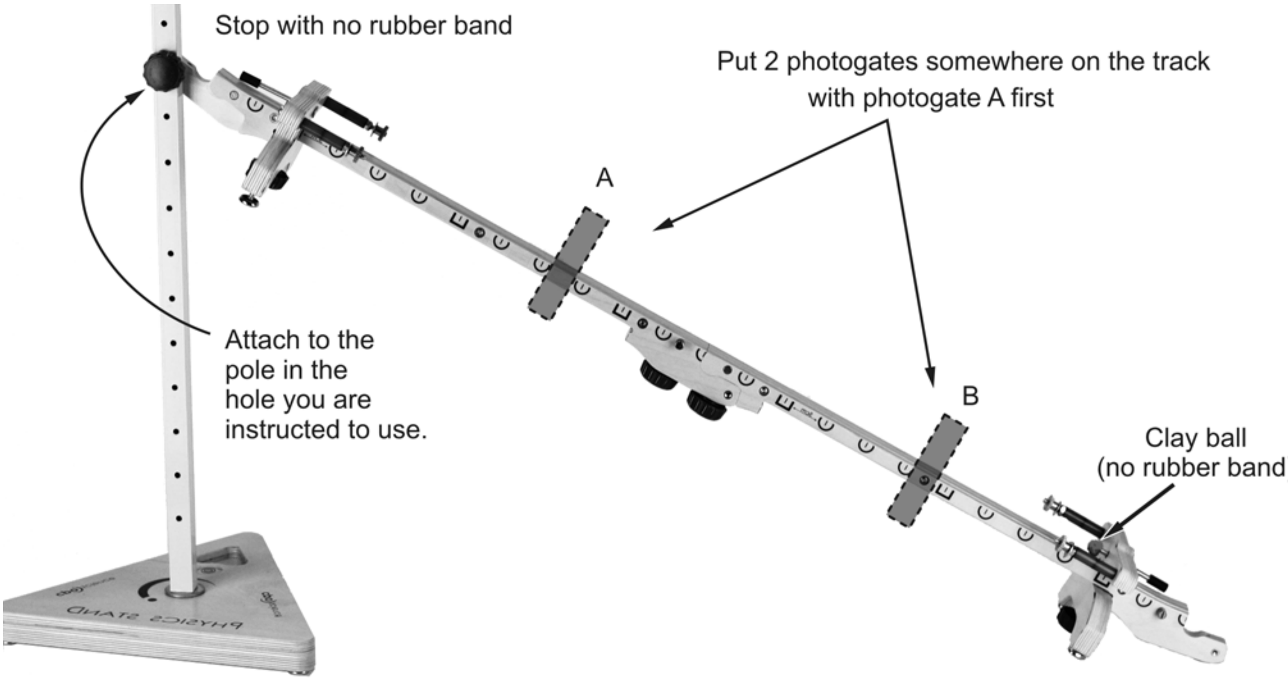
How do scientists find relationships in nature?

A system is a group of related objects and influences that you are trying to understand. Variables describe things in the system that can change.

Materials

- Energy car and track
- Timer and photogates

1 Making a system



1. Set up the track with a long straight section. Your teacher will tell you which hole in the stand to attach the track. Each group will have a different angle.
2. Put a clay ball on the stop at the bottom.
3. Place two photogates on the track with photogate A higher than photogate B.
4. Roll the car down and record the time it takes the car to pass between the photogates.

2 Stop and think

a. Which track should have the fastest car? Which track should have the shortest time between photogates?

b. Write a one sentence hypothesis that relates the time between photogates to the angle of the track.

c. Use Table 1 to record the results from each group in your class. Record the times in the column labeled “First Trial”. Leave the column labeled “Second Trial” blank. How do the results compare with your hypothesis? Can you give a reason why they did or did not behave as you expected?

Table 1: Photogate times from A to B

	First Trial	Second Trial
Attached at (holes from bottom)	Time from A to B (seconds)	Time from A to B (seconds)

3 Variables

a. List at least seven variables in your system which affect the time between photogates.

b. Which variable is the experimental variable in your class? How do you know?

c. What should be done with the other variables (other than the experimental variable)? Why should this be done?

d. Name two variables that should not be included in your system. These variables should not have much (or any) influence on the time from photogate A to B.

4 A controlled experiment

1. With your teacher and the rest of your class, decide on how to control the variables other than the experimental variable.

2. Practice rolling the car until you can get three consecutive times within 0.0010 seconds of each other.
3. Repeat the experiment in step one. Record the new data in the column titled "Second Trial".

5 Applying what you have learned

a. Does the second trial of the experiment produce results that agree with your hypothesis?

b. Why does the second trial produce better agreement with your hypothesis than the first trial did?

c. If something does not work, discuss what you should do to try and find the problem. List at least three steps that relate to variables, experiments, and controls.

2B Making Predictions From a Graph

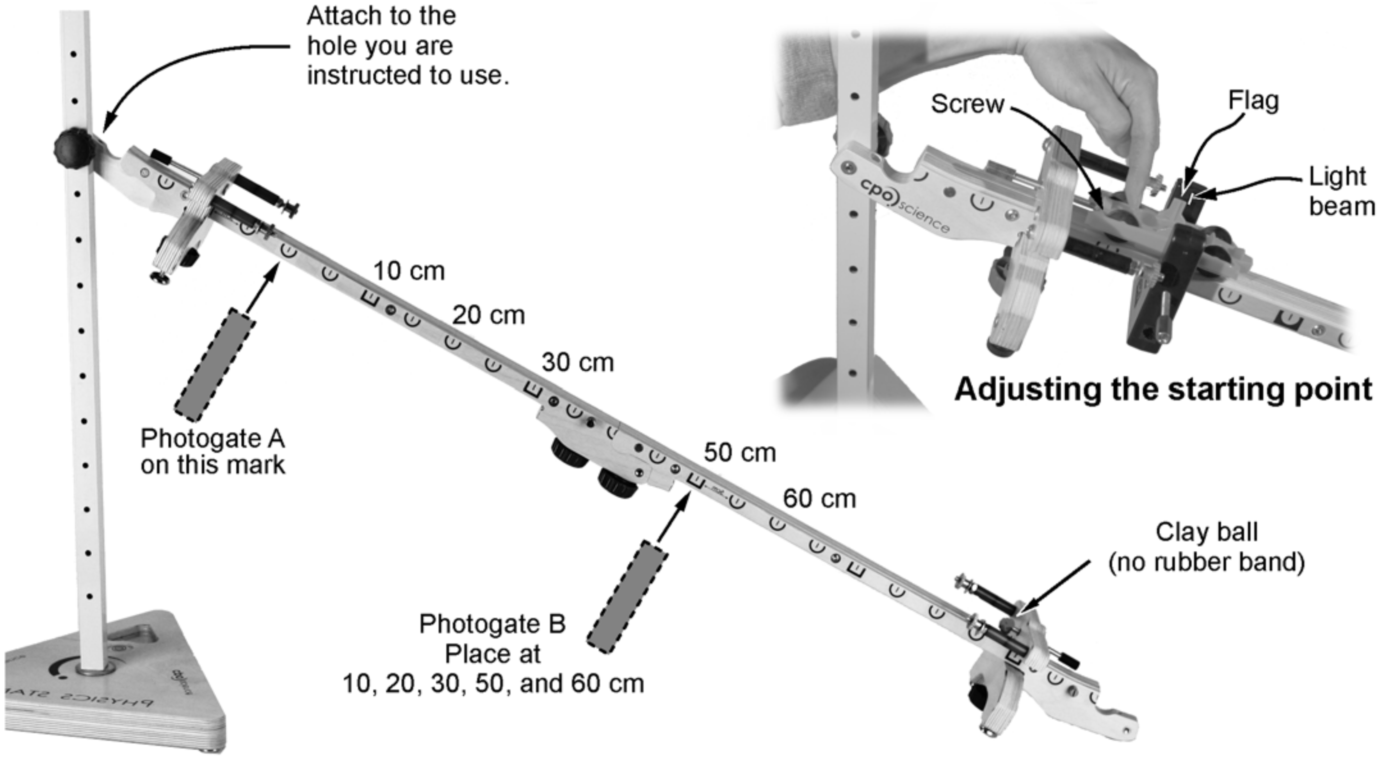
Why are graphs useful?

In science, a model is a relationship between variables. For example, the car takes a certain amount of time to roll a certain distance down the track. A model for the cars motion would allow you to predict how long it would take the car to reach any distance down the track. Graphs are a good way to visualize a model that involves two variables, such as time and distance. In this Investigation you will create a model (graph) that predicts how long it takes the car to reach anywhere on the track.

Materials

- Energy car and track
- Timer and photogates
- Meter stick

1 Setting up



1. Set up the track with a long straight section. Your teacher will tell you which hole in the stand to attach the track. Each group will have a different angle.
2. Put a clay ball on the stop at the bottom. Put the other stop at the top to provide a repeatable starting point for the car.
3. Place photogate A on the mark shown in the diagram. Adjust the screw so the car breaks the light beam just after you release it. Once you start the experiment, do not change the adjustment of the screw.
4. The marks on the track are 5 cm apart. Place photogate B two marks (10 cm) lower than photogate A. Roll the car and record the time from A to B.
5. Move photogate B to 20, 30, 50 and 60 cm from photogate A. Measure and record the time from A to B for each position. You will not be able to measure at 40 cm because of the split in the track. DO NOT measure at 70 cm (yet).

Table 1: Photogate times from A to B

Distance from A to B (cm)	Time from A to B (seconds)
10	
20	
30	
50	
60	

2 Analyze the data

a. Draw a graph showing the time from A to B on the y-axis and the distance from A to B on the x-axis. This graph is a model that shows how the time and distance are related.

Title: ____

y label: ____________________

x label: ______________________________

b. Use the graph to predict the time it should take the car to go 80 centimeters.

Prediction: ____

3 Test the model

a. Move photogate B so it is 80 cm away from photogate A.

b. Test your prediction by rolling the car and measuring the time from A to B. Do three trials with the same distance. Use the table below to record your data and calculate the error between the predicted and measured times.

Predicted time (s)	
Measured times: 3 trials at 80 cm (s)	
Average measured time (s)	

$$\% \text{ Error} = \frac{\text{predicted - measured}}{\text{predicted}}$$

$$\boxed{} = \frac{\boxed{} - \boxed{}}{\boxed{}}$$

4 Stop and think

a. How large was the difference between the prediction and the measurement? Was the difference significant (larger than the errors in the measurement)?

b. Give at least one good reason why the prediction and measurement might not be in perfect agreement.

c. Why was the time placed on the *y*-axis of the graph?

d. Give at least one way the prediction at 80 could be improved (short of doing the actual measurement).

3A Energy

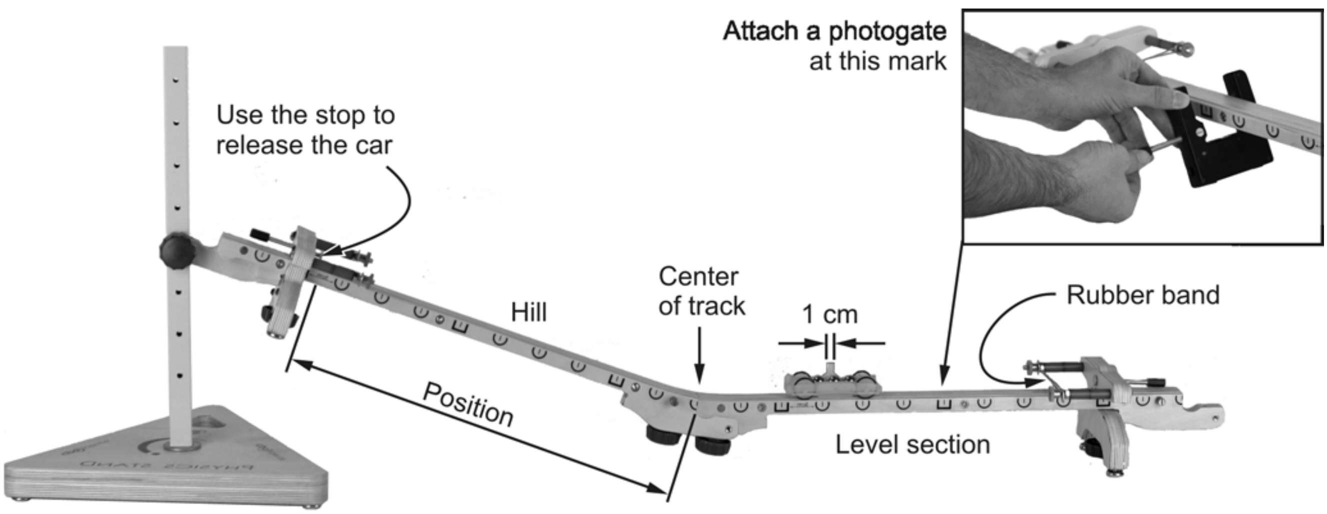
What is energy?

Energy is a very important idea that is hard to define. Energy is a measure of the ability to change or create change. A car at the top of a hill is able to move because it has energy due to its height. The car's increase in speed as it moves is a change that could not occur without energy. Temperature is another way to measure differences in energy. Warm water has more energy than cold water. Energy can appear in many forms, such as heat, motion, height, pressure, electricity, and chemical bonds between atoms. The key to understanding why things change in physical science is to follow the movement of energy.

Materials

- Energy car and track
- Timer and photogates
- Meter stick
- Mass balance
- Thermometer
- Foam cups
- Hot and cold tap water

1 Energy in height and motion



1. Set up the track with the steeper hill and a level section.
2. Put a photogate near the middle of the level section.
3. Drop the car from different heights on the hill using the screw on the stop to provide a repeatable starting point. Measure and record position from the center of the track.
4. Use the photogate to measure the time it takes the car to pass through the light beam before and after bouncing off the rubber band.
5. Drop the car from different heights to get several different speeds.

Table 1: Times before and after bouncing

Drop position (cm from center)	Before rubber band	After rubber band
	Time through photogate (sec)	Time through photogate (sec)

2 Stop and think

a. If you drop the car from a certain height does it ever go higher after bouncing off the rubber band?

b. If the car has a certain speed going into the rubber band does it ever have a greater speed after bouncing off? (Hint: use the timer's memory button.)

c. When you drop the car from a certain height it reaches a certain speed at the photogate. If you launch the cart with the same speed back up the hill, does the car ever get higher than the height at which you first dropped it? (try this experiment)

d. In one paragraph, explain how the answers to a, b, and c are explained using the idea of energy.

3 Temperature and energy

Two foam cups contain equal masses of water. One cup contains cold water and the other contains hot water. The hot water is mixed with the cold water and stirred.

1. Prepare foam cups contain 100 g each of hot and cold water.
2. Measure and record the temperatures before mixing.
3. Mix the water, stir well, and measure the final temperature.

Table 2: Temperature data for mixing equal masses of water

Cold water temperature before mixing (°C)	Hot water temperature before mixing (°C)	Mixture temperature (°C)

4 Applying what you have learned

a. Which cup has more energy, the hot one or the cold one? Why do you think so?

b. What do you think the temperature of the mixture will be? Why?

c. If the system includes both the cold and hot water, compare the energy of the system before mixing to the energy after mixing. You may ignore any energy going to air or friction.

d. In one paragraph, explain how the answers to a, b, and c are explained using the idea of energy.

3B Mass and Indirect Measurement

How do scientists measure things too small to put on a balance?

There are many situations where scientists need to measure something that is too small or too large to measure directly. In these situations scientists use indirect measurement. With indirect measurement you calculate the thing you want to know from other measurements.

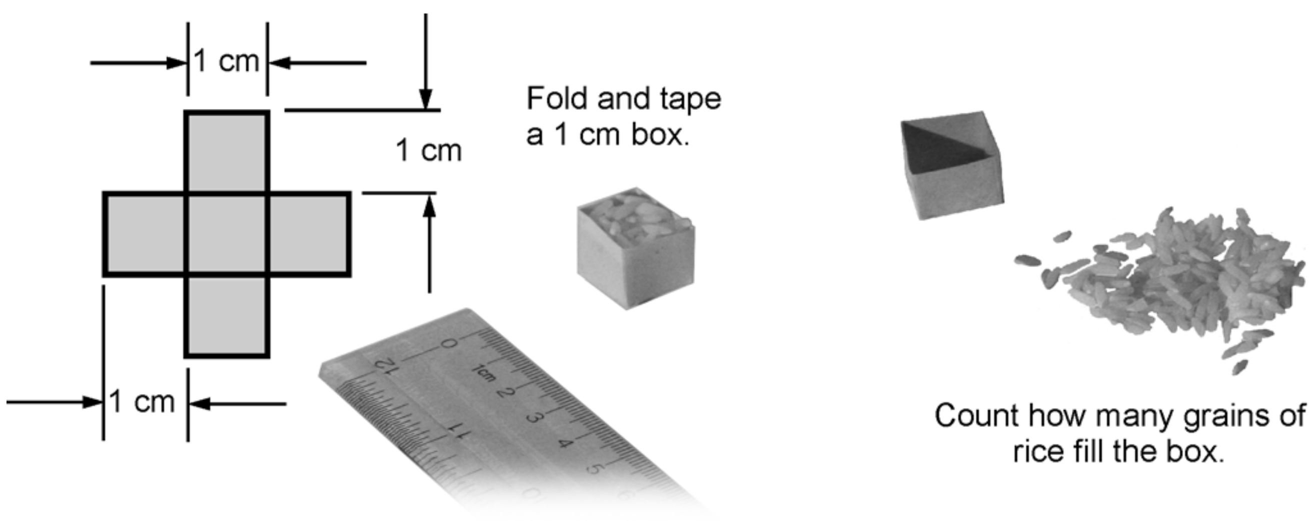
Materials

- About one quarter cup of rice
- Some cellophane tape.
- A mass balance
- Scissors
- index card

The objective of the experiment is to find the average mass of a single grain of rice. One grain of rice is much too small to weigh accurately with the balance. Instead, you will measure the mass of a three centimeter cube filled with rice. You will then estimate how many grains there are in the cube. By dividing the mass of the cube by the number of grains in the cube, you will get a very good measurement of the average mass of a single grain of rice.

1 Getting started

The first thing we need to do is find out how many grains of rice are in a cubic centimeter.



1. Cut out and fold up the small cube (made out of an index card) as shown in the diagram above. Use the cellophane tape to hold the cube together. This cube has a volume of 1 cubic centimeter (1 cc).
2. Fill the cube level with rice.
3. Carefully empty the rice in the cube onto the table. Count how many grains fit into the cube and record the value in Table 1.

4. Calculate the number of grains of rice per cubic centimeter and record this value in Table 1. Use the formula below:

number of grains / volume of cube = grains per cubic centimeter

Table 1: Data on the number of grains per cubic centimeter

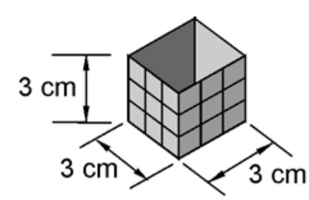
Volume of cube (cm^3)	1
Number of grains of rice	
Calculated grains per cubic centimeter	

2 Accuracy, precision, and resolution

No instrument in science makes perfect measurements. A single cubic centimeter of rice is a very small mass and difficult to measure precisely with an ordinary balance. For example, suppose you want a measurement that is precise to one percent. A typical electronic balance has a resolution of 0.1 grams. That means the smallest mass you can measure with this balance is 100 times as large as its resolution. 100×0.1 g = 10 g therefore, 10 grams is the smallest mass you can measure to a precision of one percent. Since the mass of one cubic centimeter of rice is less than 10 grams, we will use a much larger amount of rice.

3 Making a precise measurement

1. Cut out and fold up the 3 centimeter cube as shown in the diagram. Use the cellophane tape to hold the cube together.
2. Calculate the volume of this cube and write it in Table 2.
3. Place the cube on the balance and reset the balance to zero. The balance display should now read 0.0 grams.
4. Remove the cardboard cube and fill it level with rice. Place the filled cube back on the balance and record the mass.
5. Calculate the number of grains of rice in the cube based on the value of grains per cubic centimeter you calculated in Table 1.



6. Use the mass of rice in the large cube and the calculated number of rice grains to find the average mass of one grain of rice.

Table 2: Data on the mass of a grain of rice

Volume of cube (cm^3)		Number of grains of rice in 3 cm cube	
Mass of rice in cube (g)		Calculated mass of 1 grain of rice (g)	

4 Stop and think

a. Why did the balance show a small negative mass when you removed the empty cardboard cube at the beginning of step 4?

b. Why does this experiment measure the *average* mass instead of the *actual* mass of a grain of rice?

c. Why is the average mass a more useful quantity than the actual mass of any single grain of rice?

4A Density

What is density and how is it measured?

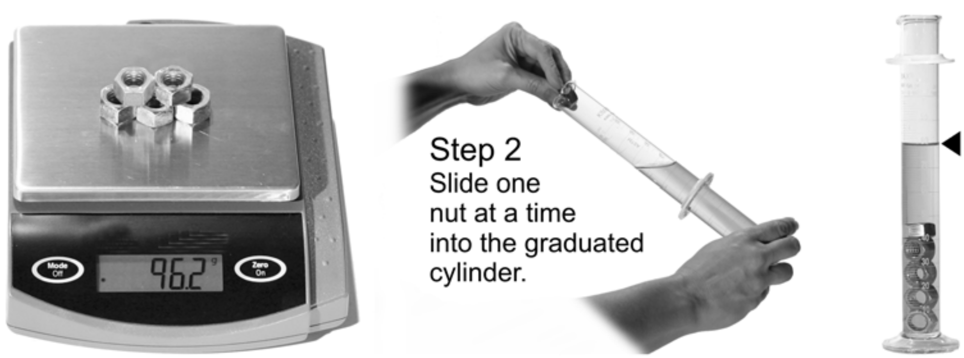
Suppose someone asks you "Which is heavier: a pound of feathers or a pound of bricks?" The answer, of course, is that they have the same weight. But why do so many people shout out "bricks" before they stop to think? The answer is because feathers are much less dense than bricks.

Materials

- Graph paper & ruler
- Balance
- disposable cups
- 250-milliliter beaker
- Graduated cylinder
- Six steel hex nuts 3/8" or 1/2" size
- Glycerin
- Corn syrup
- Molasses
- Water
- Vegetable oil
- Food coloring
- Rubber stopper

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

1 The relationship between mass and volume



1. Measure the mass of 1, 2, 3, 4, and 5 nuts.
2. Fill your graduated cylinder partly with water. Record the volume. Add one nut, tilting the cylinder so the nut slides in gently.
3. Record the volume after adding each nut for all five nuts.

Table 1: Mass and volume data

Nuts	0	1	2	3	4	5
Mass (g)						
Volume (mL)						

2 Analyzing your results

a. Plot your data on graph paper. Label the *x*-axis "volume." Label the *y*-axis "mass." Be sure to use the entire space on your graph paper for making your graph.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Is there any pattern to the data points on your graph? For example, do the points form a smooth curve, a straight line, a random scattering, or a cluster in a certain region?

____

c. Take your ruler and move it along the points of the graph. Keep moving it until you find the line on the paper that is as close as possible to all of the dots. This line is called the "line of best fit." Draw the line.

3 Finding the slope

Find the slope of the line on your mass vs. volume graph. To find the slope, choose any two points on the line. These will be represented as (X_1, Y_1) and (X_2, Y_2). Use this formula to calculate the slope of the line:

$(Y_2 - Y_1) \div (X_2 - X_1)$ = slope of the line = the density of the material you tested.

The slope tells how many grams of matter are contained in each milliliter of material you tested. The slope is the density of the material. Some substances, such as lead, have quite a few grams of matter packed into each milliliter. Others, such as styrofoam, have less than a single gram of matter packed into each milliliter. The relationship between the mass and the volume is called the density of a substance.

a. Compare your slope with the slope found by other groups.

b. Are your slopes similar or different?

4 The density of liquids

Five liquids

Tare the balance to zero with a clean, dry graduated cylinder.

Record the mass and volume for a sample of each liquid

1. Start with about 30 milliliters of each of five liquids.
2. Put the empty graduated cylinder on the balance and reset it to zero.
3. Add a quantity of each liquid and measure the mass and volume.
4. Wash and dry the graduated cylinder between each liquid.

Table 2: Density data for liquids

Substance	Mass in grams	Volume in mL	Density in g/mL
molasses			
water			
vegetable oil			
light corn syrup			
glycerin			

5 Deciding how to stack your liquids

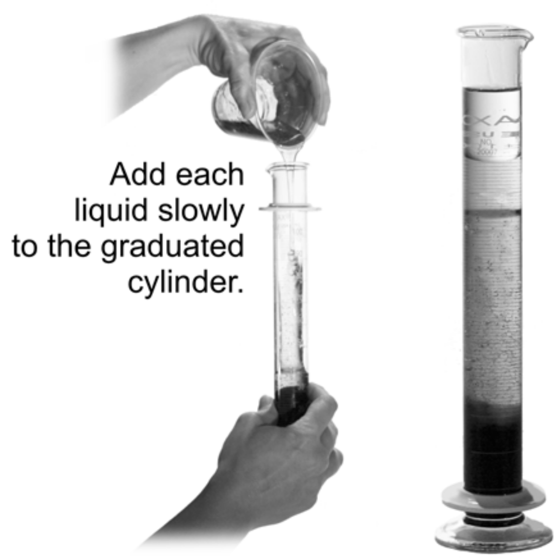
A density column is a "stack" of different liquids placed in a tall, thin cylinder. Your task is to make a density column in your graduated cylinder. First, you must decide the order that you will put the liquids in the container. Look at the density data from the table above. It should help you decide how to stack the liquids. List the order that you choose for your liquids.

Liquid 5 (top)	
Liquid 4	
Liquid 3	
Liquid 2	
Liquid 1 (bottom)	

6 Constructing your density column

You will use the remaining 20 milliliters of each liquid to make a density column. If you wish, you may add one or two drops of food coloring to the water, corn syrup, and glycerin. The different colors will make them easier to tell apart.

1. Carefully pour your first liquid into the cylinder. Try to keep the liquid from running down the inside of the cylinder.
2. Add the other liquids slowly, one at a time. Let each liquid settle before adding the next one.
3. Your completed column should have the liquids in the layers you predicted.



7 Applying what you have learned

a. Did the liquids remain in the order in which you poured them into the graduated cylinder? If not, explain why.

b. When salt is added to water, the density increases. This is why ocean water is more dense than fresh water. Suppose a sample of ocean water with the density of 1.08 grams per milliliter is added to the density column. Where would this liquid settle if it did not mix with the others?

c. Find a any rubber stopper which fits easily into the graduated cylinder without touching the sides. Carefully release the rubber stopper so it sinks into the graduate cylinder. Where does it stop sinking? What can you conclude about the density of rubber?

4B Sink or Float

Steel is denser than water so why do steel boats float?

Solid objects float if they are less dense than the liquid in which they are placed. Objects sink if they are more dense than the liquid. You may have noticed that large ships are often made of steel. Steel is much denser than water. So how does a steel boat float? The answer is in the concept of average density. You will soon discover how and why boats can be made of materials that are denser than water.

Materials

- 1/2 stick of modeling clay
- Balance
- Displacement tank
- Disposable cup
- Beakers
- Graduated cylinder
- Container for testing boats (at least 15 cm deep)

1 The density of clay

Find the density of your stick of clay before you change its shape.

1. Measure the clay's mass. Record it in Table 1.
2. Find the volume of your stick of clay using the displacement method:
   - Place a disposable cup under the displacement tank spout.
   - Fill the tank until water begins to run out of the spout (approx. 1,400 mL)
   - When the water stops flowing, remove the cup and replace it with a dry beaker.
   - Gently place your clay into the tank. Collect the water that runs out of the spout.
   - Quickly remove your clay and dry it with a paper towel. Do not allow water to mix with your clay or it will get very slimy.
   - The volume of the water you collected is equal to the volume of your clay. Use the graduated cylinder to measure the volume and record it in Table 1.

Add water until it just starts running out of the spout

Table 1: Density data for clay

Substance	Mass (g)	Volume (mL)	Density (g/mL)
Clay			

3. Calculate the density in g/ml.

4. Did your stick of clay sink or float in the displacement tank? Use the density of your stick of clay and the density of water (1.0 g/mL) to explain why.

____

____

____

2 Making the clay float

You know that steel can be formed into a shape that floats. Can you do the same thing with clay? For this activity, you must use ALL of your clay. Mold it into a shape that you think will float.

1. Fill the container with water until it is about 12 centimeters deep.
2. When you are ready to test a shape that you have made, gently place it in the water in the container. If the clay sinks, take it out of the water and dry it off right away.
3. When your clay is dry, change the shape of your "boat" and try again.
4. When you have successfully made a boat that floats, take it out of the water. Dry it with a paper towel.
5. Measure the mass of your boat and record it in Table 2.

3 Why a boat floats

1. When a boat floats, it displaces a certain volume of water. Make a prediction: Do you think your boat will displace more water, less water, or the same amount as your stick of clay?

Prediction: ____

2. To find out, first prepare the displacement tank just as you did in step 1.
3. Place your clay boat in the water in the displacement tank. Let it float there while the water flows out.
4. Measure the volume of the water displaced by your clay boat. Record this volume in Table 2.
5. Use your mass and volume data to calculate the average density of your clay boat.

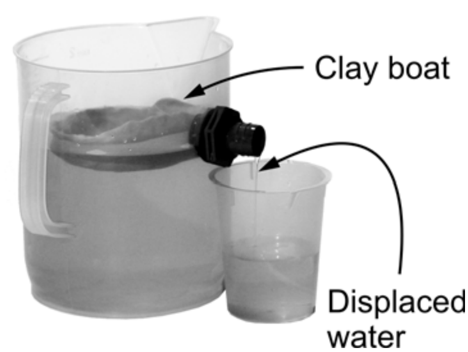


Table 2: Data for boat

Mass of boat (g)	Volume of water displaced by the boat (mL)	Average density of the boat (g/mL)

4 Thinking about what you observed

a. Which displaced more water, the stick of clay or the clay boat?

b. Assuming the mass of the clay did not change, how do you explain the difference in the volumes displaced by the stick of clay and the clay boat?

c. Look at the boat's average density. Why is it different than the density of the stick of clay? What other substance has a density very similar to the boat's average density?

d. Explain why a solid stick of clay sinks but a clay boat can be made to float.

e. What would happen if you added "cargo," like pennies, to your boat? Is there a limit to how much mass you can add before the boat sinks? Does the volume of displaced water increase or decrease when the boat gets heavier? Why? Try the experiment.

5A The Phases of Matter

How do the mass, volume, and densities of solid, liquid, and gas compare?

Air may feel like "nothing" but actually air is matter and has considerable mass! In fact, a cubic meter of air (about the size of an armchair) has a mass of about 1 kilogram. In this Investigation you will measure the amount of matter in solid, liquid, and gas and compare their densities.

Materials

- Mass balance
- Prepared bottle cap with inserted tire valve
- Tire pressure gauge
- Ice water
- Bicycle pump

1. Safety Note: Be careful with the bottle, and DO NOT exceed 70 pounds per square inch (psi) of pressure.
2. Get the prepared cap with the tire valve inside and a 1 liter carbonated soda bottle.
3. Fill the bottle to the very top with water. Empty the water into a graduated cylinder to measure the volume of the bottle.
4. Put the cap on the empty bottle (full of air) and measure the mass.
5. Use the bicycle pump to raise the pressure in the bottle to 10 psi. Check the pressure with your gauge.
6. Use the balance to measure and record the mass of the bottle (and air) at 10 psi pressure.
7. Repeat the pumping and mass measurement for pressures between 10 psi and 70 psi. DO NOT exceed 70 psi!

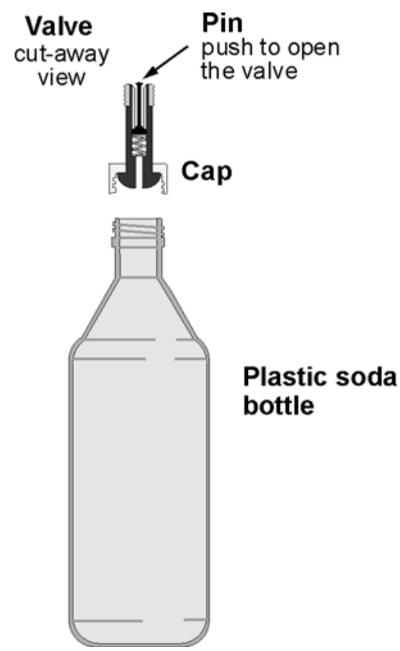


Table 1: Pressure and mass data

Gauge pressure (psi)	Mass (g)	Volume (ml)

1 Thinking about what you observed

a. Use Table 2 to calculate the mass of air added to the bottle at different pressures.

b. What happens to the mass as you increase the pressure in the bottle?

c. Explain your answer to question b.

d. Make a graph showing the mass of air plotted against the pressure.

Title:

y label:

x label:

e. Is there still air in the bottle when the pressure is zero on the gauge? Use the graph to estimate the mass of air in the bottle at atmospheric pressure (zero on the gauge).

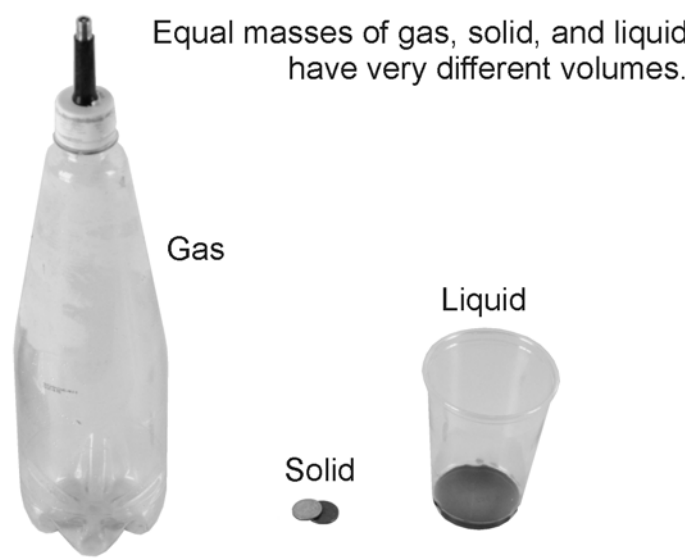
Table 2: Calculating the mass of air

Pressure (psi)	Mass of bottle and air (g)		Mass of bottle at zero gauge pressure		Mass of air added to bottle (g)
		-		=	
		-		=	
		-		=	
		-		=	
		-		=	
		-		=	

2 Liquid and solid phases

1. Use your balance to measure out a quantity of water of equal mass to the air at zero gauge pressure.

2. Use your balance to measure out a quantity of solid material (coins, salt or sugar work well) of equal mass to the air at zero gauge pressure.



3 Thinking about what you observed

a. Compare the total amount of matter in the gas, liquid, and solid samples. Does one have more matter? Does one have less matter? Or, do all have about the same amount of matter?

b. Calculate the density of the air in the soda bottle when the gauge read zero pressure. How does this density compare with the density of water (1 g/ml)?

c. What is the mass of air in your classroom? To answer the question, start by measuring the volume of your classroom in cubic meters. Once you have this number, convert the density of air in g/ml to kg/m^3 using the relationship below:

$$1.25 \text{ g/l} = 1.25 \text{ kg/m}^3$$

How does the mass of air in your classroom compare to the mass of a person?

d. Compare the relative density of each of the three samples (solid, liquid, gas).

5B Phase Changes

What happens when matter changes phase?

We experience matter in three phases: solid, liquid, and gas. Changing from one phase to another means changing the bonds between atoms, so energy must either be used or given off. This Investigation will explore how much energy it takes to change matter from one phase to the next.

Materials

- Thermometer
- Mass balance
- Foam cups
- Ice
- Cold water
- Hot water

1 Doing the experiment

Measure equal masses into all four cups
(103.9 g is example only, use your own mass)

1. Place some crushed ice in cold water, then transfer at least 100 g of ice into a cup. Try not to get any liquid water, just ice.
2. Measure the mass of the ice and cup.
3. Make another cup with an equal mass of cold ice water (with ice removed).
4. Make two cups with an equal mass of hot water
5. Measure and record the temperatures before mixing. Assume the solid ice is at 0°C.
6. Mix the ice and hot water in one cup and the hot and cold water in another cup. Stir well, and measure the final temperature of each mixture after all the ice has melted.

Table 1: Temperature data for mixing equal masses of water

Liquid cold water plus hot water		
Cold water temperature before mixing (°C)	**Hot water temperature before mixing (°C)**	**Mixture temperature (°C)**
Solid water (ice) plus hot water		
Ice temperature before mixing (°C)	**Hot water temperature before mixing (°C)**	**Mixture temperature (°C)**
0		

2 Thinking about what you observed

a. Given the actual hot and cold temperatures, what do you think the mixture temperature should have been if the ice could change to liquid (of the same temperature) without any change in energy?

____

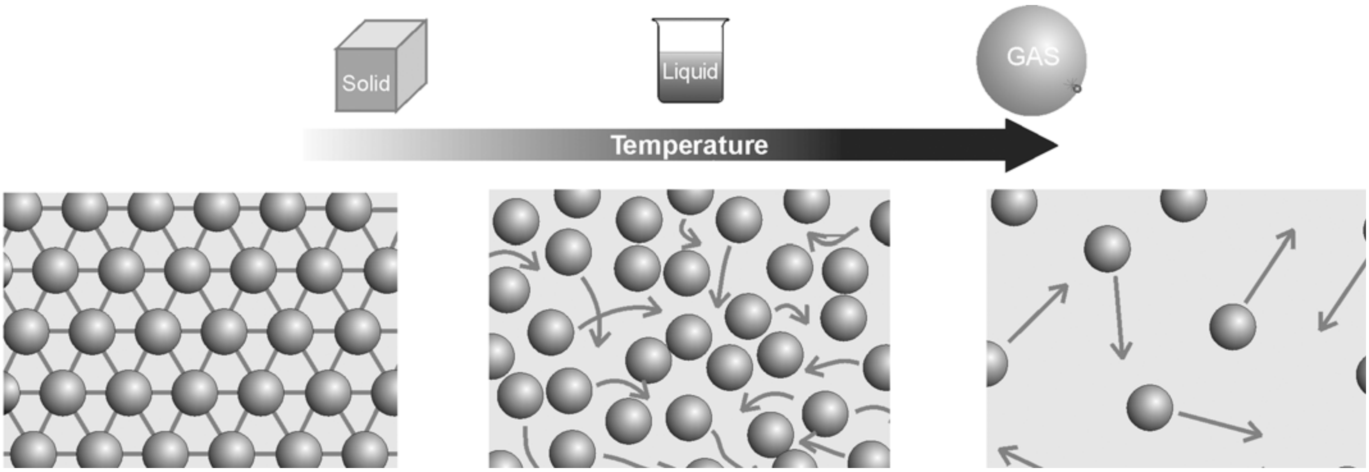
b. Was the final temperature of the mixture for the ice + water mixture about the same, more, or less than the final temperature of the water + water mixture?

____

____

____

c. Explain the difference in temperatures using the concepts of energy and phase change (heat of fusion). You may refer to the following diagram.



6A The Atom

What is inside an atom?

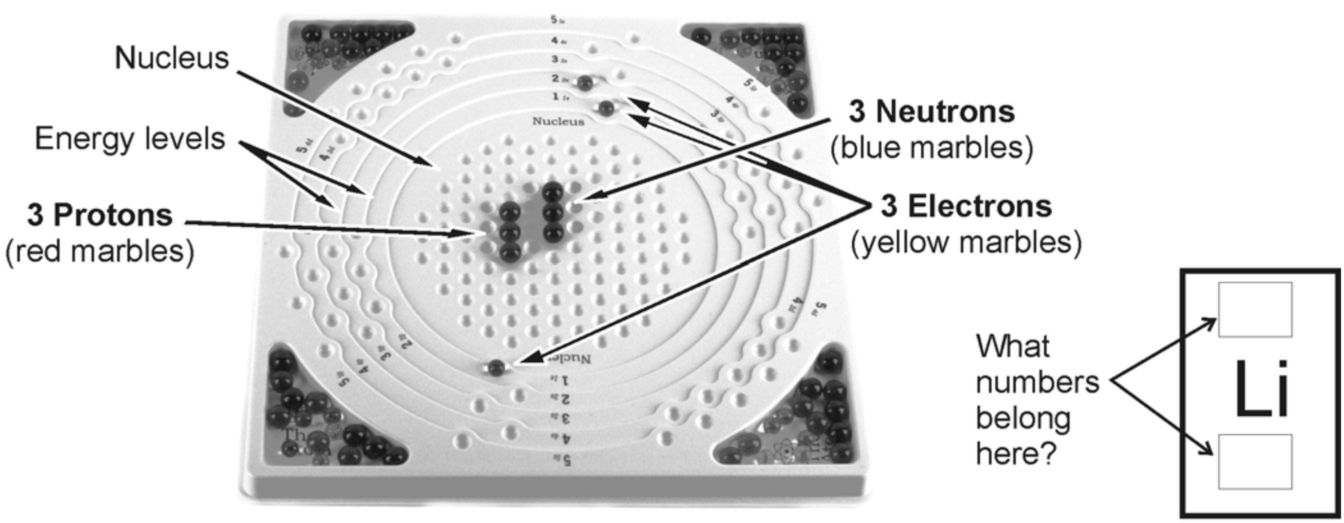
We once believed that atoms were the smallest units of matter. Then it was discovered that there are even smaller particles inside atoms! The structure of the atom explains why nearly all the properties of matter we experience are what they are. This investigation will lead you through some challenging and fun games that illustrate how atoms are built from protons, neutrons, and electrons.

Materials

- Atom building game

1 Modeling an atom

In the atom game, colored marbles represent the three kinds of particles. Red marbles are protons, blue marbles are neutrons, and yellow marbles are electrons.



1. Build the atom above using three red, three blue, and three yellow marbles.
2. Fill in the blanks in the empty periodic table box for the atom you constructed.

2 Thinking about the atom

a. What is the number below the element symbol? What does this number tell you about the the atom?

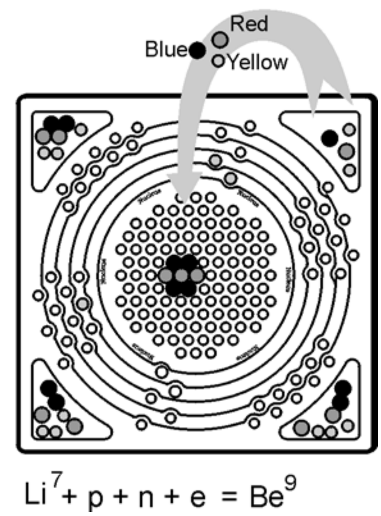
b. What is the number(s) above the element symbol called? What does this number tell you about the atom?

c. Why do some elements have more than one number above the symbol? What are the variations in this number called?

3 The Atomic Challenge

Atomic Challenge is a game that simulates the periodic table of elements.

The winner of the game is the first player to use all their marbles.



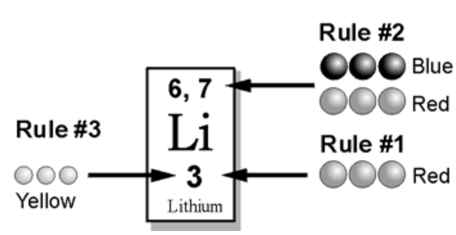
1. Each player should start with the following marbles: 6 blue marbles (neutrons), 5 red marbles (protons), and 5 yellow marbles (electrons).
2. Each player takes turns adding 1 - 5 marbles, but not more than 5. The marbles may include any mixture of electrons, protons, and neutrons.
3. Marbles played in a turn are added to the marbles already in the atom.
4. If you add marbles that make an atom NOT shown on the periodic table you have to take your marbles back and lose your turn. Only atoms where the electrons, protons, and neutrons match one of the naturally occurring elements on the table are allowed.
5. A player can trade marbles with the bank INSTEAD of taking a turn. The player can take as many marbles, and of as many colors as they need but must take at least as many total marbles as they put in. For example, a player can trade 2 yellows for 1 yellow, 1 blue, and 1 red.

The Three Rules

Rule #1: The number of protons matches the atomic number

Rule #2: The total number of protons and neutrons equals a stable mass number

Rule #3: The number of electrons matches the number of protons



4 Stop and think

Atoms which are not on the periodic table shown may exist in nature but they are radioactive and unstable. For example, carbon-14 (C^{14}) is unstable and is not listed although C^{12} and C^{13} are stable.

a. What four elements make up almost all of the mass in your body?

____

____

b. How many stable isotopes does oxygen have?______________________

c. Find one element on the chart that has no stable isotopes.______________________

d. What element has atoms with 26 protons in the nucleus?______________________

e. On most periodic tables a single atomic mass is listed instead of the mass numbers for all the stable isotopes. How is this mass related to the different isotopes?

____

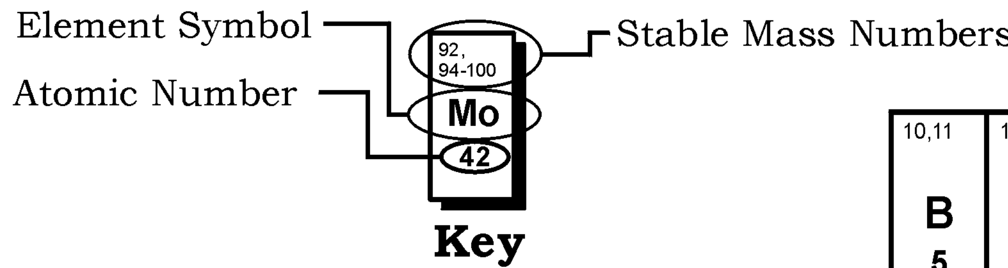
____

____

____

Periodic Table of the Elements 1- 54

(Stable isotopes)



1,2 **H** **1**																	3,4 **He** **2**
6,7 **Li** **3**	9 **Be** **4**											10,11 **B** **5**	12,13 **C** **6**	14,15 **N** **7**	16-18 **O** **8**	19 **F** **9**	20-22 **Ne** **10**
23 **Na** **11**	24-26 **Mg** **12**											27 **Al** **13**	28-30 **Si** **14**	31 **P** **15**	32-34, 36 **S** **16**	35,37 **Cl** **17**	36,38, 40 **Ar** **18**
39,41 **K** **19**	40,42-44,46, 48 **Ca** **20**	45 **Sc** **21**	46-50 **Ti** **22**	51 **V** **23**	50, 52-54 **Cr** **24**	55 **Mn** **25**	54,56-58 **Fe** **26**	59 **Co** **27**	58,60-62,64 **Ni** **28**	63,65 **Cu** **29**	64,66-68,70 **Zn** **30**	69,71 **Ga** **31**	70,72-74,76 **Ge** **32**	75 **As** **33**	74,76-78,80, 82 **Se** **34**	79,81 **Br** **35**	78,80, 82-84, 86 **Kr** **36**
85 **Rb** **37**	84, 86-88 **Sr** **38**	89 **Y** **39**	90-92, 94,96 **Zr** **40**	93 **Nb** **41**	92, 94-100 **Mo** **42**	none **Tc** **43**	96,98-103,104 **Ru** **44**	103 **Rh** **45**	102,104-106,108, 110 **Pd** **46**	107,109 **Ag** **47**	106,108, 110-112, 114,116 **Cd** **48**	113 **In** **49**	112,114-120,122, 124 **Sn** **50**	121 **Sb** **51**	120,122, 124-126, 128,130 **Te** **52**	127 **I** **53**	124,126, 128-132, 134,136 **Xe** **54**

6B Isotopes and Radioactivity

Are all atoms of the same element exactly alike or are there differences?

This Investigation is a game called Nuclear Reactions. Two to four people may play. As you play, you will try to figure out which nuclear reactions will make real atoms. In order to win, you will need to do this quickly. The game is a little like the way the elements were formed inside stars. At the center of a star, nuclear reactions combine atoms to make new elements.

Materials

- atom game with nuclear reaction cards

1 Key concepts

1. All atoms of the same element have the same number of protons in the nucleus (and the same number of electrons). For example, all lithium atoms have three protons in their nucleus.
2. Atoms of the same element may have different numbers of neutrons in the nucleus. Atoms of the same element with different numbers of neutrons are called **isotopes**.
3. Isotopes are the same element, but they have a different **mass number**. The mass number is the total number of the protons plus neutrons in the nucleus of the atom.
4. Some isotopes are **radioactive**, which means they break apart if left alone. Other isotopes are **stable**, which means they stay together. The periodic table on the next page shows the mass numbers of the stable isotopes for each element.

2 Playing the game

The objective of the game is to score 10 points. The first player to score 10 points wins.

To start the game, each player should have 5-8 of each color marble in their pocket of the board. More marbles may be taken at any time with no loss of turn.

The dealer shuffles the deck and gives five NUCLEAR REACTIONS cards to each player. Each player looks at their own cards but does not show them to the other players.

Each player holds 5 cards and may play any one in their turn

Players each take a turn. In their turn a player chooses to play one card and does what the card instructs. For example, if the card says “Add 2 Electrons”, the player must add two yellow marbles to the board. The played card is laid face-up on the table.

The player then draws a new card to maintain a hand of five and play passes to the next player on the right.

Points are scored depending on the atom which is left after a player takes their turn.

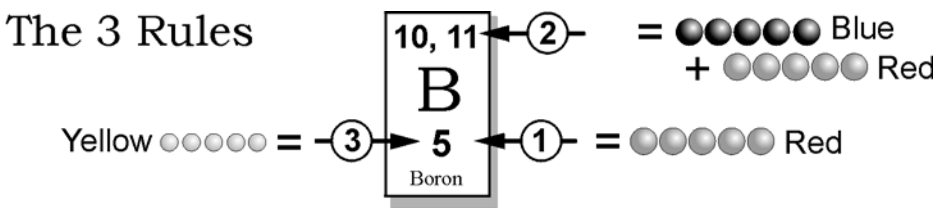
Used cards may be shuffled and re-used as needed.

3 Scoring points

The number of points scored is based on the atom that is created by each player's turn.

NOTE: it is not necessary to make stable atoms in every turn! However, if the atom created is not on the periodic table the player cannot score the maximum number of points (3) and may score no points at all.

Players score points when the atom satisfies the conditions below. Each player should use the periodic table to help decide which card to play to earn the most points.



Condition #1: The number of protons (red marbles) must match the atomic number of an element.
Condition #2: The total number of protons (red marbles) plus neutrons (blue marbles) must equal one of the correct mass numbers for the element in Condition #1. This creates a stable nucleus.
Condition #3: The number of electrons (yellow marbles) must be the same as the number of protons (red marbles). This creates a neutral atom.

Score 1 point IF You score 1 point if you create or leave a stable nucleus during your turn. To do this, you must satisfy both conditions #1 and #2.

OR

You score 1 point if you create or leave a neutral atom during your turn. A neutral atom has the same number of electrons and protons. You can do this by adding or subtracting electrons or protons.

Score 3 points IF You score 3 points if you make an atom that meets all 3 conditions during your turn. You can do this by either adding or subtracting marbles to the atom board.

4 Stop and think

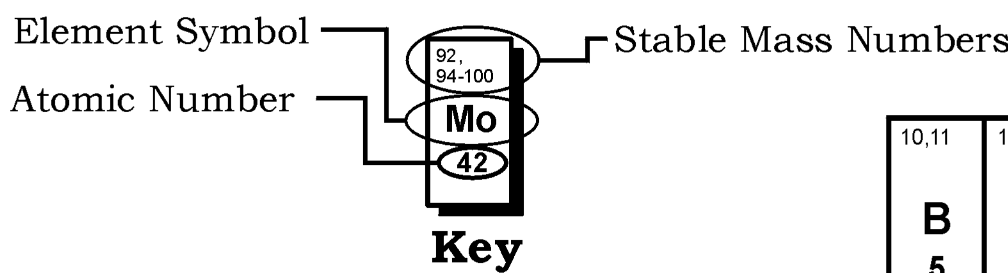
a. Hydrogen 2 is an isotope of hydrogen that has one proton and one neutron in its nucleus. What element would you get if you added one proton to the nucleus? Is the new isotope stable or radioactive?____________________________

b. What element do you get when you add three protons, three neutrons, and three electrons to boron 11? Is it stable or radioactive?____________________________

c. Write down a nuclear reaction using only two elements that would allow you to build Fluorine 19 starting with Boron 10. ____________________________

Periodic Table of the Elements 1- 54

(Stable isotopes)



1,2 H 1																	3,4 He 2
6,7 Li 3	9 Be 4											10,11 B 5	12,13 C 6	14,15 N 7	16-18 O 8	19 F 9	20-22 Ne 10
23 Na 11	24-26 Mg 12											27 Al 13	28-30 Si 14	31 P 15	32-34, 36 S 16	35,37 Cl 17	36,38, 40 Ar 18
39,41 K 19	40,42-44,46, 48 Ca 20	45 Sc 21	46-50 Ti 22	51 V 23	50, 52-54 Cr 24	55 Mn 25	54,56-58 Fe 26	59 Co 27	58,60-62,64 Ni 28	63,65 Cu 29	64,66-68,70 Zn 30	69,71 Ga 31	70,72-74,76 Ge 32	75 As 33	74,76-78,80, 82 Se 34	79,81 Br 35	78,80, 82-84, 86 Kr 36
85 Rb 37	84, 86-88 Sr 38	89 Y 39	90-92, 94,96 Zr 40	93 Nb 41	92, 94-100 Mo 42	none Tc 43	96,98-103,104 Ru 44	103 Rh 45	102,104-106,108, 110 Pd 46	107,109 Ag 47	106,108, 110-112, 114,116 Cd 48	113 In 49	112,114-120,122, 124 Sn 50	121 Sb 51	120,122, 124-126, 128,130 Te 52	127 I 53	124,126, 128-132, 134,136 Xe 54

7A The Periodic Table

What is the periodic table and how many elements are there?

Virtually all the matter you see is made up of combinations of elements. Scientists know of 118 different elements, of which about 90 occur naturally. Each element has its own unique kind of atom. The periodic table is a chart that shows all of the elements in order of increasing atomic number.

Materials

- Periodic table tiles

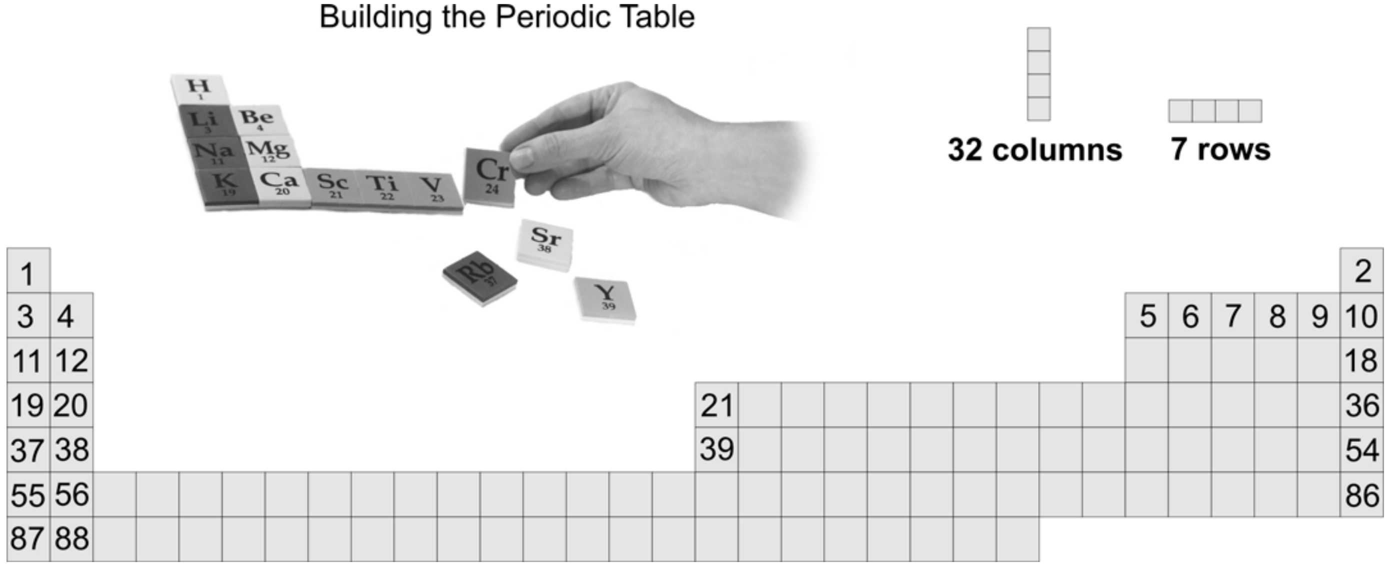
1 Elements and the atomic number

Every element is given a symbol of one or two letters. For example, the symbol for hydrogen is a capital letter H. The symbol for lithium is two letters, Li. Each element also has a unique number called the atomic number. The atomic number is the number of protons in the nucleus of all atoms of that element. Atomic number one is the element hydrogen. Hydrogen is the lightest element known, since it only has one proton in the nucleus. Atomic number 92 is the element uranium which is one of the heaviest elements that occurs in nature. Uranium has 92 protons in its nucleus.

2 Building the periodic table

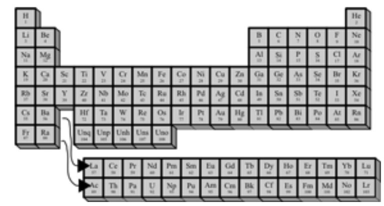
For this part of the investigation you are going to build the entire periodic table of elements. The table has a very specific shape which corresponds to the chemical properties of the elements. All of the elements fill-in this shape in order of their atomic number starting from the upper left-hand corner. As you build the table, be sure to follow the diagram below to get the right shape. Some of the squares have the atomic numbers of the elements shown to help you get the shape correct.

Building the Periodic Table



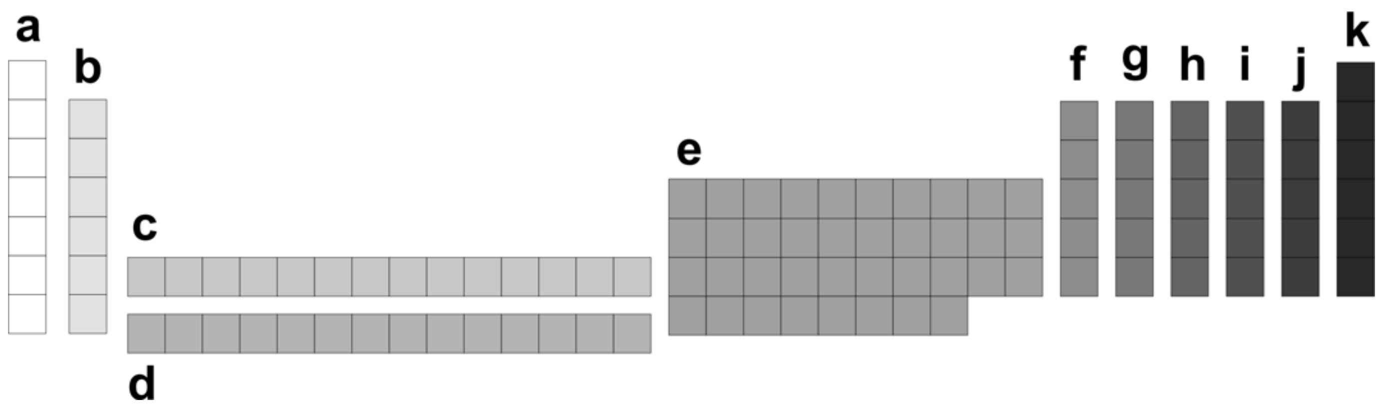
3 Stop and think

a. Many printed periodic tables look like the diagram on the right instead of having the shape that you built. Can you think of a reason why?



4 Sections of the periodic table

The periodic table is organized into 11 sections (shown as a-k). Each section contains elements with similar chemical properties. Most sections are single columns. One section includes many columns and two sections are parts of entire rows.



a. Locate the element that is the first one in each of the following sections.

b. Research the name (if any) of this section.

c. Research any properties that elements from this section share.

Table 1:

Diagram	First element (name)	Section name (if any)	Representative chemical properties
a			
b			
c			
d			
e			
f			
g			
h			
i			
j			
k			

5 Applying what you have learned

a. Each row of the periodic table contains only a certain number of elements. What does this have to do with the structure of the atom? Research this question in your textbook.

b. Which section of the periodic table above contains the element argon? What characteristic do the elements in this section share?

c. Which sections contains the element carbon? What characteristic do these elements share?

7B Periodic Table Group Challenge

How is the periodic table organized?

Each box on the periodic table tells you the element symbol, atomic number, and atomic mass for all the known elements. This is very useful information, but did you know that the arrangement of the elements on the periodic table gives you even more information? Each major column of elements represents a group of elements with similar chemical behavior. Can you see why the arrangement of elements on the periodic table is important?

Materials

- Blank periodic table bingo card sheets; 1 per player
- Caller's clues and checklist; 1 per team
- Copy of the periodic table of elements; 1 per player
- Highlighter or other marker; 1 per player

1 The challenge

Periodic Table Group Challenge is a bingo-like game that helps you understand how the elements on the periodic table are arranged. Each player will fill out their own five-by-five grid with element symbols, and then the caller will read element clues. The players must interpret the clues and highlight any boxes on the grid that fit the clue. The first player that correctly highlights five boxes across, up-and-down, or diagonally in a row is the winner.

2 Rules of play

1. Designate one member of your group to be the caller. The caller will call out clues and keep track of them on the checklist.
2. Each player will have a sheet of 4 blank grids. Fill out one of the grids with random element symbols (other grids can be used for additional games). You may choose elements in the atomic number range of 1 – 54 (hydrogen through xenon). Do not repeat symbols on the card. You will only be able to fit 25 of the possible 54 symbols on the card. You choose which ones to use, and where to place them on the grid.
3. The caller will randomly pick clues from the list, and as a clue is called out, the caller will check off the clue. The answers are only for the caller to check the winner's card!
4. When a clue is called, players check the grid to see if any of the elements fit the clue. Any elements that fit the clue must be highlighted. If no elements fit the clue, then no boxes are highlighted on that turn.
5. When a player has five boxes highlighted in a row up and down, across, or diagonally, play stops. The caller will double check the clue list and answers to see if the clues indeed match the elements. Play continues until a true winner is determined.

3 Caller's clues

Clues can be called in any order. Check off each clue as you use it.

Clue	Possible Answers
A member of the carbon family	C, Si, Ge, Sn
Chemical properties similar to calcium, but not calcium	Be, Mg, Sr
A transition metal that has a "C" in the symbol	Sc, Cr, Co, Cu, Tc, Cd,
A member of the oxygen family	O, S, Se, Te
Chemical properties similar to cesium, but not cesium	H, Li, Na, K, Rb
A member of the noble gas family	He, Ne, Ar, Kr, Xe
A nonmetal in the nitrogen family	N, P
A metal in the boron family	Al, Ga, In
A gas in the oxygen family	O
A solid in the halogen family	I
An element that is liquid at room temperature	Hg, Br
A transition metal with less than 25 protons	Cr, V, Ti, Sc
A transition metal commonly found in jewelry	Ni, Cu, Ag
A metalloid in the carbon family	Si, Ge
Chemical properties similar to aluminum, but not aluminum	B, Ga, In
A transition metal with 39 – 43 protons	Y, Zr, Nb, Mo, Tc
An element symbol with a first letter that is different from the first letter of the name	Na, K, Fe, Ag, Sn, Sb
A member of the nitrogen family with a one-letter symbol	N, P
A transition metal from period 5	Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd

4 Periodic table challenge card

Fill in each of the squares with the symbol of an element with atomic number between 1 and 54 (hydrogen - xenon)

You may not use the same element symbol twice.

8A Chemical Bonds

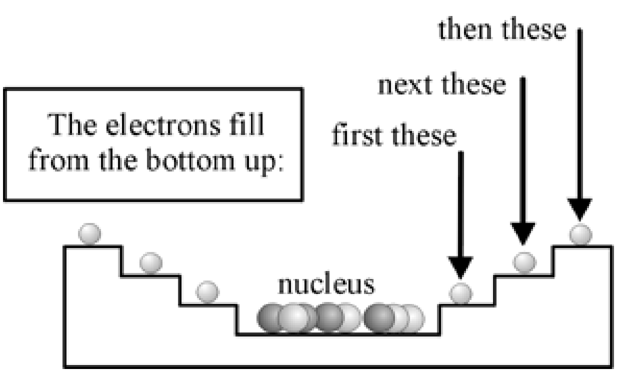
How do atoms form chemical bonds with other atoms?

Scientists have identified over 100 elements, but most matter found on Earth is not in the form of pure elements. Most matter is made up of compounds. Even if an element is pure at first, it will combine with other elements sooner or later. For example, if you leave an iron nail out in the rain, it will rust. The iron in the nail will combine with oxygen. It will form a compound called iron oxide, also known as rust. In this investigation you will learn how electrons are involved in forming chemical bonds.

Materials

- 2 atom building games

1 Electrons in an atom



- A neutral atom has the same number of electrons and protons.
- The electrons move around in energy levels that surround the nucleus.
- Since electrons are attracted to the nucleus, they fill the levels closest to the nucleus first.
- Once a lower level is full, electrons start to fill the next level.

2 How many electrons are in the outermost level?

Use the atom board to make a model of each element in the table. For each element, write the number of electrons found in the outermost level. Then write the number of unoccupied or empty spaces in the outermost level.

Table 1: Electrons in the Outermost Levels of Atoms

Element	Atomic number	Electrons in outermost level	Unoccupied spaces in outermost level
hydrogen			
helium			
lithium			
fluorine			
neon			
sodium			
chlorine			
oxygen			
carbon			

a. What do lithium and sodium have in common?

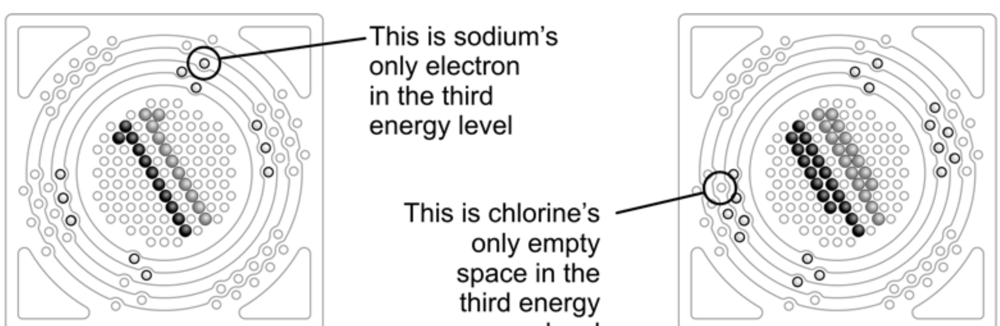
b. What do fluorine and chlorine have in common?

c. What do neon and helium have in common?

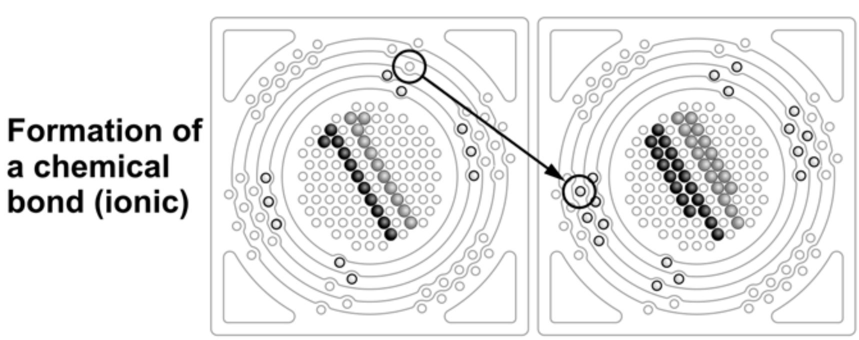
3 Modeling a chemical bond

The following concepts will help you understand why and how atoms form chemical bonds.

- An atom has its lowest energy when its outermost energy level is either completely filled or completely empty.
- Atoms trade or share electrons to fill or empty their outermost energy level.
- Atoms form bonds by trading or sharing electrons from their outer most energy levels.
- Electrons in inner energy levels do not participate in bonding with other atoms.



Sodium: 11 electrons Chlorine: 17 electrons



Sodium chloride (NaCl)

Use two atom boards and marbles. Build one sodium atom and one chlorine atom. Put them next to each other and answer the questions below.

a. A sodium atom has only one electron in its outermost level. What do you think it will do in order to complete that level? Do you think it will lose its outer electron? Or do you think it will gain seven electrons? Explain your answer.

b. Chlorine needs to complete its outermost energy level. Do you think chlorine will tend to lose all of its seven outer electrons? Or do you think it will gain one electron? Explain your answer.

c. What makes you think that sodium and chlorine might bond together? Describe what might happen if these two atoms form a chemical bond.

d. How many hydrogen atoms can bond with one oxygen atom? What chemical does this make?

e. How many chemical bonds can carbon form?

8B Molecules and Compounds

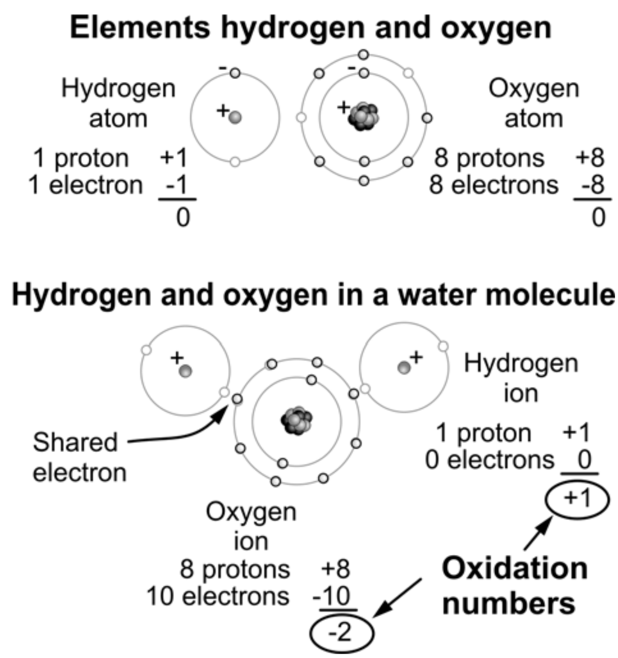
What are some molecules and compounds and what atoms are in them?

The properties of a material depend much more on the molecule than on the elements the molecule is made of. For example, aspirin is made from carbon, hydrogen, and oxygen. By themselves, these elements do not have the property of reducing pain. Other molecules formed from the same elements have different properties than aspirin. For example, polyethylene plastic wrap and formaldehyde (a toxic preservative) are also made from carbon, oxygen, and hydrogen. The beneficial properties of aspirin come from the way the atoms bond together in the particular shape of the aspirin molecule.

Materials

- Periodic table tiles

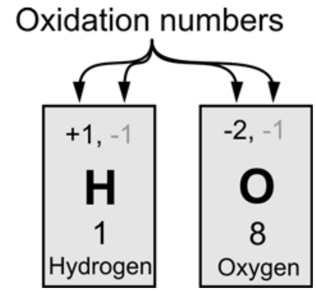
1 Electrons and oxidation numbers



- A molecule (molecular compound) is formed when two or more atoms *share* electrons by forming covalent chemical bonds.
- An atom with equal numbers of protons and electrons is neutral (charge of 0). An atom with more protons or electrons is called an ion.
- An ionic compound is formed when electrons are *transferred* from one atom to another.
- A positive oxidation number means the element forms chemical bonds by donating electrons. Hydrogen has an oxidation number of +1 because atoms of hydrogen donate one electron when forming chemical bonds.
- A negative oxidation number means the element forms chemical bonds by accepting electrons. Oxygen has an oxidation number of -2 because oxygen atoms accept two electrons when forming chemical bonds.

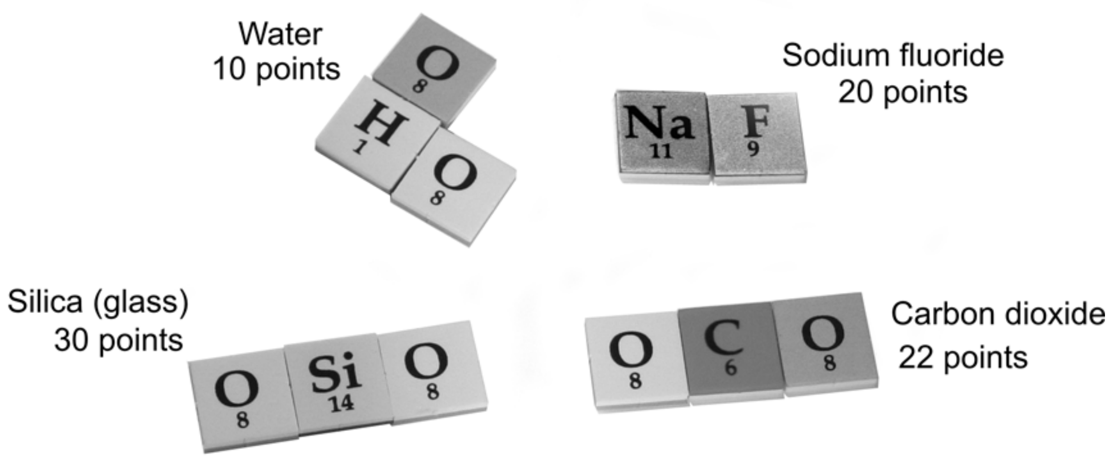
2 Oxidation numbers on the periodic table

The blue periodic table shows the oxidation numbers for all the elements. These numbers predict how each element will combine with other elements to form molecules and compounds.



- Hydrogen shows oxidation numbers of +1 and -1 which means hydrogen can either donate one electron or accept one electron to form chemical bonds. However, the +1 oxidation member is **bold** which tells you that hydrogen prefers to be +1.
- Oxygen shows oxidation numbers of -2 and -1 which means oxygen can accept two electrons (-2) or accept one electron (-1). However, the -2 oxidation member is **bold** which tells you that oxygen prefers to be -2.

3 Making molecules and compounds



The next part of the investigation is a game! The objective of the game is to make molecules and compounds which score the most points. Each player makes 3 molecules or compounds and adds the points from all 3.

- Each player chooses 10 periodic table tiles at random from a bag.
- All tiles with atomic number 18 or less should be turned yellow-side down.
- All tiles with atomic number greater than 18 should be turned yellow-side up.
- The player makes a molecule or compound from some (or all) of the tiles they have.
- The score is the sum of the atomic numbers. For example, making a water molecule (H_2O) scores 10 points: H=1, H=1, and O=8.
- The molecule must follow the rules for building molecules and compounds (below).
- Disassemble the molecule and use the same 10 tiles to make another, and a third.

4 Rules for building molecules and compounds

The oxidation numbers represent sharing or transferring electrons between each atom in a chemical bond. Since every electron accepted by one atom must be lost by another, the total molecule has a charge of zero. That means:

The oxidation numbers for all the component atoms must add up to zero.

For example:

SiO_2

Si	O	O	
+4	-2	-2	= 0

CO_2

C	O	O	
+4	-2	-2	= 0

5 Stop and think

a. How many hydrogen atoms can bond with one nitrogen atom? What is this chemical called?

____

b. Rust is a compound of iron (Fe) and oxygen (O). If the iron has an oxidation number of +3, how do you make a molecule with iron and oxygen?

____

____

9A Solubility

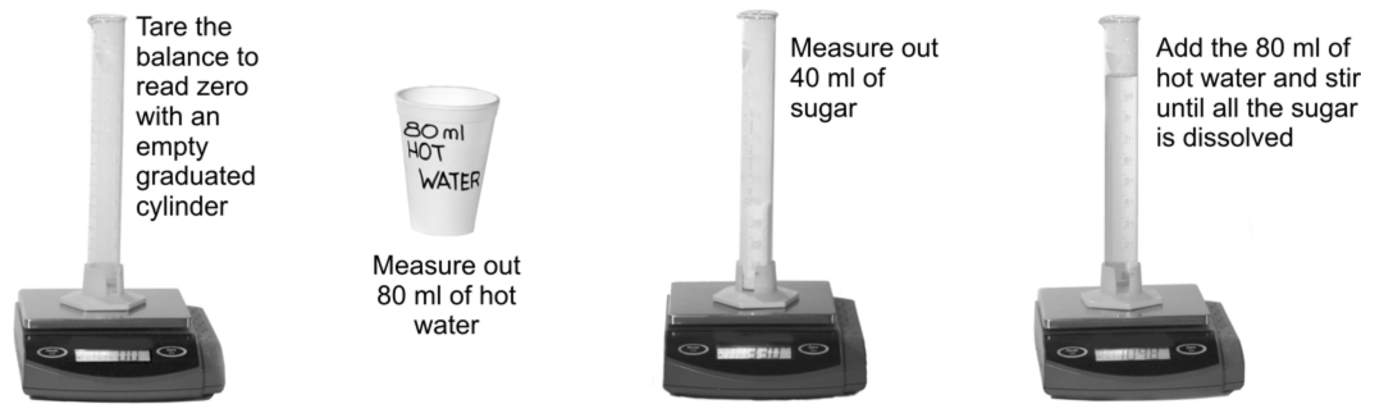
What does it mean to dissolve?

The water you drink is not pure water. There are many things dissolved in drinking water, such as minerals, oxygen, and sometimes flavorings. A solution is a homogeneous combination of different compounds, such as water and sugar. Carbonated soda is a solution containing water, sugar, dissolved carbon dioxide gas, and flavorings. Solutions are essential for life because your body's chemical processes happen in solutions. This investigation will look at some of the properties of solutions.

Materials

- Graduated cylinder
- Balance
- Granulated sugar
- hot water
- cold water
- Sugar cubes
- Timer

1 Mass and volume in solutions



1. Put a clean graduated cylinder on the balance and reset it to zero.
2. Place 80 ml of hot water into the graduated cylinder, measure the mass, then pour the water into a foam cup (you will use this water in step 4).
3. Put 40 ml of sugar into the same cylinder you used for the water. Place the graduated cylinder back on the balance and record the mass and volume of the sugar (you zeroed out the cylinder in step 1, so the mass reading in this step will just be of the sugar).
4. Remove the graduated cylinder. Add the 80 ml of hot water and stir to dissolve all the sugar. Put the graduated cylinder back on the balance and record the mass and volume of the solution.
5. Use your mass and volume data to calculate the density of the sugar, the water, and the sugar and water solution.

Table 1: Mass and volume data for solutions

Substance	Mass in grams	Volume in mL	Density in g/mL
Sugar		40	
Water		80	
Solution of sugar and water			

2 Stop and think

a. As the sugar dissolved, you couldn't see it any more. How do you know it is all still there?

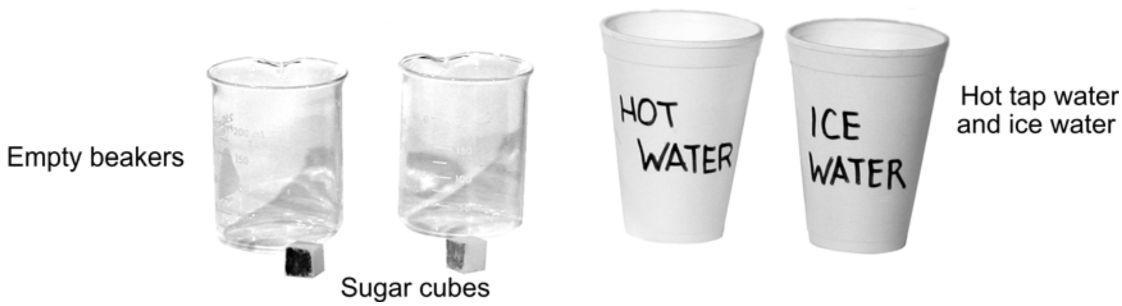
b. Compare your calculated density of sugar with your calculated density of water. Do your calculations match up with your observations? Hint; Think about density and buoyancy.

c. What happened to the volume of the water and sugar solution compared to the volume of water and sugar you started with? Can you explain this?

d. Based on the volume of water displaced by the sugar, calculate the actual density of sugar? Does this new density match up with your observations?

3 Temperature and dissolving rate

For this part of the investigation you are going to see how sugar cubes dissolve in water of different temperatures.



1. Color one face of a sugar cube with red water-soluble marker. Put the sugar cube in an empty 100 ml beaker with the colored side facing up.
2. Color one face of a second sugar cube with blue water-soluble marker. Put the sugar cube in an empty 100 ml beaker with the colored side facing up.
3. Start the timer and carefully pour the hot or cold water down the edge of each beaker until it covers the sugar cube by about one centimeter. Do not pour the water directly on the sugar cubes!
4. Watch the colored face of each sugar cube. Which one dissolves fastest?

4 Stop and think

a. Temperature is a measure of how fast the molecules of a substance are moving. Are water molecules moving faster in hot water or cold water?

____

b. When a substance dissolves, molecules of the liquid crash into the solid molecules and knock some of the solid molecules loose. Explain how this concept fits with the data you observed on the dissolving sugar cubes.

____

____

____

____

9B Acids, Bases and pH

What is pH and what does pH tell you?

pH is a number that shows whether a solution is an acid, a base, or neutral. Acids are solutions that have a pH less than 7. Bases (or alkalis) are solutions that have a pH greater than 7. A pH of 7 is called a neutral solution. pH is important because most living things can only survive in a narrow range of pH. For example, if the pH of the water in an aquarium becomes too low (acidic) or too high (alkali) the fish in the aquarium cannot survive. As you work, you will find the pH of several common solutions you probably encounter all the time. You will also learn some of the properties of acids and bases.

Materials

- Spot plates
- Pipettes
- Red cabbage juice
- Red and blue litmus paper
- 11 solutions (Table 1)

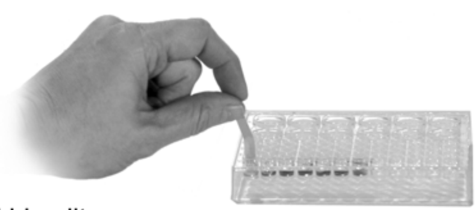
1 Make a pH scale using indicators

Safety Tip: Wear goggles and a lab apron as you work. They will protect your eyes and clothing from the household chemicals that you will use.

Step 1: Prepare your sample solutions

Step 3: Add 2 drops of each of your solutions to the red cabbage juice. Watch for color changes.

Step 2: Put 3 drops of red cabbage juice in each of 7 different wells



Step 4: Dip red and blue litmus paper into each well. Observe any color changes in the litmus paper.

1. You will use the first six solutions listed in the table to create your pH color scale, but first you should prepare your work area. Place a piece of blank paper under the spot plate and mark on the paper the name of the solution and pH for each well location.
2. Use a pipette to put three drops of red cabbage juice in each of the six labeled wells.
3. Next, add two drops of each solution to the corresponding well. Use a different pipette for each solution or clean thoroughly in between each use. Write down the color changes that you see when you add the two drops of each solution. The series of color that you see on the spot plate represents a pH scale.
4. Dip the red litmus paper and the blue litmus paper into each well of the pH test plate. Use the data table to record what you see.

Table 1: Test solutions

Name of solution	Color when mixed with red cabbage juice	Red litmus paper: If paper turns blue, write "base," if no change, write "x"	Blue litmus paper: If paper turns red, write "acid," if no change, write "x"	pH
1. lemon				**2**
2. vinegar				**3**
3. seltzer				**4**
4. baking soda solution				**8.5**
5. bar soap solution				**10**
6. ammonia				**11**
7. green tea				
8. antibacterial cleaner				
9. apple juice				
10. mystery solution A				
11. mystery solution B				

2 Evaluating the role of the pH test plate

a. What is the role of a pH indicator? You used three different indicators (red cabbage juice, red litmus paper, blue litmus paper). What is the range of pH measured by each of them?

b. What general color do basic solutions turn when added to red cabbage juice?

c. What general color do acidic solutions turn when added to red cabbage juice?

3 Using pH indicators to measure unknown pH

How can you find the pH of these solutions?

1. Get a clean spot plate and repeat the experiment (steps 1-4) for the solutions number 7, 8, and 9. You cannot write their pH numbers because you do not know them yet.
2. Find the approximate pH of your three new solutions by looking at the color changes that happened when you added two drops of each to the red cabbage juice. Compare these color changes with your previous test plate (known pH). Also, note the litmus paper results for each solution.

4 Identifying mystery solutions

a. Mystery solutions A and B are the same as two other solutions that you used in this investigation. Do the pH testing with the red cabbage juice and litmus paper to identify these solutions.

b. What is the name of mystery solution A? What is the name of mystery solution B? Give evidence to support your answers.

10A Chemical Reactions

How do you know when a chemical reaction has occurred?

Chemical changes take place all around you and even inside your body. One way to tell if a chemical change has taken place is to carefully observe substances around you. When two substances combine in a chemical reaction, they form a new product that may have very different properties than the original substances. As you work, you will carefully observe some chemical reactions. Make a list of any proof that you see of chemical changes.

Materials

- Sealable plastic freezer bags
- Balance
- Epsom salts
- Water
- Ammonia
- Phenol red
- Raw potato
- Hydrogen peroxide
- Baking soda
- Vinegar
- Calcium chloride

Safety tip: Always wear goggles and an apron while you work with chemical reactions.

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

- Your teacher will give you everything you need to do each chemical reaction.
- You will do six different chemical reactions.
- Carefully follow all of the directions below.
- For each reaction, write down exactly what you see with lots of details.
- Describe what each substance looks like before and after the chemical change takes place.
- Follow your teacher's instructions for disposal of your reactions when you are done.

1 Reaction #1

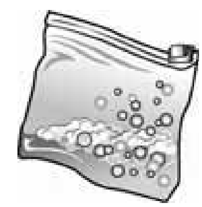
1. Put 5 grams of epsom salts into a baggie.
2. Add 10 milliliters of ammonia solution to the baggie. Close it tightly.
3. Feel the baggie with your hands as the reaction is taking place.
4. Let the baggie sit until you are done with all six reactions. Then look at this baggie again.

Reaction #2

1. Place a potato slice into a baggie.
2. Add 10 milliliters of hydrogen peroxide to the baggie. Close it tightly.
3. Feel the baggie with your hands as the reaction is taking place. You can even hold it up to your ear and listen to the reaction.
4. Let the baggie sit until you are done with all six reactions. Then look at this baggie again.

Reaction #3

1. Put 5 grams of baking soda into a baggie.
2. Add 10 milliliters of phenol red and 10 milliliters of vinegar to the baggie. Close it tightly.
3. Feel the baggie with your hands as the reaction is taking place.
4. Let the baggie sit until you are done with all six reactions. Then look at this baggie again.

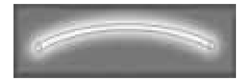


Reaction #4

1. Put 10 grams of calcium chloride into a baggie. Then put 5 grams of baking soda in with it.
2. Add 10 milliliters of phenol red to the baggie. Quickly close it tightly.
3. Feel the baggie with your hands as the reaction is taking place.
4. Write down all of your observations.
5. Let the baggie sit until you are done with all six reactions. Then look at this baggie again.

5 Reaction #5

1. Activate a glow stick as instructed by your teacher.
2. Feel the glow stick as the reaction is taking place.



6 Reaction #6

1. Activate a heat pack as instructed by your teacher.
2. Feel the heat pack with your hands as the reaction is taking place.

7 Stop and think

a. Look at the observations that you wrote for each reaction. Put your observations into categories. Use words such as bubbles, change of color, and so forth.

b. For each category, explain the evidence of a chemical change in a table like the one below. Write your observations in the table. An example has been done for you

.

observation category	evidence of chemical change
bubbles/gas formation	Gas bubbles show that a new substance that is a gas at room temperature was probably produced.

c. Use your table to identify evidence that indicates when a chemical change has taken place. Write down your evidence and share with the class.

10B Conservation of Mass

How do scientists describe what happens in a chemical reaction?

A French chemist named Antoine Lavoisier was the first to prove the law of conservation of mass. This law says that the total mass of the reactants in a chemical reaction is always equal to the total mass of the products. This is not as easy to see as you might think! As you do this investigation you will discover how tricky it is to show the law of conservation of mass.

Materials

- Periodic table tiles
- Effervescent tablet
- Balance
- Water
- small paper cup

Safety tip: Wear goggles and an apron as you work

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

1 Testing the reaction

Step 1:
Tare the balance to zero with the empty cup

Step 2:
Measure the mass of water and tablet

Step 3:
Add tablet to water and observe the reaction

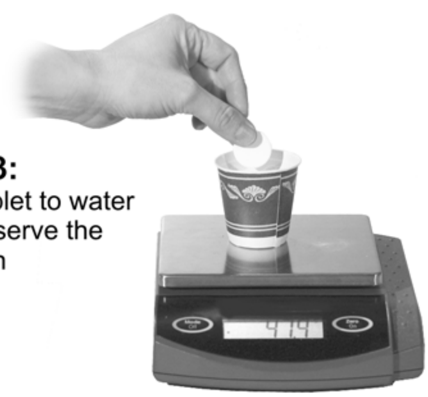


Table 1: Conservation of mass data

Step	Data and observations
1. Find the mass of the effervescent tablet.	
2. Put the paper cup on the balance and tare it to zero. Fill the cup about half way with water. Record the mass.	
3. Put the tablet on the balance beside the cup, but don't put it in the water yet. Record the total starting mass.	
4. Drop the tablet into the cup of water. You can do this while the cup is still on the balance. Record your observations.	
5. Wait for the reaction to stop. Then, tap the cup gently to release as many bubbles as you can. Measure the mass.	
6. Subtract the final mass (5) from the starting mass (3). This is the mass difference between the products and reactants.	

2 Stop and think

a. Does this experiment agree with the law of conservation of mass? Look at the data that you just recorded. Use it to help you to explain why or why not.

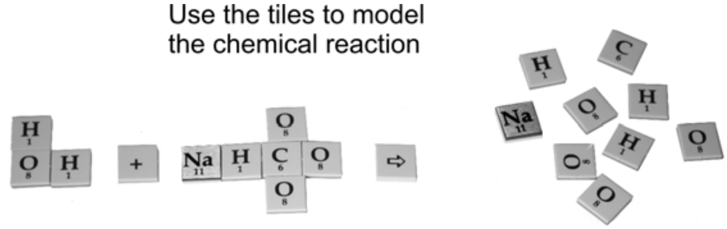
b. Explain why you observed a difference in mass. Where did the missing mass go? Did it really disappear?

3 Modeling the reaction

Scientists write chemical reactions like mathematical formulas. The reactions are on the left of the arrow and the products are on the right of the arrow.

$$\text{Reactants} \rightarrow \text{Products}$$

Use the tiles to model the chemical reaction



The effervescent tablet contains a chemical called sodium bicarbonate. This chemical reacts with water according to the following reaction.

$$H_2O + NaHCO_3 \rightarrow NaOH + CO_2 + H_2O$$

1. Build the reactants side (H_2O + $NaHCO_3$) of the chemical reaction above using the periodic table tiles.
2. Build the products side ($NaOH$ + CO_2 + H_2O) of the chemical reaction using more periodic table tiles.

4 Stop and think

Table 2: Counting atoms of each element

Element	Reactants	Products
Hydrogen		
Carbon		
Oxygen		
Sodium		

a. Fill in Table 2 with the numbers of each type of atom on the reactant side of the equation and on the product side of the equation.

b. How do the numbers of atoms of each element compare on the reactant and product side of the equation? What does this imply for the law of conservation of mass?

c. What phase are each of the reactants (solid, liquid, or gas)? What phase are each of the three products (solid, liquid, or gas)?

d. Suggest a way to do the experiment that could better demonstrate conservation of mass.

11A Organic Chemistry

What are some common molecules that contain carbon?

Living organisms are made up of a great variety of molecules, but the number of different elements involved is very small. Organic chemistry is the science of molecules that contain carbon and these are the ones most important to living organisms. This investigation will introduce you to some small organic molecules.

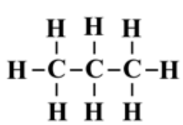
Materials

- Periodic table tiles
- Reference book of organic compounds

1 The chemistry of carbon

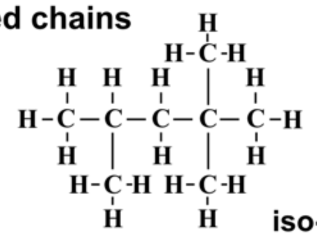
Carbon is the central element in the chemistry of living things. This is because carbon can make complex molecules. Each carbon atom can make four bonds because carbon has four electrons in the outer energy level, which can hold a total of eight. Carbon can also form double and triple bonds by sharing two or three electrons with a single atom. Because of carbon's flexible bonding ability, many molecular structures are possible.

Straight chains



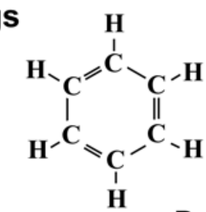
Propane
C_3H_8

Branched chains



iso-octane
C_8H_{18}

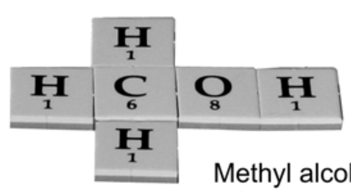
Rings



Benzene
C_6H_6

2 Single carbon molecules

Carbon dioxide
CO_2



Methyl alcohol
(methanol)
CH_3OH

Methane
CH_4

1. Build the three carbon molecules above using the periodic table tiles.
2. Build a model of carbonic acid: H_2CO_3.

3 Stop and think

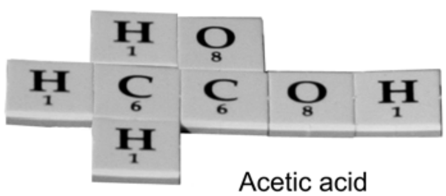
a. Research and describe three reactions which use or produce carbon dioxide.

b. Research and describe at least one use of methyl alcohol.

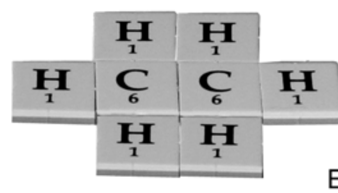
c. Research and describe the use and production of methane.

4 Molecules with two carbon atoms

Once there are two carbon atoms, the structures get more complicated. The carbon atoms may share a single, double, or triple bond between them.



Acetic acid
CH_3COOH



Ethane
C_2H_6

1. Build the 2-carbon molecules above using the periodic table tiles.
2. Build a model of ethyl alcohol (ethanol): C_2H_5OH.
   (Hint: Each carbon atom makes 4 bonds and the oxygen atom makes two bonds)
3. Build a model of acetylene: C_2H_2.
   (Hint: there is a triple bond between the two carbon atoms)

5 Stop and think

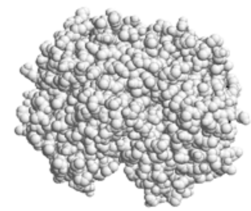
a. Research and describe where acetic acid is found.

b. Research and describe at least one use of ethyl alcohol.

c. Research and describe a reaction between acetylene and oxygen that is used in welding metal.

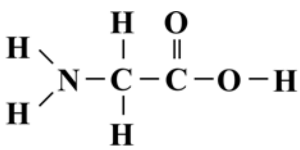
6 Biological molecules

Living organisms are constructed mainly of proteins, which are very large carbon-based molecules, such as hemoglobin (right). A single protein may contain 10,000 or more atoms. Proteins themselves are constructed of simpler units called amino acids. For example, the hemoglobin molecule contains 584 amino acids.

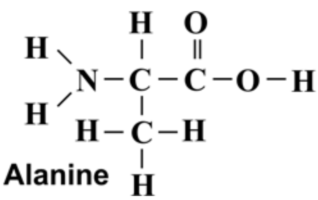


Hemoglobin molecule

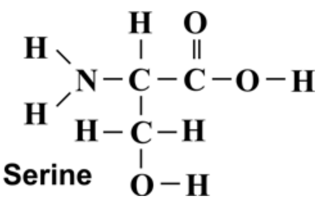
Use the periodic table tiles to build models of the three smallest amino acids.



Glycine



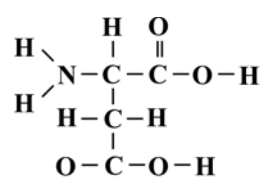
Alanine



Serine

7 Stop and think

a. What is similar about all three amino acids?



Is this an amino acid?

b. Is the chemical in the diagram on the right an amino acid? Explain why you think your answer is correct.

11B The Structure of DNA

How does a DNA molecule carry information?

DNA is found in all living creatures we know. This complex molecule contains the information on how to build every protein used in your body. DNA is like a blueprint for building a living creature. The DNA molecule itself is a fascinating structure, as you will see in this activity.

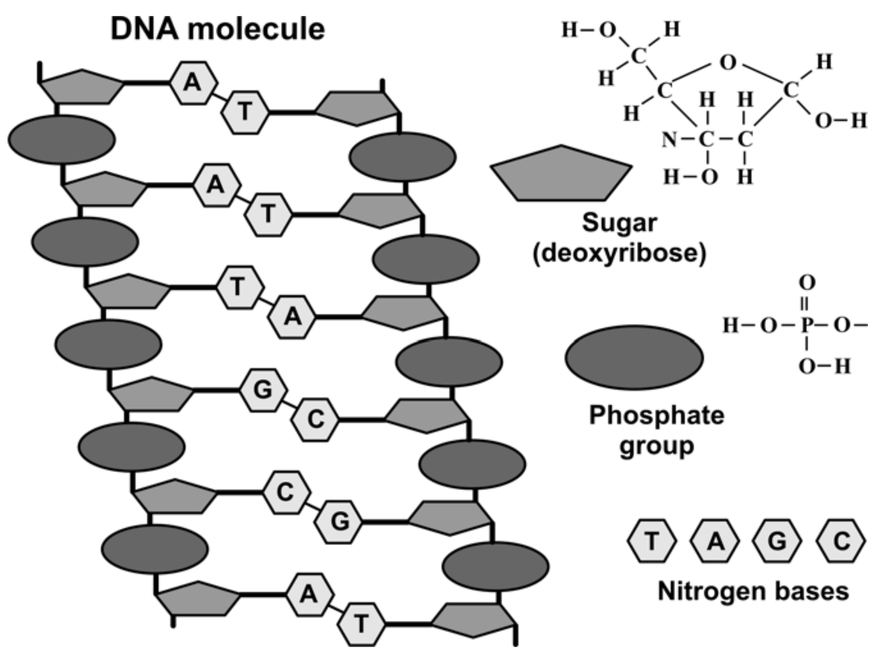
Materials

- Licorice sticks (about 6” long)
- Round toothpicks
- Colored gum drops

1 About the DNA molecule

A DNA molecule is put together like a twisted ladder, or double helix. Each side of each rung of the ladder is made of a 5-carbon sugar called deoxyribose, a phosphate group, and a nitrogen base. Two nitrogen bases are paired in the center of the ladder so each rung is composed of two similar groups.

The genetic code in a DNA molecule is stored in the sequence of the nitrogen bases. For example the sequence AATGCA is coded in the DNA molecule in the diagram.



2 Building a DNA molecule out of gum drops

There are four different nitrogen base groups in a DNA molecule. Each should be represented with a different color of gum drop. Choose the color you want to use to represent each nitrogen base (A, G, C, T).

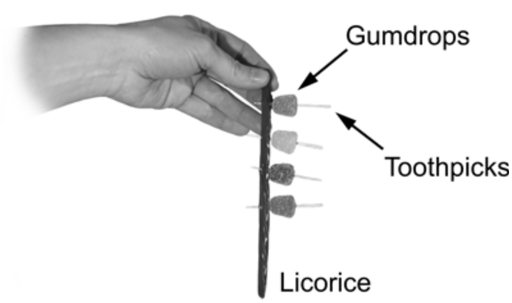


Table 1: Nitrogen base colors

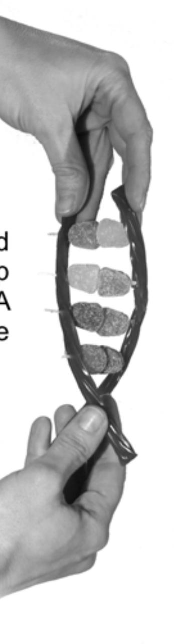
Adenine (A)	Guanine (G)	Cytosine (C)	Thymine (T)

1. The licorice will be the backbone of sugar and phosphate. Put 8 toothpicks through the licorice (evenly spaced) and push a gum drop past the middle of each toothpick.
2. The color sequence of your gum drops will be your DNA code!

3 Pairing up the nitrogen bases

The nitrogen bases in a DNA molecule pair up with each other. Adenine pairs with thymine and guanine pairs with cytosine.

1. Use Table 2 to record the 8-letter genetic code for the left side of your DNA molecule. Put the colors in row 1 and the letter codes in row 2.
2. Use the pairing of the nitrogen bases (A-T or C-G) to complete row 3 for the right side of your DNA molecule.
3. Use Table 1 to determine which gum drop colors correspond to the nitrogen bases in row 3.
4. Complete your DNA molecule by building the opposite half of the ladder! You can give your DNA ladder a gentle twist so it looks like the real double helix shape.



The completed gum-drop DNA molecule

Table 2: The DNA code

1	Colors								
2	Letters (A, G, C, T)								
3	Letters (A, G, C, T)								
4	Colors								

4 How DNA is reproduced

When a living creature reproduces, its genetic code is passed on to its offspring through DNA. On the molecular level, reproduction starts when the DNA strand divides down the center, splitting apart the nitrogen bases.

a. Research and describe how an identical new DNA molecule is created once the original DNA molecule has been split down the center.

b. Suppose one side of a DNA molecule had the nitrogen base sequence TAGGCCA. What nitrogen base sequence must be on the other side of the DNA molecule?

c. Research approximately how many base pairs are in a typical DNA molecule such as might be found in a human cell.

12A Distance, Time, and Speed

How do scientists describe motion?

The average speed is the ratio of the distance traveled divided by the time taken. This is an idea you already use. For example, if your car is moving at a speed of 60 miles per hour that means the ratio of the distance the car moves divided by the time it takes is always equal to 60 miles/hour. If you go 120 miles in 2 hours, your average speed is 60 miles per hour because the ratio 120 miles/2 hours equals 60 miles/hour.

Materials

- Energy car and track
- Timer and photogates
- Rubber band

1 The relationship between distance, time, and speed

Speed

Speed (m/sec) $$v = \frac{d}{t}$$ Distance traveled (meters) / Time taken (seconds)

In science, you will mostly be working with speeds in units of centimeters per second (cm/s) or meters per second (m/s).

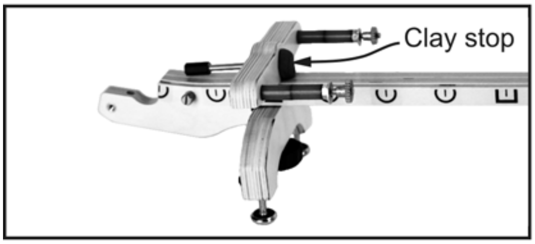
a. A duck swims 10 meters in 5 seconds. What is the average speed of the duck?

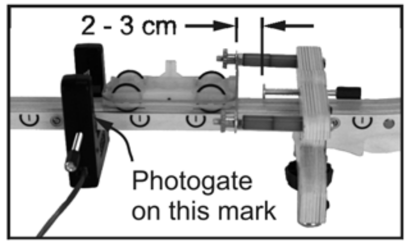
b. A car on cruise control is moving at a constant speed of 55 mph. How far does the car travel in three hours?

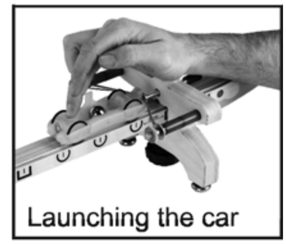
c. A jet aircraft is moving at a constant speed of 500 kilometers per hour. How long does it take the jet to travel 2,000 kilometers?

2 Setting up for constant speed

Setting up the straight track







1. Put the track together as shown in the diagram. Use one rubber band on the launching end and a ball of clay on the catching end to stop the car.
2. Adjust the stop so the rubber band has 2 - 3 cm of deflection. Put a photogate on the mark just ahead of the car. Practice launching the car until you can get 3 successive photogate times to within 0.0010 seconds of each other.

3 Making the car move at constant speed

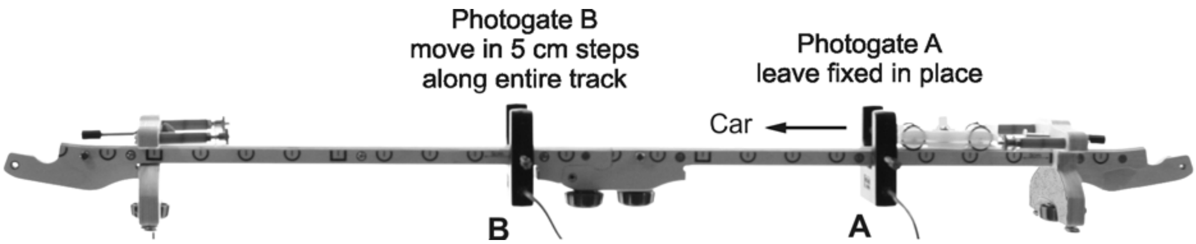
1. Put two photogates on the track.
2. Adjust the height of the feet on one end or the other until the times from photogates A and B are within 0.0010 seconds of each other. You may also use a thin book or pad of paper to prop up one end.
3. Be careful not to disturb the track once you get it set up.

4 Stop and think

a. Describe how the photogate measurements prove that the car has constant speed, or nearly constant speed.

b. Calculate the speed of the car in meters per second (m/sec).

5 Measuring position versus time



1. Put photogate A near the start so the car breaks the light beam just after it is launched.
2. Move photogate B to different positions 10 cm apart along the track (measure position).
3. For every position of photogate B, record the time through the beam at photogates A and B and also the time from A to B.
4. Take at least 6 data points along the track being careful to start the car the same way every time. Use photogate A to test whether you should keep the data from a trial or do it over.

Table 1: Position versus time data

Position (cm)	Time through photogate A (sec.)	Time through photogate B (sec.)	Time from photogate A to B (sec.)

6 Making the position versus time graph

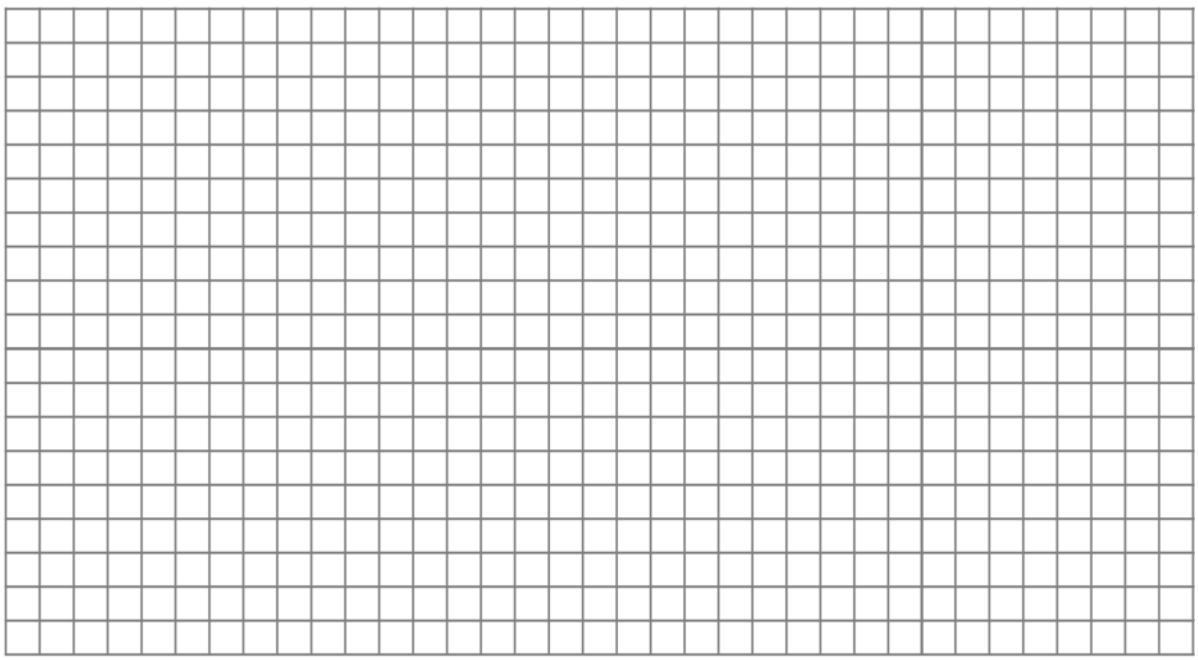
a. Start the graph by putting the position of the car on the vertical (y) axis. Position is where you placed photogate B.

b. Put the time from photogate A to B on the horizontal (x) axis. This is the time that the car has traveled between A and B.

c. Finish the graph by plotting the points from Table 1 and giving the graph a title.

Title: ____

y label: ______________________



x label: ______________________________

7 Stop and think

a. What shape does the position versus time graph have? Describe the line or curve that you get.

____

____

b. Calculate the average speed of the car from the graph or your data.

____

c. How long would it take the car to travel a distance of 2 meters if it kept the same speed?

____

d. The car moved at a constant speed as it rolled along the level track. What would happen to the speed of the car as it rolled down a track placed at a steep angle?

e. What shape would the graph have if the car was speeding up as it went down the track?

f. What shape would the graph have if the car was moving at a constant speed that was double the average speed of your car?

g. How is the shape of the position versus time graph related to the speed of the car?

12B Motion with Changing Speed

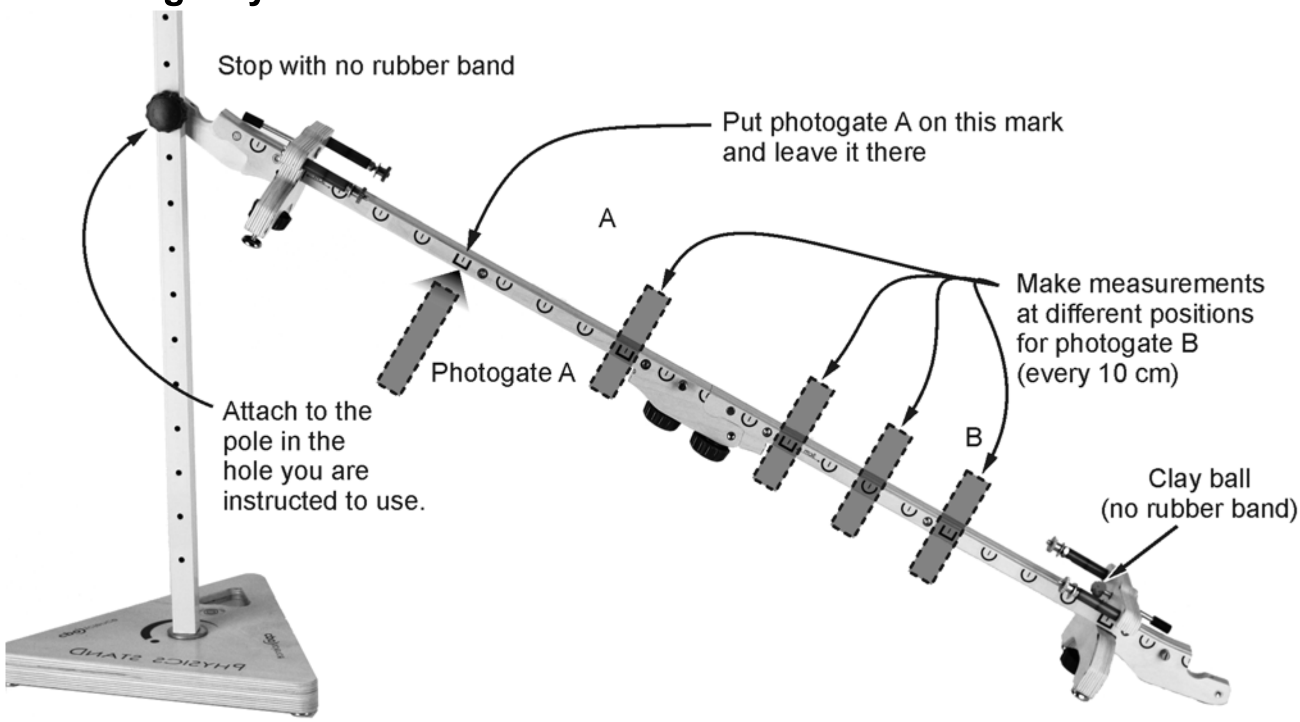
How do we describe motion for which the speed is not constant?

Almost nothing moves at constant speed for very long. Think about your own speed as you drive somewhere, speeds are always changing. What kind of graphs can be made that show changing speeds? How do you tell that speed is changing from a graph? These are questions for this investigation.

Materials

- Energy car and track
- Timer and photogates

1 Making a system



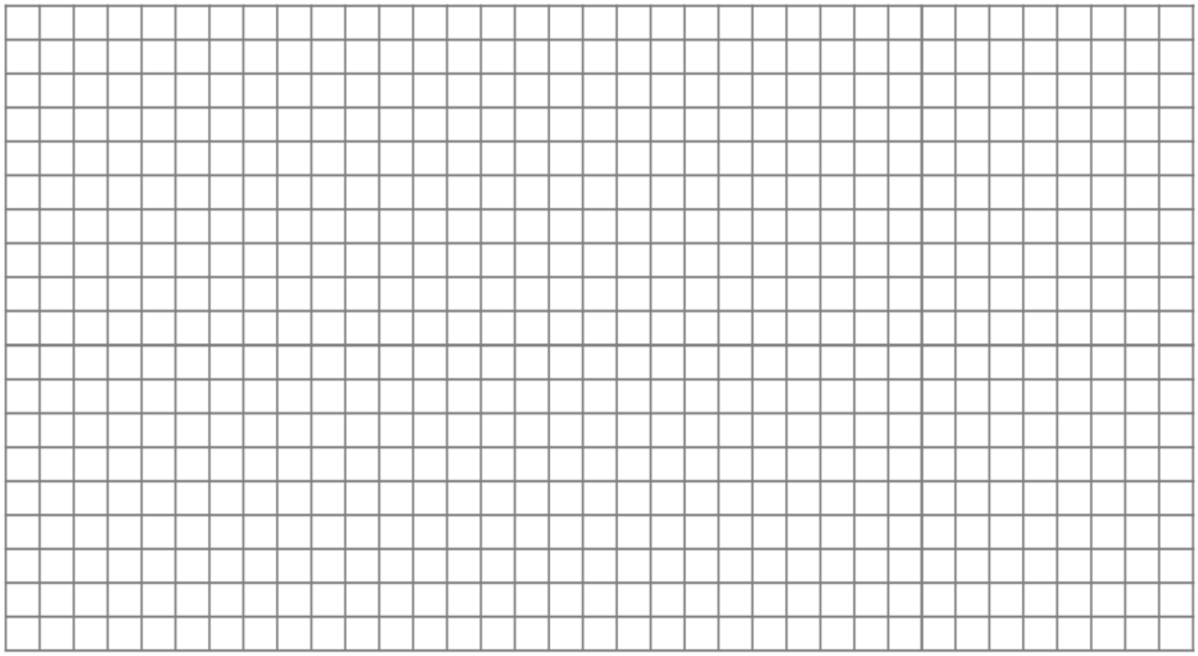
1. Set up the track as a long straight hill. Your teacher will tell which hole in the stand to attach the track.
2. Move photogate B to different positions 10 cm apart along the track (measure position).
3. For every position of photogate B, record the time through the beam at photogates A and B and also the time from A to B. Leave the “Speed at B” column blank for now.
4. Take at least 6 data points along the track being careful to start the car the same way every time. Use photogate A to test whether you should keep the data from a trial or do it over

2 Making the position versus time graph

1. Start the graph by putting the position of the car on the vertical (y) axis. Position is where you placed photogate B.
2. Put the time from photogate A to B on the horizontal (x) axis.

3. Finish the graph by plotting the points from Table 1 and giving the graph a title.

Title: ______________________________



y label: ______________________________

x label: ______________________________

Table 1: Position versus time data

Position of Photogate B (cm)	Time through photogate A (sec.)	Time through photogate B (sec.)	Time from A to B (sec.)	Speed at Photogate A (cm/sec)	Speed at Photogate B (cm/sec)

3 Stop and think

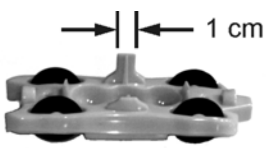
a. Describe how the position versus time graph is similar and how it is different from the one you did in the last Investigation (4A).

---

b. By looking at the graph, what can you tell about the speed of the car? Hint: the slope of the position versus time graph is the speed of the car.

---

4 Calculating the speeds



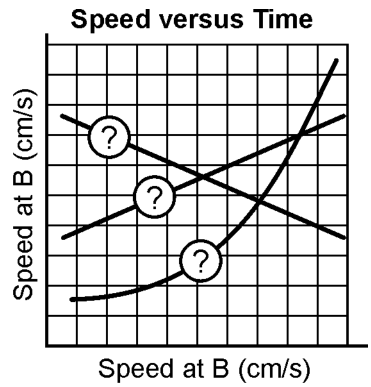
$$\text{speed} = \frac{\text{distance traveled}}{\text{time taken}} = \frac{1\text{ cm}}{\text{time through photogate (A or B)}}$$

For this experiment you need to calculate the speed of the car at photogate B and also at photogate A. During the time the light beam is broken the car travels a distance of one centimeter, the width of the wing on top of the car. That means the speed of the car is one centimeter divided by the time it takes to pass through a single photogate.

Use the data in table 1 to calculate the speed of the car at photogate A and photogate B. Write your results in the last two columns of table 1.

5 Making the speed versus time graph

What does the speed versus time graph look like?

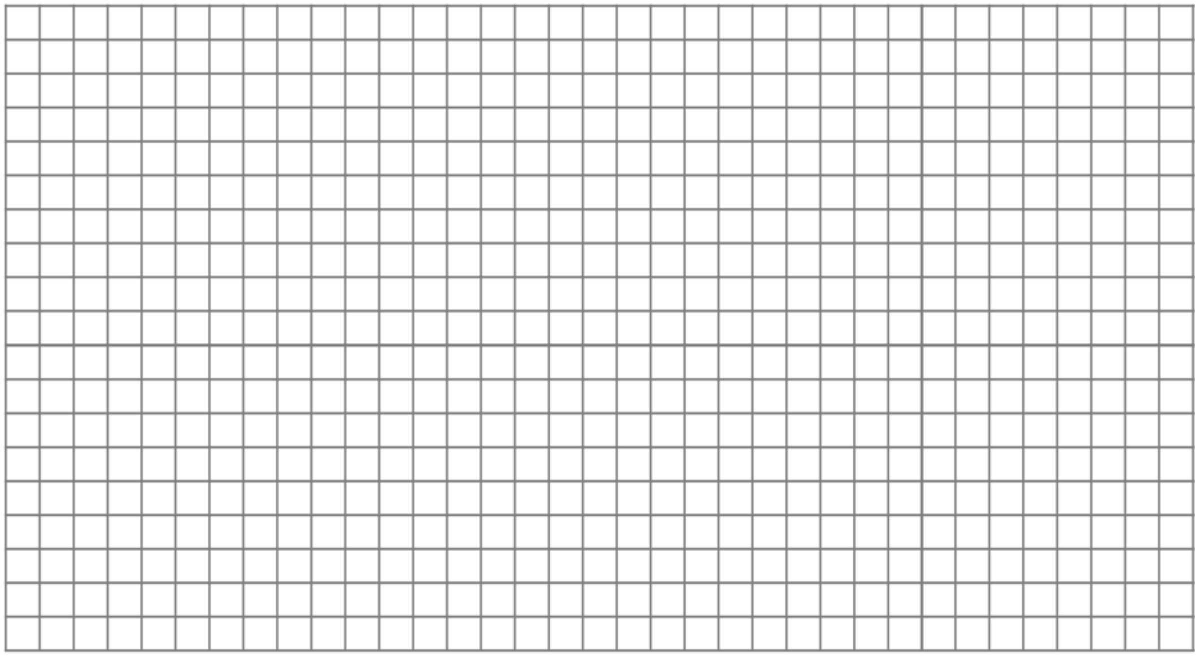


1. Start the graph by putting the speed of the car at photogate B on the vertical (y) axis.
2. Put the time from photogate A to B on the horizontal (x) axis. This is the time that the car has traveled between A and B.

3. Finish the graph by plotting the points from table 1 and giving the graph a title.

Title: ____________________

y label: ____________________



x label: ____________________

6 Stop and think

a. What shape does the speed versus time graph have?
Describe the line or curve that you get.

____

____

____

b. The point where a line intersects the vertical axis is called the y-intercept. For the speed versus time graph, the y-intercept has a physical meeting. What does this point on the graph mean? Did you make another measurement of the same variable? How do the two values relate to each other?

____

____

____

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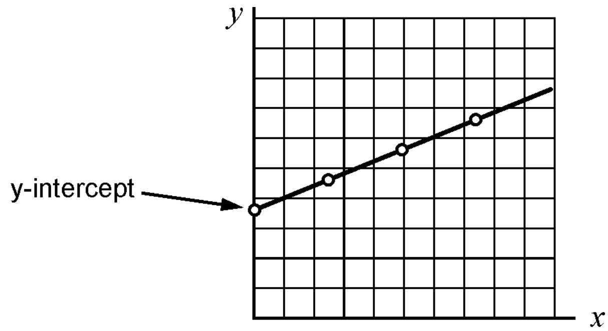


c. Suppose the speed of the car was a constant 30 cm/s. Sketch how this would look on your speed versus time graph.

d. Describe in one sentence how a graph of constant speed looks different from a graph of changing speed.

____

____

e. Use your speed versus time graph to predict how much time the car would have to roll before it reaches a speed of 200 cm/s.

Prediction:______________________________________

f. Use your position versus time graph to predict where on the track this would happen.

Prediction:______________________________________

g. Test your predictions with a photogate at your predicted location. Were your predictions accurate?

____

____

____

____

13A Forces

What is force and how is it measured?

The idea of force is central to our understanding of motion. You can think of force as a push or a pull. Objects interact with each other (and you) through forces. It takes force to start an object moving and also force to stop an object from moving. In physical science, we will need a precise definition for force and units for describing the strength of forces.

Materials

- Four force scales
- Washers
- Loops of string
- Friction block
- Mass balance

1 Measuring forces

Forces have two important properties: strength and direction. In the English system of units, the strength of a force is measured in pounds. When you measure your own weight in pounds, you are measuring the force of gravity acting on your body. In the metric system, the strength of a force is measured in newtons (N). One newton (1 N) is a smaller force than one pound. In fact, there are 4.448 N in 1 pound.

Calibrating a spring scale

1. In the laboratory, you can measure force with a spring scale. Locate a spring scale and calibrate it by adjusting the nut so the pointer reads zero.
2. Pull on the spring scale. When you pull you are applying a force to the spring scale. Can you make a force of two newtons (2 N)?

2 Weight: the force of gravity

Weight is one of the most common forces. All objects that have mass also have weight. Weight comes from the action of the Earth's gravity on an object's mass.

1. Take a loop of string and attach 5 steel washers.
2. Use a calibrated force scale to measure the weight of the washers.
3. Measure the mass using a mass balance.
4. Repeat the experiment for 5, 10, 15, 20, 25, and 30 washers.

Measure the mass of each group of washers after you tie them to the string loop

Use a spring scale to measure the weight of each group of washers

Table 1: Mass and weight data

Number of washers	Mass (kg)	Weight (N)

3 Stop and think

a. Make a graph of your data from table 1 showing weight on the y-axis and mass on the x-axis.

Title: ____________________

y label: ____________________

x label: ____________________

b. Describe the graph. What does it tell you about the relationship between mass and weight?

c. At the surface of earth, the strength of gravity is about 9.8 newtons per kilogram. What does this number mean?

d. If an object has a mass of 10 kilograms, how much does it weigh?

4 Friction

Friction is a force that comes from relative motion between an object and other matter, including air. The force of friction always acts in a direction opposite to motion that produces it. You encounter friction every day. Without friction, cars wouldn't move, you couldn't write with a pencil, and you would have difficulty staying on your chair!

1. Measure the mass of the friction block and record it in Table 2. Calculate the weight by multiplying by 9.8 N/kg
2. Place the block on the table with the smooth side facing down. Attach a spring scale so the newton markings are facing upward.
3. Gently pull on the scale until the block is moving slowly. Record the friction force as you slowly slide the block along at constant speed.
4. Divide the friction force by the total weight and record the resulting ratio as a decimal value in the last column of Table 2.
5. Add weight to the block and repeat the experiment for at least four different weights.

Measure the friction force with no weights

Measure the friction force with weights

Table 2: Friction data

Mass (kg)	Weight (N)	Friction force (N)	Ratio

5 Applying what you have learned

a. What happened to the friction force as the weight of the pulled objects increased? Discuss a possible explanation for the relationship.

b. The ratio of the friction force to the weight of the pulled objects is called the *coefficient of friction*. How did this ratio change as the weight was changed?

c. What effect would placing the block on a rougher surface (such as sandpaper) have on the coefficient of friction? Try flipping the block over to test its wood side.

13B Equilibrium

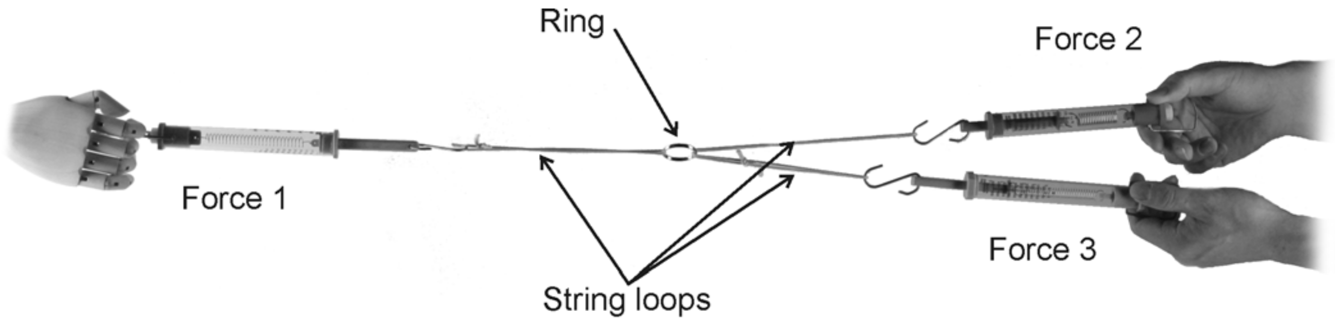
Are there still forces even when things are not moving?

When nothing is moving it does not mean there are no forces acting. It means things are in equilibrium. In equilibrium the total (net) force is zero. You can have as many forces as you wish, they just have to be arranged so the total is zero. This Investigation explores the concept of equilibrium using force scales.

Materials

- Four force scales
- Key ring
- Loops of string
- Rubber bands

1 Making equilibrium



The ring is in equilibrium when it is not moving

Try to keep your spring scales as parallel as possible, not at an angle as in this illustration

1. Hold each spring scale vertically and check that it is properly calibrated. If it needs to be adjusted, turn the nut at the top of the scale until it reads zero.
2. Attach three scales to the loops of string with the key ring in the middle.
3. Have three people each pull a scale, keeping the ring motionless with all the scales in a line.
4. Record the forces when 2 people are pulling against 1.
5. Try a few different combinations of scales and forces.

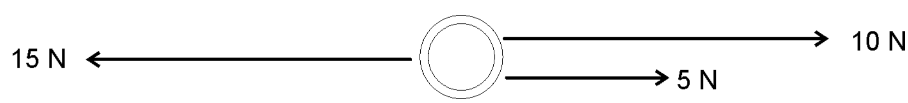
Table 1: Force data

Scale #1 (N)	Scale #2 (N)	Scale #3 (N)

2 Stop and think

a. What do your observations tell you about the relationship between the three forces acting on the ring?

Example
free body diagram

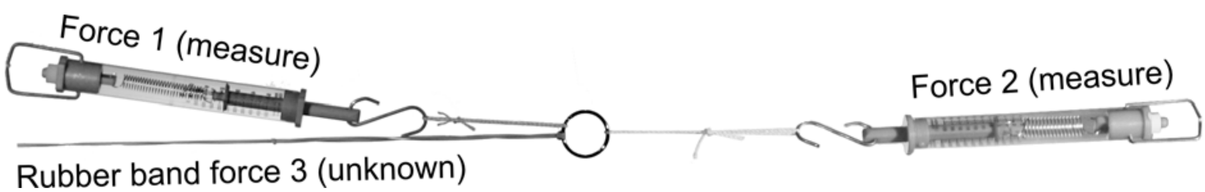


b. Draw a diagram showing the forces acting on the ring as arrows. Make the length of each arrow proportional to the strength of each force. For example, 1 cm per N might be a reasonable length scale. This kind of diagram is called a *free body diagram*.

c. If an object is not moving, what do you know about the forces acting on the object?

3 Determining an unknown force

In many situations, such as designing a bridge or a house, you know forces are there but you cannot always measure them directly. The people who design and build houses and bridges use equilibrium to deduce the strength of forces that they cannot measure.



1. Set up the experiment with the key ring again using loops of string except this time replace one of the two loops with a rubber band.
2. Have two students pull on to spring scales opposite of each other. The third student should pull on the rubber band.
3. Record the two forces when the key ring is not moving. The force from the rubber band is the unknown force.

4 Applying what you have learned

a. Draw a free body diagram showing the three forces acting on the key ring.

b. Use what you know about equilibrium to calculate the force from the rubber band. How do you know this is the correct force even if it was not measured?

c. Draw a free body diagram of a bridge with cars on it. Label the forces which must be there, such as the weight of the cars and the weight of the bridge. Be sure to include the forces that hold the bridge up and keeping from moving. Where do these forces come from?

14A Newton's Third Law

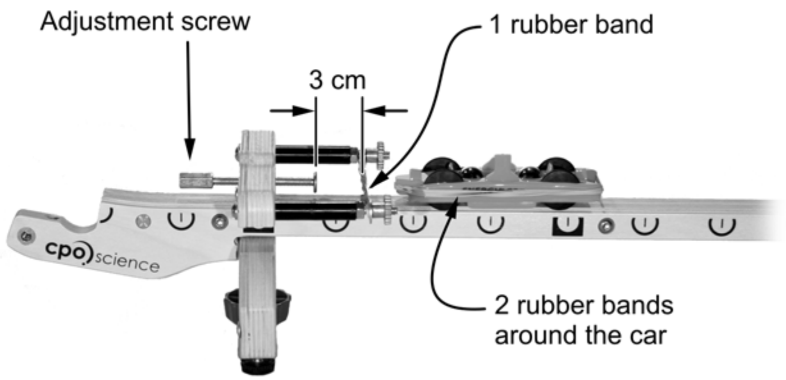
Why do things bounce back when they collide?

When you apply a force to throw a ball you also feel the force of the ball against your hand. That is because all forces come in pairs called action and reaction. There can never be a single force (action) without its opposite (reaction) partner. Action and reaction forces always act in opposite directions.

Materials

- Energy Car and Track
- CPO Timer
- 4 rubber bands
- Mass balance

1 Making a collision



Launching the car

Rest your palm on the wood and pull the car against the screw with your finger on the tab nearest the far end of the car.

1. Set up the long straight track with a rubber band launcher on one end and a clay ball on the other end. Use the bubble level to set the track level.
2. Set the adjustment screw to get 3 cm of deflection from the launcher rubber band.
3. Place one steel marble in each car.
4. Wrap one car with two rubber bands. This is the moving car. The nose of the car should be facing the launcher rubber band and the "V" should be facing the center of the track.
5. Set the other car in the center of the track with the nose end facing the launcher. This is the target car. The cars will collide with each other at the center of the track.
6. Launch the moving car and observe the motion of both cars before and just after they collide. Discuss with your group what you think the answers are to the following questions as you observe the collision.

Does the moving car bounce back after the collision? ________________

Does the moving car keep going forward after the collision? ________________

Does the moving car stop at the collision? ________________

How does the target car behave? ________________

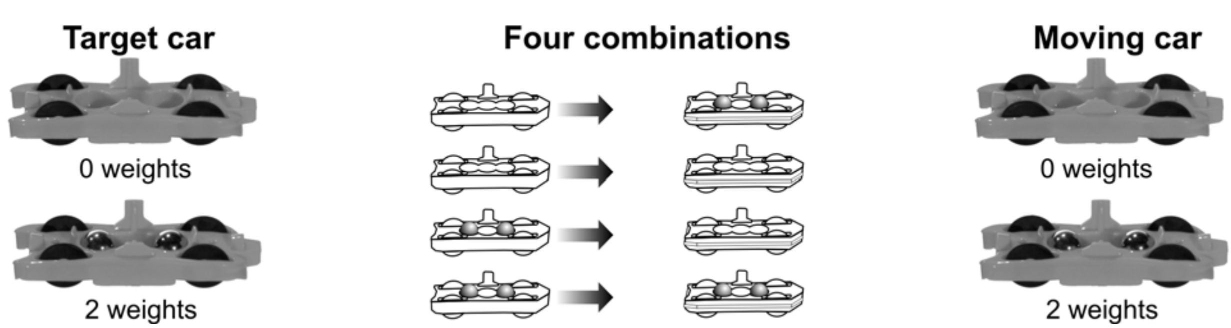
2 Thinking about what you observed.

a. Describe in words the motion of the two cars before and after the collision.

b. The target car must exert a force on the rolling car to stop it. How strong is this force relative to the force the moving car exerts on the target car to get it moving? What experimental evidence supports your answer?

c. Look up Newton's third law and state how it applies to the collision of the two cars.

3 Changing the masses



1. Try the experiment with the four combinations of mass shown above.

4 Applying what you have learned

a. Describe the motion of the two cars when the target car has more mass than the rolling car.

b. Describe the motion of the two cars when the target car has less mass than the rolling car.

c. Explain how your observations support the idea that there are action and reaction forces.

d. If the action and reaction forces are equal in strength, why does one car move at a different speed after the collision than the other car when the masses are unequal? Hint: the answer involves the Second Law.

e. Draw a free-body diagram of each car during the collision showing the action and reaction forces.

14B Newton's Second Law

What is the relationship between force and motion?

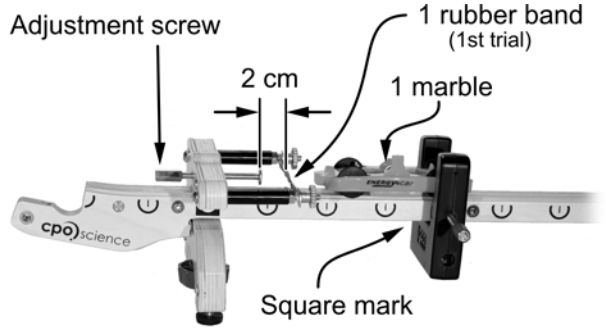
The relationships between force and motion are known as Newton's laws. These are among the most widely used relationships in all of physics. This investigation is about the second law which relates the force acting on an object to the object's change in speed and its mass.

Materials

- Energy Car and Track
- CPO Timer
- 3 rubber bands
- Mass balance

1 Changing force with constant mass

For the first part of the investigation you will use different amounts of force to launch the car. What do you think will happen? As the force gets larger, what happens to the speed of the car?



1. Set up the long straight track with a rubber band on one end and a clay ball on the other end. Adjust the screw so the rubber band deflects about two centimeters.
2. Put one photogate about 20 cm away from the rubber band.
3. Put one marble in the center of the car. Use the screw to launch the car using the same deflection of the rubber band each time. This means the same force is applied to each launch. Try to get three launches with times that are within 0.0015 seconds of each other. Record your three closest results.
4. Repeat the experiment with two and three rubber bands.

Table 1: Changing force data

Number of rubber bands	Time through photogate (sec)	Speed (cm/sec)

2 Stop and think

a. During which portion of the car's motion is the rubber band affecting its speed?

b. Make a graph showing the speed of the car on the y-axis and the number of rubber bands on the x-axis. As the force was increased, what happened to the speed of the car?

c. Why was the same mass used for all trials (with different force)?

3 Changing mass with the constant force

Use 1 rubber band to launch cars with 0, 1, 2, and 3 marbles.


0 marbles


2 marbles


1 marble


3 marbles

1. Put a single rubber band on the launching end of the track. Leave the photogate in the same place as it was (20 centimeters in front of the rubber band).
2. With the screw in the same place, launch cars of four different masses and observe their speeds when they pass through the photogate.
3. Measure the mass of the car with 0, 1, 2, and 3 steel balls.

Table 2: Changing mass data

Mass of car (kg)	Time through photogate (sec)	Speed (m/sec)

4 Applying what you have learned

a. Use Table 2 to graph the speed of the car (y) against the mass (x). Does your graph show a direct relationship or an inverse relationship?

b. Why did the speed change when the same launching force from the rubber band was applied to carts of different mass? How do your observations support your answer?

c. Do you think the force applied to an object causes speed itself or causes changes in speed? Support your answer with at least one sentence of explanation for why you believe your answer is correct.

When an object's speed changes we say the object *accelerates*. Acceleration occurs whenever speed changes. To be precise, acceleration means the "change in speed divided by the change in time".

$$\textbf{Acceleration} = \frac{\textbf{change in speed}}{\textbf{change in time}}$$

d. Based on your experimental results, propose a mathematical relationship between the variables F (force), a (acceleration), and m (mass).

15A The Size of the Solar System

How big is the Solar System?

It is difficult to comprehend great distances. For example, how great a distance is 150,000,000 kilometers, the distance from Earth to the sun? One way to get a sense of these distances is to create a scale model. A globe is a scale model of Earth and road maps are scale models of geographic regions. Scale models help us visualize the true sizes of objects and the distances between them. In this Investigation, you will make a scale model representing distances in the Solar System. The results may surprise you.

Materials

- Metric track and field tape measure (25 m or more)

1 Using proportions to determine scale distances

Pluto is an average distance of 5.9 billion kilometers from the sun. We can use a *proportion* to determine a scale distance for our model. Assume the largest distance you can measure is 100 meters. The length of a soccer field is usually between 90 and 120 meters long. For this Investigation, we will use 100 meters as the scale distance between the sun and Pluto.

$$100 \text{ m} = 5,900,000,000 \text{ km}$$

If the distance from the sun to Pluto equals 100 meters, where would you find the other planets? You can answer this question by setting up the following proportion where x is the distance from the sun to any planet, in meters:

$$\frac{x}{\text{Distance from the sun to planet}} = \frac{100 \text{ m}}{5{,}900{,}000{,}000 \text{ km}}$$

Mercury is 58,000,000 kilometers from the sun. Using our proportion, we can find the scale distance:

$$\frac{x}{58{,}000{,}000 \text{ km}} = \frac{100 \text{ m}}{5{,}900{,}000{,}000 \text{ km}}$$

Cross-multiply and rearrange the variables to solve for x:

$$x = \frac{100 \text{ m}}{5{,}900{,}000{,}000 \text{ km}} \times 58{,}000{,}000 \text{ km} = 0.98 \text{ m}$$

Mercury is 0.98 meters from the sun using this scale.

2 Determining scale distances for the other planets

1. Based on the example in Part 1, you would place Mercury 0.98 meters or 98 centimeters from the sun in your 100-meter scale model.

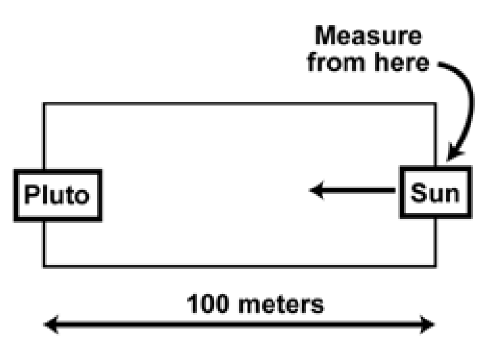
2. Calculate the scaled distances from the sun to the other planets. Write the distance in meters for each planet in Table 1.

Table 1: Scale distances from the sun to the planets

Planet	Actual distance to sun (km)	Proportional distance from the sun (m)
Mercury	58,000,000	0.98
Venus	108,000,000	
Earth	150,000,000	
Mars	228,000,000	
Jupiter	778,000,000	
Saturn	1,430,000,000	
Uranus	2,870,000,000	
Neptune	4,500,000,000	
Pluto (dwarf)	5,900,000,000	100

3 Setting up the scale model

1. To begin, make signs for each of the planets and one for the sun. In your scale model, a student in your class will hold the sign at each position of the planet.
2. In an area that is at least 100-meters long, identify the location of the sun. A student will stand in this position with a sign that says "Sun."
3. Measure 100 meters from the position of the sun. At the 100-meter mark, a student will stand with a sign that says "Pluto." In this model, 100 meters is the scale distance from the sun to Pluto.
4. Now, use the scale distances from Table 1 to find the locations of each planet. At the location of each planet, a student will stand with the appropriate sign. Then, answer the questions.



4 Applying what you have learned

a. After constructing your model, what is your impression of our solar system?

b. Describe some disadvantages and advantages to using this model of the solar system.

c. Alpha Centauri is the closest star to Earth at 274,332 AU (astronomical units). One astronomical unit is equal to 150 million kilometers. Where would you place this star in the 100-meter scale model?

d. The diameter of the Milky Way galaxy is known to be about 100,000 light years. One light year is 63,000 AU. How does the size of the Milky Way galaxy compare with the size of the solar system?

Footnote: On August 24, 2006, the International Astronomical Union (IAU) passed a new definition of a planet. The new definition excludes Pluto as a planet. According to the new definition, Pluto is classified as a "dwarf planet."

15B The Sizes of the Planets

How big are the planets relative to Earth?

Compared to the distances between them, the planets are relatively tiny. Although Earth seems large while standing on it, you could fit almost 12,000 Earths in the space between Earth and the sun! Earth is small compared to some of the other planets, such as Jupiter or Saturn. But other planets are smaller than Earth's moon! This investigation will look at the relative sizes of the planets.

Materials

- Metric tape measure (sewing tape)
- Lacrosse ball
- Other sizes of balls

1 Determining scale sizes of the planets compared to the solar system

What would the planets look like in a 100 meter scale model of the solar system? For example, Mercury has a diameter of 4,880 kilometers. How big would Mercury be in a 100-meter scale model? You can use the same method to determine the scale diameter of Mercury that you used in the last investigation:

$$\frac{x}{4{,}880\text{ km}} = \frac{100\text{ m}}{5{,}900{,}000{,}000\text{ km}}$$

Cross-multiply and rearrange the variables to solve for x:

$$x = \frac{100\,\text{m}}{5{,}900{,}000{,}000\,\text{km}} \times 4{,}880\,\text{km} = 0.000083\,\text{m}$$

Based on the example above, the diameter of Mercury in a 100-meter scale solar system would be 0.000083 meters or 0.083 millimeters. This is about the thickness of a human hair! If the distance from the sun to Pluto were 100 meters, Mercury would be smaller than the period at the end of this sentence. The space between the planets is enormous compared to the size of the planets themselves.

2 Calculating the scaled sizes of the planets

Calculate the scaled diameters of the other planets as well as the sun and Earth's moon. Write these values in units of meters in the third column of Table 1.

Table 1: Diameters of the planets, Earth's moon, and sun

Planet	Actual diameter (km)	Scale diameter (m)	Scale diameter (mm)
Sun	1,391,980		
Mercury	4,880	**0.000083**	
Venus	12,100		
Earth	12,800		
Moon	3,475		
Mars	6,800		
Jupiter	142,000		
Saturn	120,000		
Uranus	51,800		
Neptune	49,500		
Pluto (dwarf)	2,300		

3 Stop and think

a. How big is the sun in this model in cm? ______________________

b. How much larger is the sun's diameter compared with Earth's? How much larger is Earth's diameter compared with the moon's?

____

c. The smallest object that the human eye can see without magnification is 0.100 millimeters. Given this information, which planets would be visible to the human eye? Would you be able to see the sun or the moon on this 100-meter scale model of the solar system?

____

d. What is your impression of how the size of the planets and the sun compare with the size of the solar system?

____

____

4 Modeling the sizes of the planets

To get a relative sense of the sizes of the planets, we need to work at a much larger scale. Suppose Earth were the size of a lacrosse ball. The diameter of a lacrosse ball is 6.4 cm. The best way to measure the diameter of a ball is to measure the circumference by wrapping a tape measure around the widest part. The diameter is the circumference divided by π (3.14).

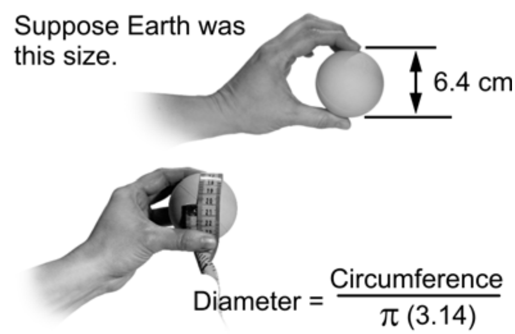


Table 2: Diameters of the planets, Earth's moon, and sun

Planet	Actual diameter (km)	Scale diameter (cm)
Sun	1,391,980	
Mercury	4,880	
Venus	12,100	
Earth	12,800	6.4
Moon	3,475	
Mars	6,800	
Jupiter	142,000	
Saturn	120,000	
Uranus	51,800	
Neptune	49,500	
Pluto (dwarf)	2,300	

5 Stop and think

a. See if you can find some spheres that are the approximate sizes of the scale diameters from Table 2. Compare these to the size of the lacrosse ball that represented Earth.

b. Cut circles out of construction paper or cardboard to represent the size of each planet. The circle for Earth should be 6.4 centimeters in diameter. Use the scale diameters from Table 2 for the other planets.

6 Extension: Making a larger scale model of the solar system

In this part of the Investigation, you will use common objects to compare the diameters of planets, the sun, and Earth's moon in our solar system. For example, we could use an Earth globe to represent the scale size of Earth. The diameter of the globe we will use is 30 centimeters.

1. If an Earth globe is used to represent the size of Earth, what would the sizes of the sun and the other planets be? How big would the moon be? Use what you have learned in this Investigation to calculate the scale diameters of the other planets, the moon, and the sun. Fill in the third column of Table 3 with these values.
2. What objects could be used to represent each of the planets, the moon, and the sun? Fill in the fourth column of Table 3 with your answers to this question.
3. Answer the questions that follow the table.

Table 3:Table 3: A scale model of the solar system

Planet	Actual diameter of planet (km)	Scale diameter of sun or planet (cm)	Representative object and its diameter or length (cm)
Sun	1,391,980		
Mercury	4,880		
Venus	12,100		
Earth	**12,800**	**30 cm**	**Earth globe, 30 cm**
Moon	3,475		
Mars	6,800		
Jupiter	142,000		
Saturn	120,000		
Uranus	51,800		
Neptune	49,500		
Pluto (dwarf)	2,300		

a. How many times bigger is 30 centimeters than 0.20 millimeters? These are the diameters of Earth for the two scale models you created.

b. Using your answer to question 5a, what would be the distance between the sun and Pluto on this larger scale? Come up with a way to explain or model this distance.

c. Why is it challenging to make a scale model of the solar system that includes the distances between planets and the sun and the sizes of the planets?

16A Distance and Brightness

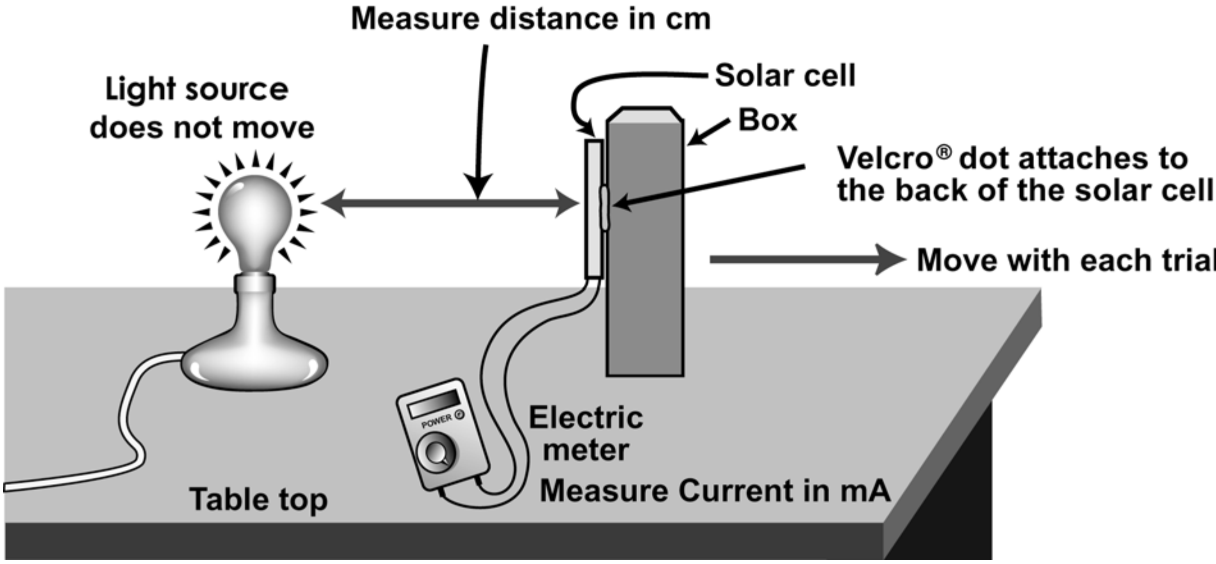
How does light from a star spread out on its way to us?

The brightness of a star depends both the star's distance and on how much light the star actually produces (its luminosity). When astronomers know a star's brightness and luminosity they can calculate the distance to the star. In this Investigation, you will discover the mathematical relationship between how bright a light source appears and it's distance. You will then understand how astronomers are able to use light to measure the distances to faraway stars and galaxies.

Materials

- Incandescent lamp base & 100w bulb
- Digital multimeter
- Solar cell
- Meter stick
- Small cardboard box

1 Setting up



1. Turn on your light source and turn off the overhead lights in the classroom.
2. Place the solar cell exactly 10 centimeters from the light bulb. Make sure the solar cell is directly facing the light bulb and is not at an angle.
3. Make sure the electric meter is set to measure current in milliamps (mA).
4. Measure the light's brightness in mA and record your results in Table 1.
5. Measure the brightness at 10-centimeter intervals and record your data in Table 1.

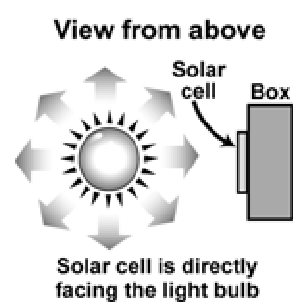


Table 1: Brightness and distance data

Distance (cm)	10	20	30	40	50	60	70	80	90	100
Brightness (mA)										

2 Stop and think

The **brightness** of a light source describes the amount of light reaching an observer. In this case the observer is the solar cell. Brightness depends on the distance between the source of light and the observer. The **luminosity** of a light source describes the total amount of light given off by the source in all directions. Luminosity is a property of the light source itself and does not depend on distance.

a. Does this experiment measure the *brightness* or the *luminosity* of the light bulb? Explain your answer.

b. Is the power rating of the light bulb (100 watts) a measure of the light bulb's *brightness* or *luminosity*? Explain your answer.

c. What effect did increasing the distance have on your solar cell measurements?

3 Analyzing your data

Make a graph of brightness in mA versus distance in centimeters. Plot brightness on the y-axis and distance on the x-axis.

Title: ______________________________

y label: ______________________________

x label: ______________________________

a. Is your graph increasing or decreasing from left to right? ______________________________

b. Describe the shape of the curve on your graph. Have you seen a curve like this before?

____

____

c. Is there a mathematical relationship between brightness and distance from your graph? Explain your answer.

____

____

____

____

____

____

4 Inverse relationships

When one variable increases as another decreases, it is called an **inverse relationship**. This is shown mathematically using the variables *B* for brightness and *D* for distance, where:

$$\text{Brightness} \longrightarrow B = \underbrace{\frac{1}{D}}_{\text{Inverse of distance}}$$

Here are three of many possible inverse mathematical relationships:

$$B = \frac{1}{D} \quad \text{or} \quad B = \frac{1}{D^2} \quad \text{or} \quad B = \frac{1}{D^3}$$

The first equation says the brightness is inversely related to the distance. The second equation says the brightness varies with the inverse of the distance *squared*.

a. What does the third equation say about the relationship between B and D?

____

____

b. Assume the correct equation is one of the three above. How could you figure out which is the correct one?

____

____

____

c. Which equation do you think is the correct one? Explain your reasoning.

____

____

____

____

5 Identifying the correct inverse relationship

To figure out which equation is correct, you will need to further analyze your data from Part 2.

1. Enter your distance data from Table 1 into the first row of Table 2 below. You will need to convert centimeters to meters. The first two values are done for you.
2. Calculate 1/D and enter the results in the second row of Table 2. The first two are done for you.
3. Calculate $1/D^2$ and $1/D^3$ and enter the values in rows three and four of Table 2.
4. Enter your brightness data from Table 1 into the fifth row of Table 2.
5. Make the following three graphs:

   Graph 1: *Brightness vs. 1/D*

   Graph 2: *Brightness vs.* $1/D^2$

   Graph 3: *Brightness vs.* $1/D^3$

Title: ________________________________

y label: ________________________________

x label: ________________________________

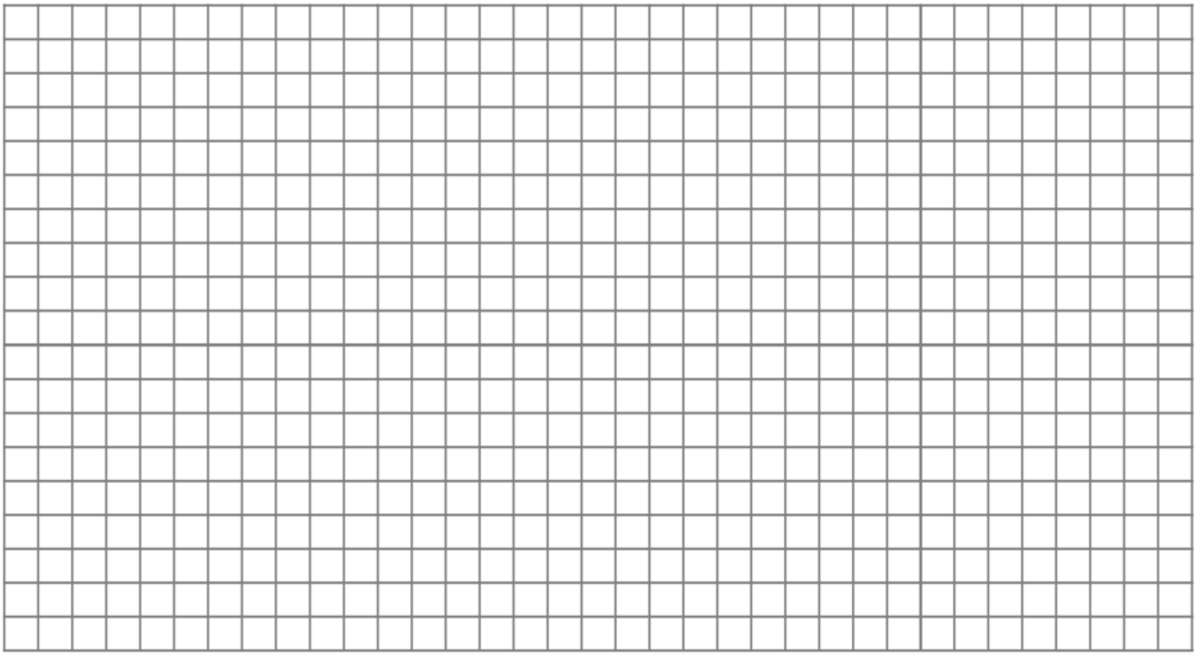
Title: ________________________________

y label: ________________________________

x label: ________________________________

Title: ____________________

y label: ____________________



x label: ____________________

Table 2: Analyzing your distance and brightness data

Distance (cm)	10	20	30	40	50	60	70	80	90	100
Distance (m)	0.10	0.20								
1/D	10	5								
$1/D^2$	100	25								
$1/D^3$										
Brightness (mA)										

6 Reaching a conclusion

a. Which graph identifies the correct inverse relationship between brightness and distance? Explain your choice.

b. Write down the correct formula for the relationship between brightness and distance.

7 Testing your model

Test your formula by following these steps:

a. Choose a distance for which you did not measure brightness (for example, 45 cm).

b. Calculate brightness in mA using your formula. This is your *predicted brightness*.

Prediction: ______

c. Move the solar cell to the distance you chose and measure the brightness of the light. This is your *actual brightness*.

d. Calculate your percent error using the following formula:

$$\left(\frac{\text{predicted brightness - actual brightness}}{\text{predicted brightness}}\right)\times 100 = \text{percent error}$$

16B Spectroscopy

How do we know other stars are like the sun?

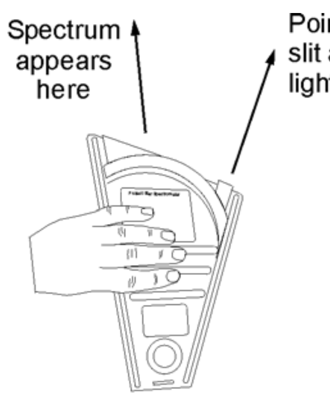
With the exception of the sun, stars appear as mere specks of light in the night sky. Using spectroscopy, astronomers can analyze the light from stars to determine their temperature, chemical composition, and even how fast they are moving. In this Investigation, you will learn how to analyze light using spectroscopy to determine which elements are present in different light sources. You will then analyze the light emitted by a main sequence star (the sun) to determine its chemical composition.

Materials

- Project STAR spectrometer
- Colored pencils
- Access to light from incandescent and fluorescent light fixtures

1 The spectrometer

A **spectrometer** splits light into a spectrum of colors and displays the different colors of light along a scale. The lower scale measures the wavelength of different colors of light in nanometers (nm). One nanometer is one trillionth of a meter so individual light waves are very small! Red light has the longest wavelength, around 650 nm. Blue light has the shortest wavelength, around 400 nm.

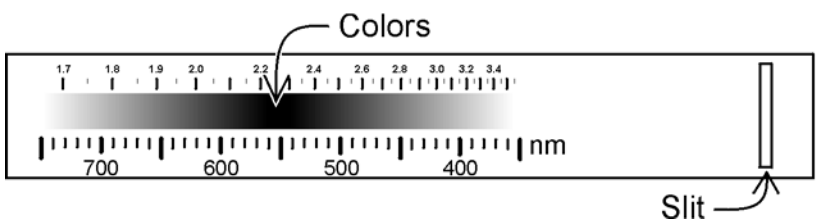


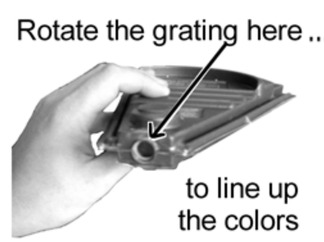
Safety Tip: Never look directly into any light source—especially the sun!

1.Hold the spectrometer so the printed side faces up.

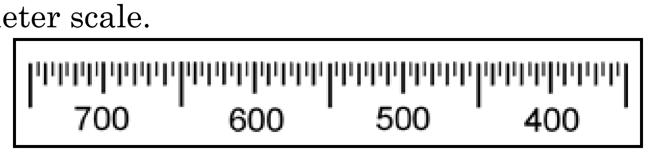
2.Look in the short end with one eye while you point the slit at a bright light. *Direct your eye to the left to see the colors*. You should see a a band of colors in between two rows of numbers (scales) like the diagram below.

3.If the colored band is crooked, rotate the disk until the colored band lines up between the two scales.





a. While looking through the eyepiece, point the slit of the spectrometer directly at an incandescent bulb. Use colored pencils to show where the different colors of light appear in on the spectrometer scale.

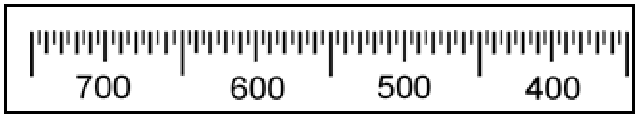


b. Blue light has the highest energy and red light the lowest. Based on your observations with the spectrometer, what is the relationship between wavelength and amount of energy?

2 Using a spectrometer to identify elements in a fluorescent light

1. Look through the spectrometer at light from a fluorescent bulb (most likely the ones in your classroom). You should see colored lines (called **spectral lines**) instead of a smooth rainbow like you saw from the incandescent light.
2. You should see a green line at 546 nanometers on the scale. If the green line is not at 546 nanometers, ask your teacher to calibrate the spectrometer for you.

a. Use colored pencils to sketch the lines you observe. Be very precise in your sketch by placing the lines you see in the *exact* positions on the scale below.



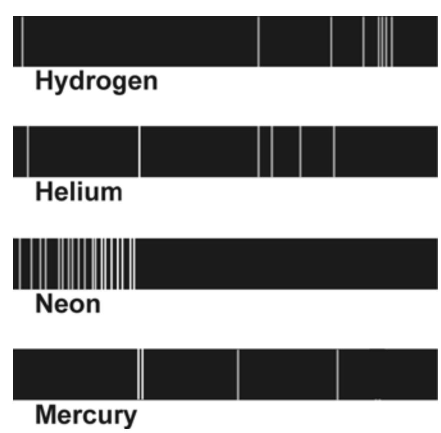
b. Identify the wavelength of each spectral line, from left to right, then fill in Table 1.

Table 1: Spectral lines produced by a fluorescent light

Line number	Spectral line color	Spectral line wavelength (nm)
1		
2		
3		
4		

3 What do the lines mean?

When elements are heated until they are hot enough to emit light (like those elements that make up stars), they produce characteristic spectral lines. Each element produces a pattern of spectral lines that is like a fingerprint. Shown to the right are some examples of the spectral lines produced by four different elements. Each line has a specific wavelength (these values are not shown in the diagram).



The light produced by a fluorescent source is created when electric current is passed through a gas inside of the tube. This gas, which is made of only one element, absorbs energy, and emits light.

a. The light from most fluorescent tubes comes from only one element. Compare the spectral lines you observed with the ones in the diagram above. Which element does the bulb contain?

b. Fluorescent tubes have special instructions for disposal and must not end up in a landfill. Based on your spectral analysis of the gas inside the tube, why is this so?

c. Stars are made up of more than one type of element. When astronomers use a spectrometer to analyze the light produced by stars, they observe the combined spectral lines of all of the elements present in the star. What specific information would an astronomer need to know in order to determine which elements are present in a star?

17A The Milky Way Galaxy

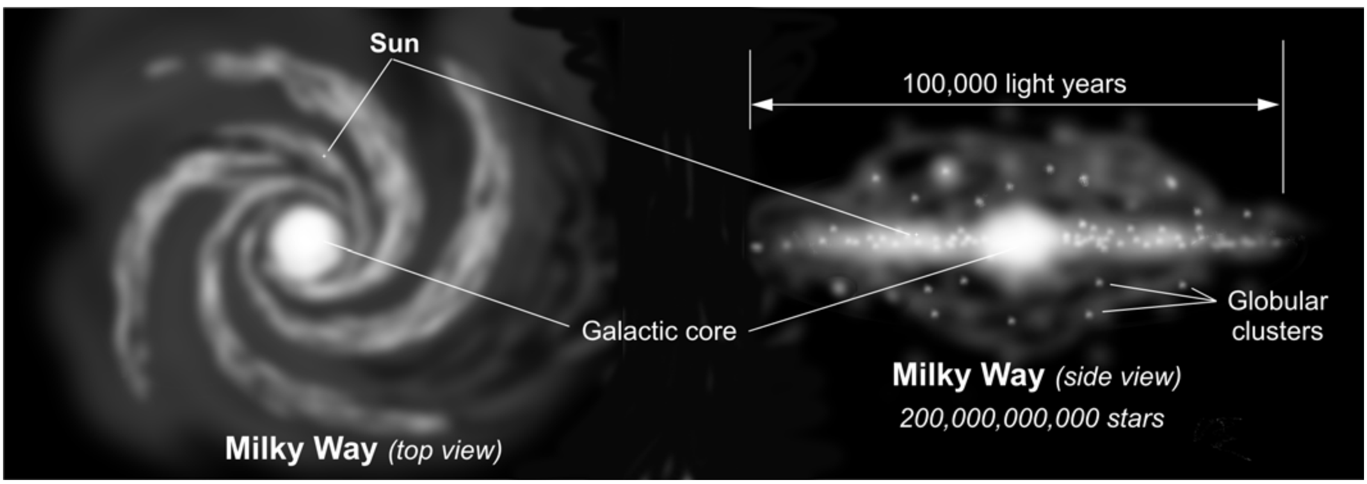
What do we know about the Milky Way, our own galaxy?

A galaxy is an enormous collection of stars, dust, gas and other objects bound together by gravity. Our sun and solar system is in the Milky Way galaxy. Astronomers estimate that the Milky Way galaxy contains 200 billion stars. On a dark night, far from city lights, you can see the Milky Way as a faint band stretching across the sky. This activity will introduce you to some properties of the Milky Way galaxy and other galaxies.

Materials

- Astronomy reference materials

1 The Milky Way galaxy



The Milky Way galaxy is about 100,000 light-years across. The galaxy is shaped like a disk with a bulge in the center. Our sun is located on one of the Milky Way's four spiral arms, about 26,000 light years from the center. The sun is in the disc of the galaxy, slightly above the center.

Research and discuss the following questions.

a. Are there other stars with planets in our galaxy?

b. Suppose only one in every million stars has a solar system with a planet like Earth. How many earthlike planets would that make in the Milky Way galaxy?

c. Something unusual is happening at the very core of the galaxy. What do astronomers think is hiding there?

d. How long does it take the Milky Way galaxy to make one complete rotation?

e. Roughly how old is the Milky Way galaxy?

f. The fastest spacecraft built by humans goes 30 kilometers per second. How long would this spacecraft take to cross the galaxy?

17B The Time Machine

How long does it take for starlight to reach Earth?

Light travels very fast at 300,000 kilometers per second. However, the universe is very large. Light that reaches your eyes from distant stars or galaxies has been traveling for a long time. Suppose you look through a telescope and see a galaxy that is one million light-years away. Because it takes one million years for the light to reach you, you are actually seeing the galaxy as it was one million years ago! Looking out into the universe is like looking back in time. The farther away you look in space, the farther back you see in time.

Materials

- Astronomy reference materials

1 How fast is fast?

When you travel in a car or a jet, your speed is usually measured in miles per hour or kilometers per hour. It takes about six hours to fly across the country on a modern airliner, which travels about 1000 km/hr. This is about as fast as a person can travel today, but it is nothing compared to how fast light travels.

Complete Table 1 below and compare the speeds of these fast moving objects to the speed of light (rounded to 300,000 km/sec). To calculate the percent of speed of light;

$$\frac{\text{Speed of object}}{\text{Speed of light}} \times 100 = \text{Percent of speed of light}$$

Table 1: Comparing speeds

Object	Speed in km/hr	Speed in km/sec	Time to reach the moon 384,400 km away (hours and days)	% of speed of light
Diving falcon	250			
Mag-Lev Train	430			
Top fuel dragster	535			
Commercial jet	1000			
Space shuttle	28,000			
Comet	200,000			

a. Earth is about 150,000,000 km from the sun. How long does it take the light from the sun to reach Earth?

____

b. Jupiter is 778,000,000 km from the sun. How long does it take the light from the sun to reach Jupiter?

____

c. Pluto is 5,900,000,000 km away from the sun, the farthest planet away. How long does it take light from the sun to reach Pluto?

____

2 How far is far?

When we looked the size of the solar system we saw that the distances between the planets were enormous in comparison with the distances we experience in our everyday lives here on Earth. In the study of the universe scientists often use the term light year as a measure of distance. This represents the distance light travels in one year, and since light is moving at 300,000 km/sec the distance adds up quickly. How quickly? Fill in Table 2 to find out.

Table 2: Light year data

Unit	Speed of light (in km/sec)		Time in seconds	Distance (in km)
1 light second	300,000	x	1	300,000
1 light minute	300,000	x	60	
1 light hour	300,000	x		
1 light day	300,000	x		
1 light week	300,000	x		
1 light year	300,000			

3 Looking back in time

The light from the sun that we see took several minutes to get here, even at the amazingly fast speed that light travels. But the light we see from stars takes much, much longer. Scientists measure the distances to objects like stars and planets outside our solar system in units of light years because the distances between objects in space is so huge. In fact, the closest star to Earth (other than our sun) is Alpha Centauri, which is 4.3 light years away. The light from that star took 4.3 years to get to us, so it is like looking back a little over four years into the past. The further objects are from Earth the longer the light takes to get to us, and the further back in time we are looking. When an astronomer looks at Alpha Centauri she is not seeing Alpha Centauri as it is right at this second, she is seeing it as it was 4.3 years ago.

Most of the stars we see in the night sky reside right here with us in the Milky Way galaxy. The ones that are not are actually galaxies that are very, very far away.

Research these night sky objects and see if you can locate them to look back in time.

Table 3: Night sky objects

Object	Distance from Earth (light years)	Years looking back in time
Sirius		
Vega		
Arcturus		
Canopus		
Polaris		
Betelgeuse		
Rigel		
Andromeda Galaxy (M31)		

Safety Skills

LAB SKILLS

What can I do to protect myself and others in the lab?

Science equipment and supplies are fun to use. However, these materials must always be used with care. Here you will learn how to be safe in a science lab.

Materials

- Poster board
- Felt-tip markers

1 Follow these basic safety guidelines

Your teacher will divide the class into groups. Each group should create a poster-sized display of one of the following guidelines. Hang the posters in the lab. Review these safety guidelines before each Investigation.

1. **Prepare** for each Investigation.
   a. Read the Investigation sheets carefully.
   b. Take special note of safety instructions.
2. **Listen** to your teacher's instructions before, during, and after the Investigation. Take notes to help you remember what your teacher has said.
3. **Get ready to work:** Roll long sleeves above the wrist. Tie back long hair. Remove dangling jewelry and any loose, bulky outer layers of clothing. Wear shoes that cover the toes.
4. **Gather** protective clothing (goggles, apron, gloves) at the beginning of the Investigation.
5. **Emphasize teamwork**. Help each other. Watch out for one another's safety.
6. **Clean up** spills immediately. Clean up all materials and supplies after an Investigation.

2 Know what to do when...

1. **working with heat.**
   a. Always handle hot items with a hot pad. Never use your bare hands.
   b. Move carefully when you are near hot items. Sudden movements could cause burns if you touch or spill something hot.
   c. Inform others if they are near hot items or liquids
2. **working with electricity.**
   a. Always keep electric cords away from water.
   b. Extension cords must not be placed where they may cause someone to trip or fall.

c. If an electrical appliance isn't working, feels hot, or smells hot, tell a teacher right away.

3. **disposing of materials and supplies.**

a. Generally, liquid household chemicals can be poured into a sink. Completely wash the chemical down the drain with plenty of water.

b. Generally, solid household chemicals can be placed in a trash can.

c. Any liquids or solids that **should not** be poured down the sink or placed in the trash have special disposal guidelines. Follow your teacher's instructions.

d. If glass breaks, do not use your bare hands to pick up the pieces. Use a dustpan and a brush to clean up. "Sharps" trash (trash that has pieces of glass) should be well labeled. The best way to throw away broken glass is to seal it in a labeled cardboard box.

4. you are concerned about your safety or the safety of others.

a. Talk to your teacher immediately. Here are some examples:

- You smell chemical or gas fumes. This might indicate a chemical or gas leak.
- You smell something burning.
- You injure yourself or see someone else who is injured.
- You are having trouble using your equipment.
- You do not understand the instructions for the Investigation.

b. Listen carefully to your teacher's instructions.

c. Follow your teacher's instructions exactly.

3 Safety quiz

LAB SKILLS

1. Draw a diagram of your science lab in the space below. Include in your diagram the following items. Include notes that explain how to use these important safety items.

- Exit/entrance ways
- Fire extinguisher(s)
- Fire blanket
- Eye wash and shower
- First aid kit
- Location of eye goggles and lab aprons
- Sink
- Trash cans
- Location of special safety instructions

2. How many fire extinguishers are in your science lab? Explain how to use them.

3. List the steps that your teacher and your class would take to safely exit the science lab and the building in case of a fire or other emergency.

4. Before beginning certain Investigations, why should you first put on protective goggles and clothing?

5. Why is teamwork important when you are working in a science lab?

6. Why should you clean up after every Investigation?

7. List at least three things you should you do if you sense danger or see an emergency in your classroom or lab.

8. Five lab situations are described below. What would you do in each situation?
   a. You accidentally knock over a glass container and it breaks on the floor.

   b. You accidentally spill a large amount of water on the floor.

c. You suddenly you begin to smell a “chemical” odor that gives you a headache.

d. You hear the fire alarm while you are working in the lab. You are wearing your goggles and lab apron.

e. While your lab partner has her lab goggles off, she gets some liquid from the experiment in her eye.

f. A fire starts in the lab.

Safety in the science lab is everyone’s responsibility!

4 Safety contract

Keep this contract in your notebook at all times.

By signing it, you agree to follow all the steps necessary to be safe in your science class and lab.

I, ____________________, (Your name)

☑ Have learned about the use and location of the following:
- Aprons, gloves
- Eye protection
- Eyewash fountain
- Fire extinguisher and fire blanket
- First aid kit
- Heat sources (burners, hot plate, etc) and how to use them safely
- Waste-disposal containers for glass, chemicals, matches, paper, and wood

☑ Understand the safety information presented.

☑ Will ask questions when I do not understand safety instructions.

☑ Pledge to follow all of the safety guidelines that are presented on the Safety Skill Sheet at all times.

☑ Pledge to follow all of the safety guidelines that are presented on Investigation sheets.

☑ Will always follow the safety instructions that my teacher provides.

Additionally, I pledge to be careful about my own safety and to help others be safe. I understand that I am responsible for helping to create a safe environment in the classroom and lab.

Signed and dated,

____

Parent's or Guardian's statement:

I have read the Safety Skills sheet and give my consent for the student who has signed the preceding statement to engage in laboratory activities using a variety of equipment and materials, including those described. I pledge my cooperation in urging that she or he observe the safety regulations prescribed.

______________________________ ______________________________

Signature of Parent or Guardian Date

Writing a Lab Report

How do you share the results of an experiment?

A lab report is like a story about an experiment. The details in the story help others learn from what you did. A good lab report makes it possible for someone else to repeat your experiment. If their results and conclusions are similar to yours, you have support for your ideas. Through this process we come to understand more about how the world works.

1 The parts of a lab report

A lab report follows the steps of the scientific method. Use the checklist below to create your own lab reports:

- ☐ **Title:** The title makes it easy for readers to quickly identify the topic of your experiment.
- ☐ **Research question:** The research question tells the reader exactly what you want to find out through your experiment.
- ☐ **Introduction:** This paragraph describes what you already know about the topic, and shows how this information relates to your experiment.
- ☐ **Hypothesis:** The hypothesis states the prediction you plan to test in your experiment.
- ☐ **Materials:** List all the materials you need to do the experiment.
- ☐ **Procedure:** Describe the steps involved in your experiment. Make sure that you provide enough detail so readers can repeat what you did. You may want to provide sketches of the lab setup. Be sure to name the experimental variable and tell which variables you controlled.
- ☐ **Data/Observations:** This is where you record what happened, using descriptive words, data tables, and graphs.
- ☐ **Analysis:** In this section, describe your data in words. Here's a good way to start: *My data shows that...*
- ☐ **Conclusion:** This paragraph states whether your hypothesis was correct or incorrect. It may suggest a new research question or a new hypothesis.

2 A sample lab report

Use the sample lab report on the next two pages as a guide for writing your own lab reports. Remember that you are telling a story about something you did so that others can repeat your experiment.

Name: Lucy O. **Date:** January 24, 2007

Title: Pressure and Speed

Research question: How does pressure affect the speed of the CPO air rocket?

Introduction:

Air pressure is a term used to describe how tightly air molecules are packed into a certain space. When air pressure increases, more air molecules are packed into the same amount of space. These molecules are moving around and colliding with each other and the walls of the container. As the number of molecules in the container increases, the number of molecular collisions in the container increases. A pressure gauge measures the force of these molecules as they strike a surface.

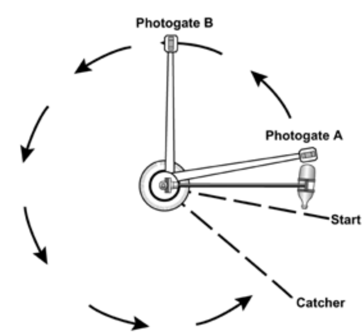
In this lab, I will measure the speed of the CPO air rocket when it is launched with different amounts of initial pressure inside the plastic bottle. I want to know if a greater amount of initial air pressure will cause the air rocket to travel at a greater speed.

Hypothesis: When I increase the pressure of the air rocket, the speed will increase.

Materials:

CPO air rocket	CPO photogates
CPO timer	Goggles

Procedure:

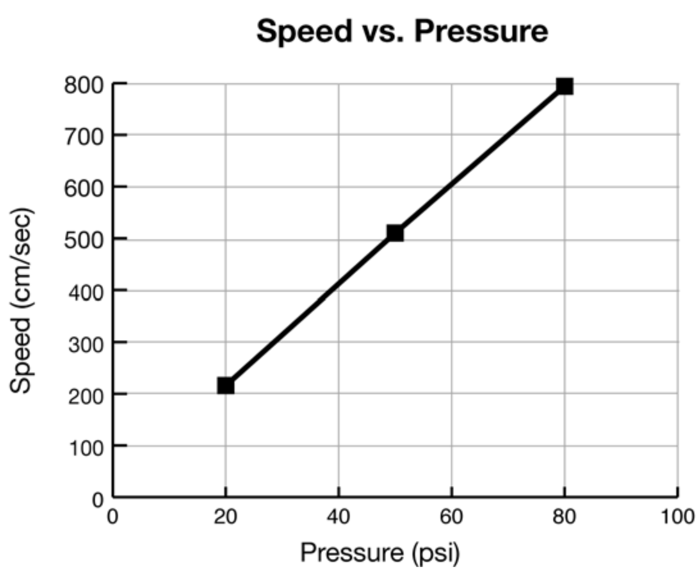


1. I put on goggles and made sure the area was clear.
2. The air rocket is attached to an arm so that it travels in a circular path. After it travels about 330°, the air rocket hits a stopper and its flight ends. I set up the photogate at 90°.
3. My control variables were the mass of the rocket and launch technique, so I kept these constant throughout the experiment.
4. My experimental variable was the initial pressure applied to the rocket. I tested the air rocket at three different initial pressures. The pressures that work effectively with this equipment range from 15 psi to 90 psi. I tested the air rocket at 20 psi, 50 psi, and 80 psi. I did three trials at each pressure.
5. The length of the rocket wing is 5 cm. The wing breaks the photogate's light beam. The photogate reports the amount of time that the wing took to pass through the beam. Therefore, I used wing length as distance and divide by time to calculate speed of the air rocket.
6. I found the average speed in centimeters per second for each pressure.

Data/Observations:

Table 1: Air pressure and speed of rocket

Initial air pressure	Time (sec) at 90°	Speed (m/sec) at 90°	Average speed cm/sec
20 psi	0.0227	2.20	216
	0.0231	2.16	
	0.0237	2.11	
50 psi	0.0097	5.15	510
	0.0099	5.05	
	0.0098	5.10	
80 psi	0.0060	8.33	794
	0.0064	7.81	
	0.0065	7.69	



Analysis:

My graph shows that the plots of the data for photogates A and B are linear. As the values for pressure increased, the speed increased also.

Conclusion:

The data shows that pressure does have an effect on speed. The graph shows that my hypothesis is correct. As the initial pressure of the rocket increased, the speed of the rocket increased as well. There is a direct relationship between pressure and speed of the rocket.

Measuring Length

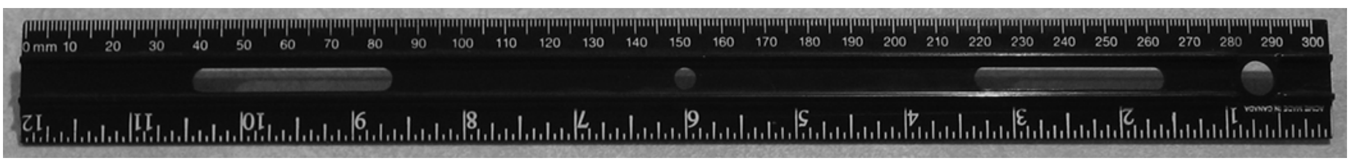
How do you find the length of an object?

Size matters! When you describe the length of an object, or the distance between two objects, you are describing something very important about the object. Is it as small as a bacteria (2 micrometers)? Is it a light year away (9.46 × 10^{15} meters)? By using the metric system you can quickly see the difference in size between objects.

Materials

- Metric ruler
- Pencil
- Paper
- Small objects
- Calculator

1 Reading the meter scale correctly



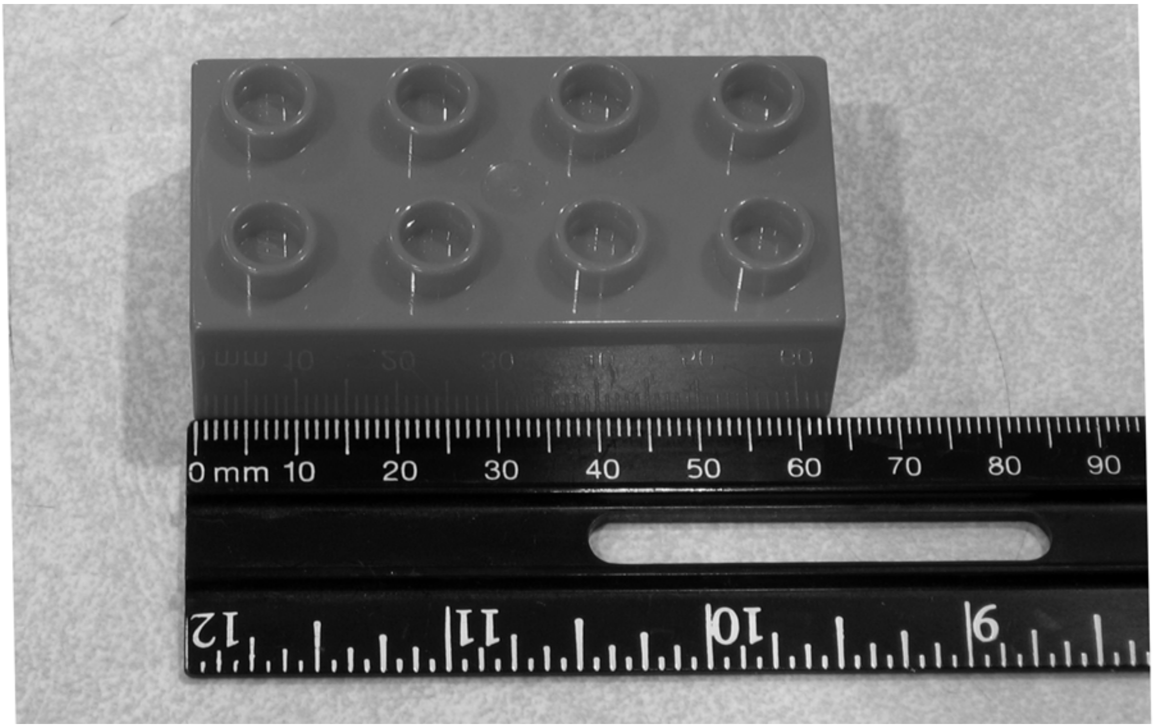
Look at the ruler in the picture above. Each small line on the top of the ruler represents one millimeter. Larger lines stand for 5 millimeter and 10 millimeter intervals. When the object you are measuring falls between the lines, read the number to the nearest 0.5 millimeter. Practice measuring several objects with your own metric ruler. Compare your results with a lab partner.

2 Stop and think

a. You may have seen a ruler like this marked in centimeter units. How many millimeters are in one centimeter?

b. Notice that the ruler also has markings for reading the English system. Give an example of when it would be better to measure with the English system than the metric system. Give a different example of when it would be better to use the metric system.

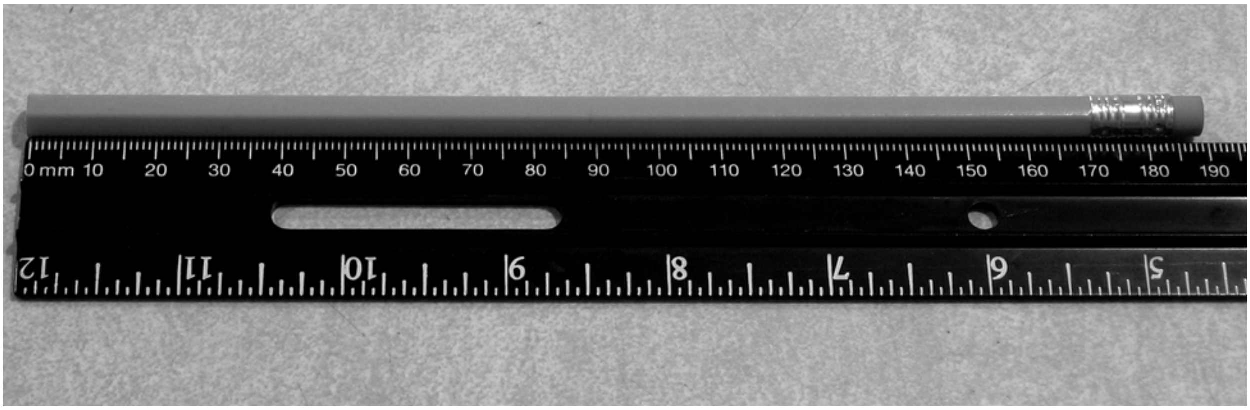
3 Example 1: Measuring objects correctly



Look at the picture above. How long is the building block?

1. Report the length of the building block to the nearest 0.5 millimeters.
2. Convert your answer to centimeters.
3. Convert your answer to meters.

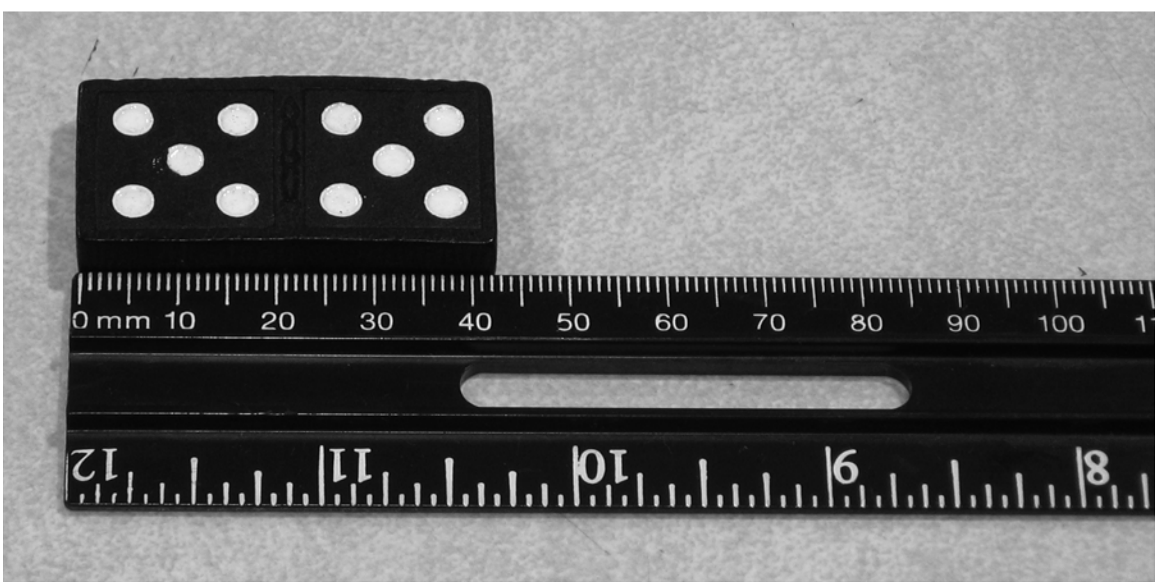
4 Example 2: Measuring objects correctly



Look at the picture above. How long is the pencil?

1. Report the length of the pencil to the nearest 0.5 millimeters.
2. Challenge: How many building blocks in example 1 will it take to equal the length of the pencil?
3. Challenge: Convert the length of the pencil to inches by dividing your answer by 25.4 millimeters per inch.

5 Example 3: Measuring objects correctly



Look at the picture above. How long is the domino?

1. Report the length of the domino to the nearest 0.5 millimeters.
2. Challenge: How many dominoes will fit end to end on the 30 cm ruler?

6 Practice converting units for length

By completing the examples above you show that you are familiar with some of the prefixes used in the metric system like milli- and centi-. The table below gives other prefixes you may be less familiar with. Try converting the length of the domino from millimeters into all the other units given in the table.

Refer to the multiplication factor this way:

- 1 kilometer equals 1000 meters.
- 1000 millimeters equals 1 meter.

1. How many millimeters are in a kilometer?

   1000 millimeters per meter × 1000 meters per kilometer = 1,000,000 millimeters per kilometer

2. Fill in the table with your multiplication factor by converting millimeters to the unit given. The first one is done for you.

   1000 millimeters per meter × 10^{-12} meters per picometer = 10^{-9} millimeters per picometer

3. Divide the domino's length in millimeters by the number in your multiplication factor column. This is the answer you will put in the last column.

Prefix	Symbol	Multiplication factor	Scientific notation in meters	Your multiplication factor	Your domino length in:
pico-	p	0.000000000001	10^{-12}	10^{-9}	pm
nano-	n	0.000000001	10^{-9}		nm
micro-	μ	0.000001	10^{-6}		μm
milli	m	0.001	10^{-3}		mm
centi-	c	0.01	10^{-2}		cm
deci-	d	0.1	10^{-1}		dm
deka-	da	10	10^{1}		dam
hecto-	h	100	10^{2}		hm
kilo-	k	1000	10^{3}		km

Measuring Temperature

How do you find the temperature of a substance?

There are many different kinds of thermometers used to measure temperature. Can you think of some you find at home? In your classroom you will use a glass immersion thermometer to find the temperature of a liquid. The thermometer contains alcohol with a red dye in it so you can see the alcohol level inside the thermometer. The alcohol level changes depending on the surrounding temperature. You will practice reading the scale on the thermometer and report your readings in degrees Celsius.

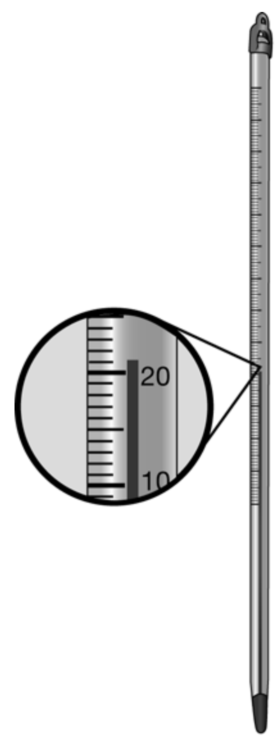
Materials

- Alcohol immersion thermometer
- Beakers
- Water at different temperatures
- Ice

Safety: Glass thermometers are breakable. Handle them carefully. Overheating the thermometer can cause the alcohol to separate and give incorrect readings. Glass thermometers should be stored horizontally or vertically (never upside down) to prevent alcohol from separating.

1 Reading the temperature scale correctly

Look at the picture at right. See the close-up of the line inside the thermometer on the scale. The tens scale numbers are given. The ones scale appears as lines. Each small line equals 1 degree Celsius. Practice reading the scale from the bottom to the top. One small line above 20°C is read as 21°C. When the level of the alcohol is between two small lines on the scale, report the number to the nearest 0.5°C.



2 Stop and think

a. What number does the large line between 20°C and 30°C equal? Figure out by counting the number of small lines between 20°C and 30°C.

b. Give the temperature of the thermometer in the picture above.

c. Practice rounding the following temperature values to the nearest 0.5°C: 23.1°C, 29.8°C, 30.0°C, 31.6°C, 31.4°C.

d. Water at 0°C and 100°C has different properties. Describe what water looks like at these temperatures.

e. What will happen to the level of the alcohol if you hold the thermometer by the bulb?

3 Reading the temperature of water in a beaker

An immersion thermometer must be placed in liquid up to the solid line on the thermometer (at least 2 and one half inches of liquid). Wait about 3 minutes for the temperature of the thermometer to equal the temperature of the liquid. Record the temperature to the nearest 0.5°C when the level stops moving.

1. Place the thermometer in the beaker. Check to make sure that the water level is above the solid line on the thermometer.

2. Wait until the alcohol level stops moving (about three minutes). Record the temperature to the nearest 0.5°C.

4 Reading the temperature of warm water in a beaker

A warm liquid will cool to room temperature. For a warm liquid, record the warmest temperature you observe before the temperature begins to decrease.

1. Repeat the procedure above with a beaker of warm (not boiling) water.

2. Take temperature readings every 30 seconds. Record the warmest temperature you observe.

5 Reading the temperature of ice water in a beaker

When a large amount of ice is added to water, the temperature of the water will drop until the ice and water are the same temperature. After the ice has melted, the cold water will warm to room temperature.

1. Repeat the procedure above with a beaker of ice and water.
2. Take temperature readings every 30 seconds. Record the coldest temperature you observe.

Calculating Volume

How do you find the volume of a three dimensional shape?

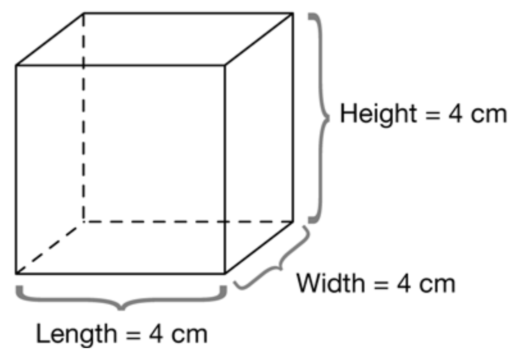
Volume is the amount of space an object takes up. If you know the dimensions of a solid object, you can find the object's volume. A two dimensional shape has length and width. A three dimensional object has length, width, and height. This investigation will give you practice finding volume for different solid objects.

Materials

- Pencil
- Calculator

1 Calculating volume of a cube

A cube is a geometric solid that has length, width and height. If you measure the sides of a cube, you will find that all the edges have the same measurement. The volume of a cube is found by multiplying the length times width times height. In the picture each side is 4 centimeters so the problem looks like this:



$$V = l \times w \times h$$

Example:

Volume = 4 centimeters × 4 centimeters × 4 centimeters = 64 centimeters^3

2 Stop and think

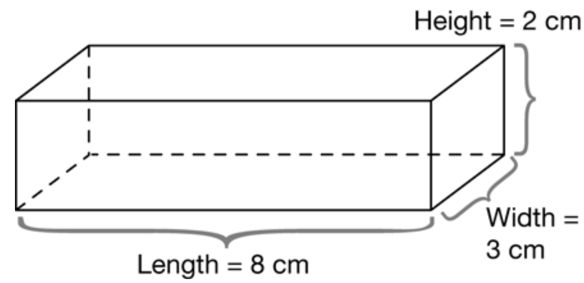
a. What are the units for volume in the example above?

b. In the example above, if the edge of the cube is 4 inches, what will the volume be? Give the units.

c. How is finding volume different from finding area?

d. If you had cubes with a length of 1 centimeter, how many would you need to build the cube in the picture above?

3 Calculating volume of a rectangular prism

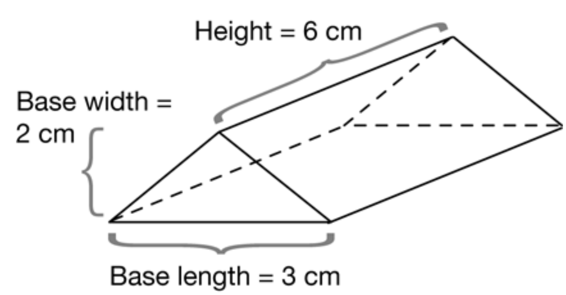


Rectangular prisms are like cubes, except not all of the sides are equal. A shoebox is a rectangular prism. You can find the volume of a rectangular prism using the same formula given above $V = l \times w \times h$.

Another way to say it is to multiply the area of the base times the height.

1. Find the area of the base for the rectangular prism pictured above.
2. Multiply the area of the base times the height. Record the volume of the rectangular prism.
3. PRACTICE: Find the volume for a rectangular prism with a height 6 cm, length 5 cm, and width 3 cm. Be sure to include the units in all of your answers.

4 Calculating volume for a triangular prism

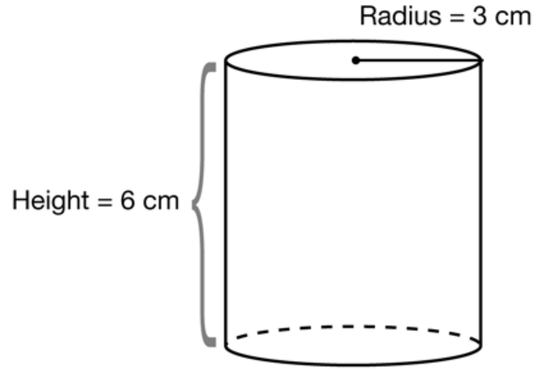


Triangular prisms have three sides and two triangular bases. The volume of the triangular prism is found by multiplying the area of the base times the height. The base is a triangle.

1. Find the area of the base by solving for the area of the triangle: $B = {}^{1}/_{2} \times l \times w$.
2. Find the volume by multiplying the area of the base times the height of the prism: $V = B \times h$. Record the volume of the triangular prism shown above.
3. PRACTICE: Find the volume of the triangular prism with a height 10 cm, triangular base width 4 cm, and triangular base length 5 cm.

5 Calculating volume for a cylinder

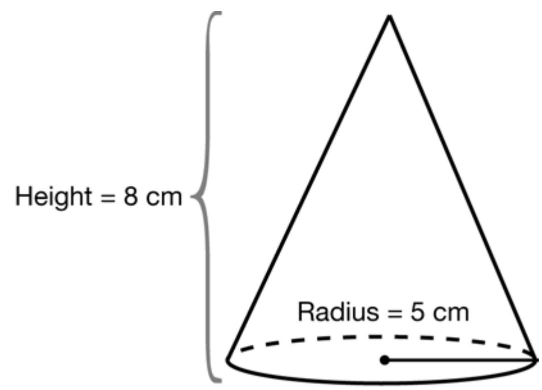
A soup can is a cylinder. A cylinder has two circular bases and a round surface. The volume of the cylinder is found by multiplying the area of the base times the height. The base is a circle.



1. Find the area of the base by solving for the area of a circle: $A = \pi \times r^2$.
2. Find the volume by multiplying the area of the base times the height of the cylinder: $V = A \times h$. Record the volume of the cylinder shown above.
3. PRACTICE: Find the volume of the cylinder with height 8 cm and radius 4 cm.

6 Calculating volume for a cone

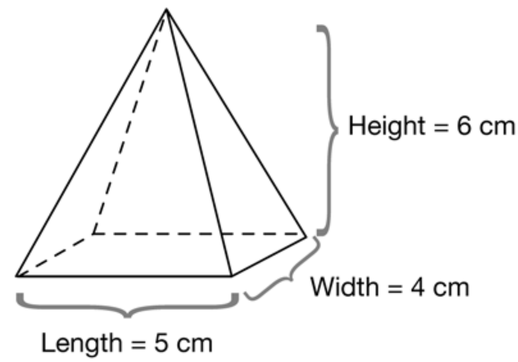
An ice cream cone really is a cone! A cone has height and a circular base. The volume of the cone is found by multiplying $^1/_2$ times the area of the base times the height.



1. Find the area of the base by solving for the area of a circle: $A = \pi \times r^2$.
2. Find the volume by multiplying? times the area of the base times the height: $V = {^1/_2} \times A \times h$. Record the volume of the cone shown above.
3. PRACTICE: Find the volume of the cone with height 8 cm and radius 4 cm. Contrast your answer with the volume you found for the cylinder with the same dimensions. What is the difference in volume? Does this make sense?

7 Calculating the volume for a rectangular pyramid

A pyramid looks like a cone. It has height and a rectangular base. The volume of the rectangular pyramid is found by multiplying $^1/_2$ times the area of the base times the height.



1. Find the area of the base by multiplying the length times the width: $A = l \times w$.
2. Find the volume by multiplying $^1/_3$ times the area of the base times the height: $V = {}^1/_3 \times A \times h$. Record the volume of the rectangular pyramid shown above.
3. PRACTICE: Find the volume of a rectangular pyramid with height 10 cm and width 4 cm and length 5 cm.

---

4. EXTRA CHALLENGE: If a rectangular pyramid had a height of 8 cm and a width of 4 cm, what length would it need to have to give the same volume as the cone in practice question 4 above?

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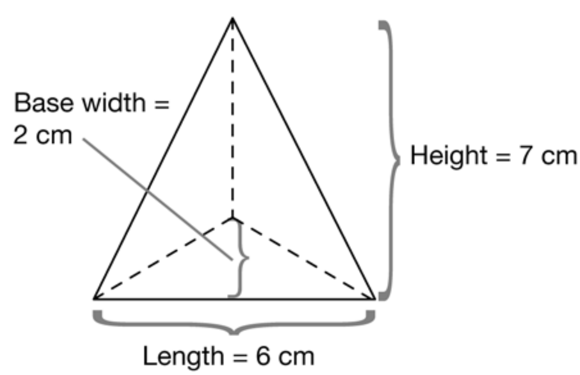
8 Calculating volume for a triangular pyramid

A triangular pyramid is like a rectangular pyramid, but its base is a triangle. Find the area of the base first. Then calculate the volume by multiplying $^1/_3$ times the area of the base times the height.



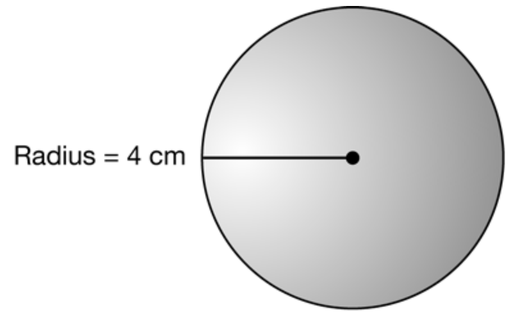
1. Find the area of the base by solving for the area of a triangle: $B = {}^1/_2 \times l \times w$.
2. Find the volume by multiplying $^1/_3$ times the area of the base times the height: $V = {}^1/_3 \times A \times h$. Find the volume of the triangular pyramid shown above.
3. PRACTICE: Find the volume of the triangular pyramid with height 10 cm and width 6 cm and length 5 cm.

---

9 Calculating volume for a sphere

LAB SKILLS

To find the volume of a sphere, you only need to know one dimension about the sphere, its radius.



1. Find the volume of a sphere: $V = {}^4/_3\pi r^3$. Find the volume for the sphere shown above.

2. PRACTICE: Find the volume for a sphere with radius 2 cm.

3. EXTRA CHALLENGE: Find the volume for a sphere with diameter 10 cm.

Measuring Volume

LAB SKILLS

How do you find the volume of an irregular object?

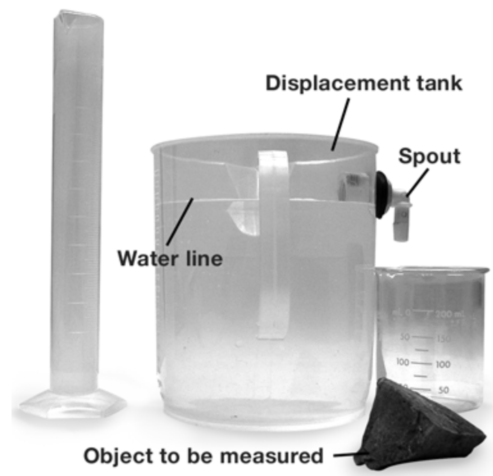
It's easy to find the volume of a shoebox or a basketball. You just take a few measurements, plug the numbers into a math formula, and you have figured it out. But what if you want to find the volume of a bumpy rock, or an acorn, or a house key? There aren't any simple math formulas to help you out. However, there's an easy way to find the volume of an irregular object, as long the object is waterproof!

Materials

- Displacement tank
- Water source
- Disposable cup
- Beaker
- Graduated cylinder
- Sponges or paper towel
- Object to be measured

1 Setting up the displacement tank

Set the displacement tank on a level surface. Place a disposable cup under the tank's spout. Carefully fill the tank until the water begins to drip out of the spout. When the water stops flowing, discard the water collected in the disposable cup. Set the cup aside and place a beaker under the spout.



2 Stop and think

a. What do you think will happen when you place an object into the tank?

b. Which object would cause more water to come out of the spout, an acorn or a fist-sized rock?

c. Why are we interested in how much water comes out of the spout?

d. Explain how the displacement tank measures volume.

3 Measuring volume with the displacement tank

1. Gently place a waterproof object into the displacement tank. It is important to avoid splashing the water or creating a wave that causes extra water to flow out of the spout. It may take a little practice to master this step.

2. When the water stops flowing out of the spout, it can be poured from the beaker into a graduated cylinder for precise measurement. The volume of the water displaced is equal to the object's volume.
   Note: Occasionally, when a small object is placed in the tank, no water will flow out. This happens because an air bubble has formed in the spout. Simply tap the spout with a pencil to release the air bubble.

3. If you wish to measure the volume of another object, don't forget to refill the tank with water first!

Measuring Mass with a Triple Beam Balance

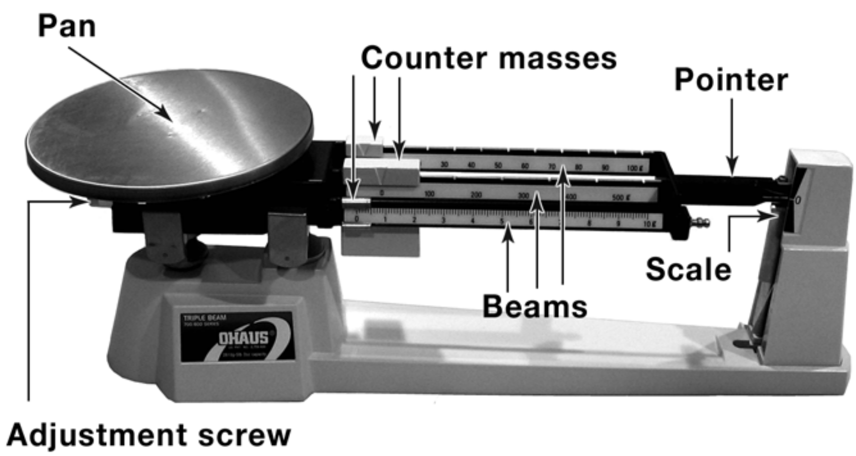
How do you find the mass of an object?

Why can't you use a bathroom scale to measure the mass of a paperclip? You could if you were finding the mass of a lot of them at one time! To find the mass of objects less than a kilogram you will need to use the triple beam balance.

Materials

- Triple beam balance
- Small objects
- Mass set (optional)
- Beaker

1 Parts of the triple beam balance



2 Setting up and zeroing the balance

The triple beam balance works like a see-saw. When the mass of your object is perfectly balanced by the counter masses on the beam, the pointer will rest at 0. Add up the readings on the three beams to find the mass of your object. The unit of measure for this triple beam balance is grams.

1. Place the balance on a level surface.
2. Clean any objects or dust off the pan.
3. Move all counter masses to 0. The pointer should rest at 0. Use the adjustment screw to adjust the pointer to 0, if necessary. When the pointer rests at 0 with no objects on the pan, the balance is said to be zeroed.

3 Finding a known mass

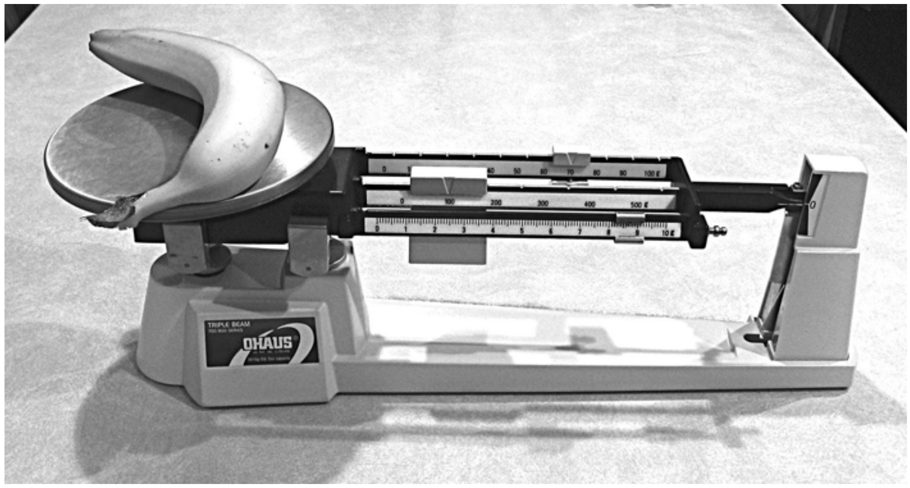
You can check that the triple beam balance is working correctly by using a mass set. Your teacher will provide the correct mass value for these objects.

1. After zeroing the balance, place an object with a known mass on the pan.
2. Move the counter masses to the right one at a time from largest to smallest. When the pointer is resting at 0 the numbers under the three counter masses should add up to the known mass.
3. If the pointer is above or below 0, recheck the balance set up. Recheck the position of the counter masses. Counter masses must be properly seated in a groove. Check with your teacher to make sure you are getting the correct mass before finding the mass an unknown object.

4 Finding the mass of an unknown object

1. After zeroing the balance, place an object with an unknown mass on the pan. Do not place hot objects or chemicals directly on the pan
2. Move the largest counter mass first. Place it in the first notch after zero. Wait until the pointer stops moving. If the pointer is above 0, move the counter mass to the next notch. Continue to move the counter mass to the right, one notch at a time until the pointer is slightly above 0. Go to step 3. If the pointer is below 0, move the counter mass back one notch. When the pointer rests at 0, you do not need to move any more counter masses.
3. Move the next largest counter mass from 0 to the first notch. Watch to see where the pointer rests. If it rests above 0, move the counter mass to the next notch. Repeat until the point rests at 0, or slightly above. If the pointer is slightly above 0, go to step 4.
4. Move the smallest counter mass from 0 to the position on the beam where the pointer rests at 0.
5. Add the masses from the three beams to get the mass of the unknown object. You should be able to record a number for the hundreds place, the tens place, the ones place, and the tenths place and the hundredths place. The hundredths place can be read to 0.00 or 0.05. You may have zeros in your answer.

5 Reading the balance correctly



Look at the picture above. To find the mass of the object, locate the counter mass on each beam. Read the numbers directly below each counter mass. You can read the smallest mass to 0.05 grams. Write down the three numbers. Add them together. Report your answer in grams. Does your answer agree with others? If not, check your mass values from each beam to find your mistake.

6 Finding the mass of an object in a container

To measure the mass of a liquid or powder you will need an empty container on the pan to hold the sample. You must find the mass of the empty container first. After you place the object in the container and find the total mass, you can subtract the container's mass from the total to find the object's mass.

1. After zeroing the balance, place a beaker on the pan.
2. Follow directions for finding the mass of an unknown object. Record the mass of the beaker.
3. Place a small object in the beaker.
4. Move the counter masses to the right, largest to smallest, to find the total mass.
5. Subtract the beaker's mass from the total mass. This is the mass of your object in grams.

Recording Observations in the Lab

How do you record valid observations for an experiment in the lab?

When you perform an experiment you will be making important observations. You and others will use these observations to test a hypothesis. In order for an experiment to be valid, the evidence you collect must be objective and repeatable. This investigation will give you practice making and recording good observations.

Materials

- Paper
- Pencil
- Calculator
- Ruler

1 Making valid observations

Valid scientific observations are objective and repeatable. Scientific observations are limited to one's senses and the equipment used to make these observations. An objective observation means that the observer describes only what happened. The observer uses data, words, and pictures to describe the observations as exactly as possible. An experiment is repeatable if other scientists can see or repeat the same result. The following exercise gives you practice identifying good scientific observations.

2 Exercise 1

1. **Which observation is the most objective? Circle the correct letter.**
   a. My frog died after 3 days in the aquarium. I miss him.
   b. The frog died after 3 days in the aquarium. We will test the temperature and water conditions to find out why.
   c. Frogs tend to die in captivity. Ours did after three days.
2. **Which observation is the most descriptive? Circle the correct letter.**
   a. After weighing 3.000 grams of sodium bicarbonate into an Erlenmeyer flask, we slowly added 50.0 milliliters of vinegar. The contents of the flask began to bubble.
   b. We weighed the powder into a glass container. We added acid. It bubbled a lot.
   c. We saw a fizzy reaction.

3. **Which experiment has enough detail to repeat? Circle the correct letter.**
   a. Each student took a swab culture from his or her teeth. The swab was streaked onto nutrient agar plates and incubated at 37 C.
   b. Each student received a nutrient agar plate and a swab. Each student performed a swab culture of his or her teeth. The swab was streaked onto the agar plate. The plates were stored face down in the 37 C incubator and checked daily for growth. After 48 hours the plates were removed from the incubator and each student recorded his or her results.
   c. Each student received a nutrient agar plate and a swab. Each student performed a swab culture of his or her teeth. The swab was streaked onto the agar plate. The plates were stored face down in the 37 C incubator and checked daily for growth. After 48 hours the plates were removed from the incubator and each student counted the number of colonies present on the surface of the agar.

3 Recording valid observations

As a part of your investigations you will be asked to record observations on a skill sheet or in the results section of a lab report. There are different ways to show your observations. Here are some examples:

1. **Short description:** Use descriptive words to explain what you did or saw. Write complete sentences. Give as much detail as possible about the experiment. Try to answer the following questions: What? Where? When? Why? and How?

2. **Tables:** Tables are a good way to display the data you have collected. Later, the data can be plotted on a graph. Be sure to include a title for the table, labels for the sets of data, and units for the values. Check values to make sure you have the correct number of significant figures.

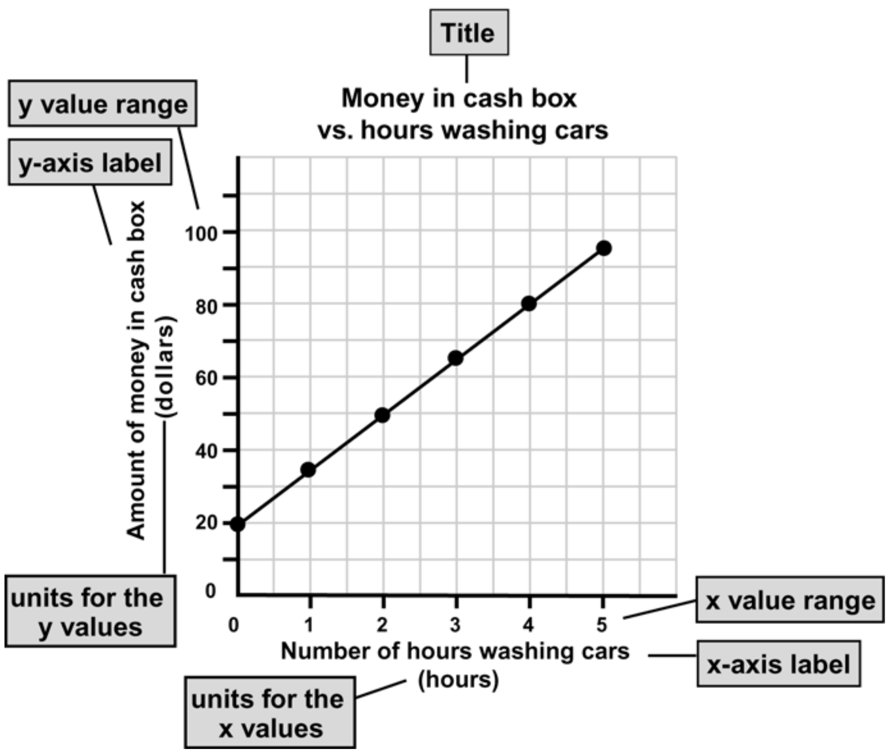
Table 1: U.S. penny mass by year

Year manufactured	1977	1978	1979	1980	1981	1982	1983	1984	1985
Mass (grams)	3.0845	3.0921	3.0689	2.9915	3.0023	2.5188	2.5042	2.4883	2.5230

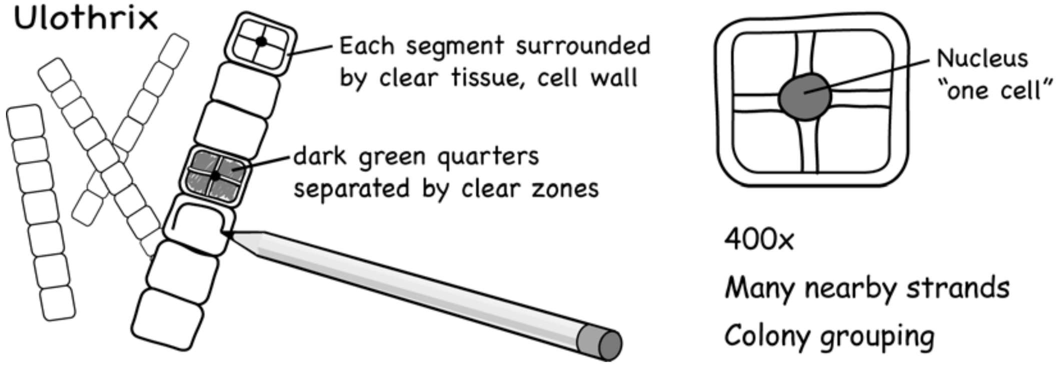
3. **Graphs and charts:** A graph or chart is a picture of your data. There are different kinds of graphs and charts: line graphs, trend charts, bar graphs, and pie graphs, for example. A line graph is shown below.

   Label the important parts of your graph. Give your graph a title. The x-axis and y-axis should have labels for the data, the unit values, and the number range on the graph.

   The line graph in the example has a straight line through the data. Sometimes data does not fit a straight line. Often scientists will plot data first in a trend chart to see how the data looks. Check with your instructor if you are unsure how to display your data.



4. **Drawings:** Sometimes you will record observations by drawing a sketch of what you see. The example below was observed under a microscope.



Give the name of the specimen. Draw enough detail to make the sketch look realistic. Use color, when possible. Identify parts of the object you were asked to observe. Provide the magnification or size of the image.

4 Exercise 2: Practice recording valid observations

A lab report form has been given to you by your instructor. This exercise gives you a chance to read through an experiment and fill in information in the appropriate sections of the lab report form. Use this opportunity to practice writing and graphing scientific observations. Then answer the following questions about the experiment.

A student notices that when he presses several pennies in a pressed penny machine, his brand new penny has some copper color missing and he can see silver-like material underneath. He wonders, "Are some pennies made differently than others?" The student has a theory that not all U.S. pennies are made the same. He thinks that if pennies are made differently now he might be able to find out when the change occurred. He decides to collect a U.S. penny for each year from 1977 to the present, record the date, and take its mass. The student records the data in a table and creates a graph plotting U.S. penny mass vs. year. Below is a table of some of his data:

Table 2: U.S. penny mass by year

Year manufactured	1977	1978	1979	1980	1981	1982	1983	1984	1985
Mass (grams)	3.0845	3.0921	3.0689	2.9915	3.0023	2.5188	2.5042	2.4883	2.5230

5 Stop and think

a. What observation did the student make first before he began his experiment?

b. How did the student display his observations?

c. In what section of the lab report did you show observations?

d. What method did you use to display the observations? Explain why you chose this one.