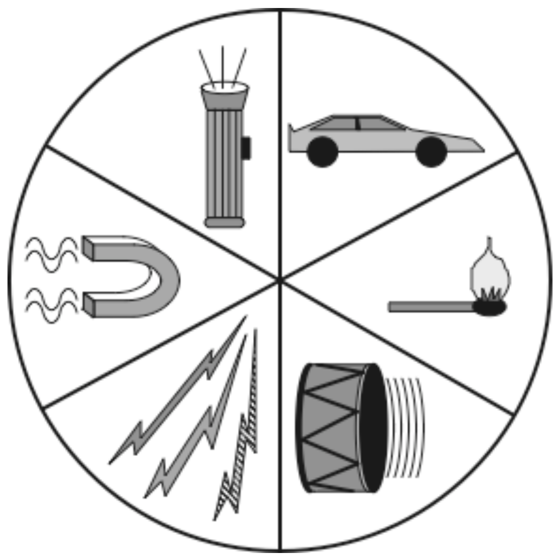
Physics Experiments
That You Can Do at Home



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The Wonders of Physics

University of Wisconsin – Madison

The Wonders of Physics

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Wonders of Physics Homepage

(information on annual public presentations, tickets, DVDs, books):
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An electronic version of this document can be found at:
http://uw.physics.wisc.edu/~wonders/HomeExperiments.pdf

Experiments written by Uma Bhatt, Rachael Lancor, David Newman, Clint Sprott, & Chris Watts. Revised 9/2007.

Welcome to the exciting world of physics!

We hope that these experiments will help you to learn more about the world around you. Physics is primarily the study of motion and energy, but that energy can take many forms. The experiments are arranged according to the six areas of classical physics, which happen to be six different types of energy.

Table of Contents

Have fun!!

Motion

Make a Miniature Roller Coaster

What you need:

- Foam tubes (Available at most hardware stores.)
- Masking Tape

You can build a roller coaster from the foam tubes that are often used for pipe insulation. Cut the foam tubing in half and you have a track for a marble to roll down. The foaming can be taped on the wall (using masking tape) and moved around to make a roller coaster.

Try this:

1. Change the height of the first hill. How does that change the speed of the marble at the bottom?
2. Try to make a loop. What do you have to do so the marble makes the loop?
3. Try to launch the marble off the end into a cup.
4. Get creative! What else can you make your roller coaster do?

What's going on?

Roller coasters work on the principle of energy conservation. At the top of the first hill, the marble has potential energy meaning it has the potential to move if you let go of it. When you let go of the marble its potential energy is converted into kinetic energy, the energy of motion. The loop is tricky; it takes extra energy for the marble to stay on the track, so it has to slow down when it goes through the loop. When the marble finally gets to the floor, it has all kinetic energy and no potential energy. Assuming there is no friction, the total amount of energy in the system is always the same. In the real world there is friction, so some mechanical energy will be lost to heat.

Motion

Spin like an Ice Skater

What you need:

- a spinning chair, like an office chair

Try this:

1. Sit on the chair with your arms stretched out to the sides. Have someone spin you around and then bring your arms in. What happens?
2. Try it again with extra weight in your hands. You can use small hand weights or cans of soup.


What's going on?

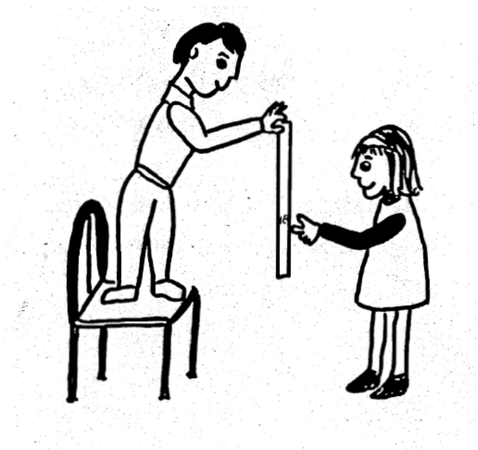
The spinning ice skater is a demonstration of conservation of angular momentum. What do all those big words mean? Conservation means that it is always the same. Angular means you are spinning and momentum is a combination of your speed and your inertia (how hard it is to move you). With your arms out, it's harder to move you, so you go slower. With arms in, it is easier to move you and so you go faster.

Motion

Measure your Reaction Time

How quick do you think you are? With the help of a friend, you can find out.

What you need:
- Yard stick
- Chair to stand on



Try this to find your reaction time:

1. Have your friend hold a yardstick from the top so that it is up and down with the bottom several feet above the floor. Your friend may have to stand on a chair to do this.
2. You hold your fingers opposite the 18-inch mark, but don't touch the stick! Without warning your friend should let go of the yardstick, and you should try to catch it with your fingers.
3. Notice what inch mark your fingers are on when you catch the stick. Subtract this number from 18 or subtract 18 from the number to see how many inches the stick fell before you caught it. Try it several times to see if you get the same answer. Let your friend try to catch it while you drop it. Who has the quickest reaction time?
4. Your reaction time can be determined from the table below:

Distance Dropped	Reaction Time
2 inches	0.10 seconds
4 inches	0.14 seconds
6 inches	0.18 seconds
8 inches	0.20 seconds
10 inches	0.23 seconds
12 inches	0.25 seconds
14 inches	0.27 seconds
16 inches	0.29 seconds
18 inches	0.31 seconds

Why do you think it takes time for your fingers to react when your eyes see the stick start to fall? Can you think of reasons the reaction time might be different for an adult and a child? Perhaps you could test your theory with several adults and children.

What's going on?
Gravity is pulling down on the yardstick at a constant rate. The longer it falls, the faster it goes. By measuring how far the yardstick falls, we can calculate the speed at which it is moving and the time it took you to catch it.

Motion

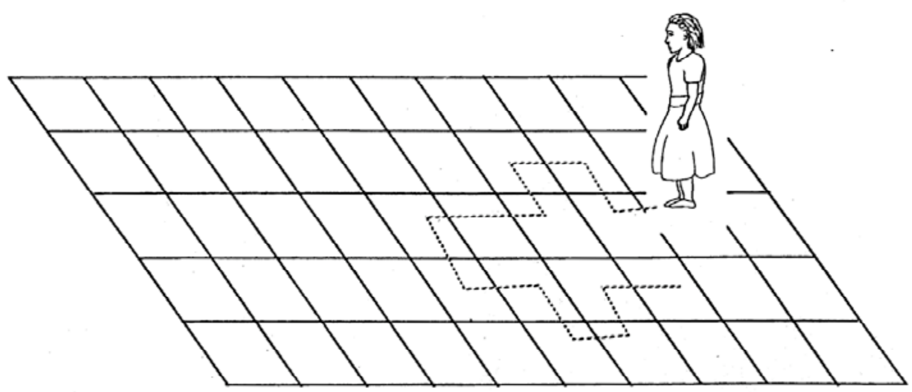
Take a Random Walk

Things in nature often move in complicated ways. You have probably watched the way a butterfly moves. The molecules of the air that you are breathing move in a similar way. This type of motion we call a random walk. You can also take a random walk.

What you need:

- A coin to flip
- Open space

Try This:
Go out to a large open field and mark a spot on the ground. Take with you a coin like a nickel or a quarter. Stand on the spot and flip the coin. If the coin comes up heads, turn to the right and take a large step. If the coin comes up tails, turn to the left and take a large step. Keep doing this many times and see where you end up.



What's going on?
If you flip the coin 25 times you will probably be about five steps away from where you started. This is because five times five equals 25. How far would you expect to be if you flipped the coin 100 times? A random walk is not a very fast way to get anywhere!

When you try this, you will notice that sometimes you go much farther than you expect and sometimes you end up very close to where you started. But if you repeat it many times or get several of your friends to do it with you with coins of their own, the average distance should come out as expected. In science we can often predict what will happen on the average even when the process is random.

Home Meteorology

Most of us have heard a television meteorologist talk about the dew point and the relative humidity, yet few of us know what those quantities are. All air has some moisture in it, but how wet the air feels depends not just on the amount of moisture but also the temperature of the air. Imagine that you can put one cup of water in a roomful of air at 60 degrees Fahrenheit. If you cool the room down it will no longer be able to hold the same amount of water, so a fog may develop and some water may condense on the walls. We have all seen this on a cold winter's day in the bathroom when you run hot water in the shower or sink. The temperature at which fog or condensation occurs is the dew point temperature (because dew forms). You can find the dew point temperature with a simple experiment.

What you need:

- A large metal can or pot
- A thermometer that can read temperatures down to 35° or 40° Fahrenheit
- Some ice

Try this:

1. Fill the can 3⁄4 full with room temperature water.
2. Place the thermometer in the water and measure its temperature.
3. With the thermometer still in the water, slowly stir in some ice a little bit at a time. Do this slowly so you can watch the temperature fall on the thermometer.
4. At some point water will start to condense on the outside of your can. The temperature at which this happens is the dew point temperature.
5. Try it in a bathroom right after someone has taken a shower. Try it right next to a heating vent. You should be able to find different places and days when the dew point is very different. On a dry winter day it is possible that the dew point may be below freezing, and then this method of finding the dew point will not work because you can not make the water colder than its freezing point. However, it will still work in a humid bathroom.

What’s going on?

Relative humidity is closely related to the dew point temperature. The relative humidity tells us how close the air is to being full of water (saturated). Remember that if the air temperature falls to the dew point the air cannot hold any more water (we get fog), so then the relative humidity is 100%. To find the relative humidity you need to know the dew point temperature and the air temperature.

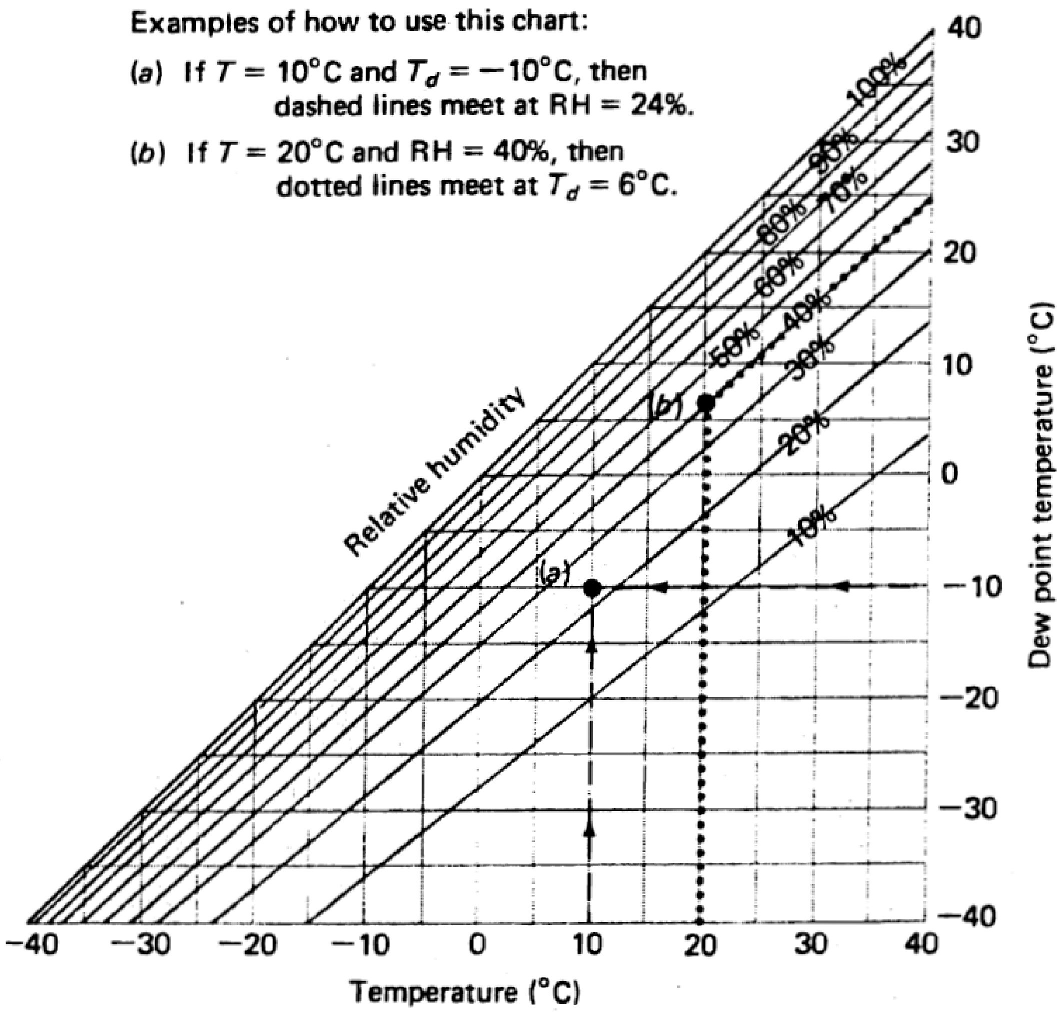
Look on the graph on the next page and draw a straight line up from the air temperature and a straight line to the left from the dew point temperature. The place where these two lines meet gives the relative humidity. If the lines don't meet on one of the relative humidity lines estimate the value by guessing how far the meeting point is from the two nearest lines. For example if your meeting point is halfway between 50% and 60% then the relative humidity is about 55%.

On the graph the temperatures are in °C. To get from °F to °C add 40 to your temperature in °F, then multiply by 5/9, and then subtract 40.

°C = (°F + 40) 5/9 - 40

and the reverse:

°F = (°C + 40) 9/5 - 40



The graph is *from The Science and Wonders of the Atmosphere* by Stanley David Gedzelman, published by John Wiley & Sons.

A Vortex Bottle

In the world around us there are many examples of vortices: tornados, whirlpools in a sink or tub, swirling vortices in rivers and oceans and, of course, hurricanes. You can make your own vortex to use for experiments.

What you need:

- Two empty clear plastic soda bottles (with the labels removed)
- a washer
- Some duct tape

Try This:

1. Fill one of the bottles about 2/3 full with water, place the washer on the mouth of this bottle.
2. You can make the vortex more visible by adding a little food color to the water or some glitter or little foam beads.
3. Next invert the second bottle onto the washer and tape them together firmly.
4. Turn the two bottles over so the full one is on top. Swirl the bottle vigorously to start the water spinning.
5. Set the bottles down and watch the vortex form.
6. See how big you can make the vortex by spinning the water faster.
7. Experiment with washers that have different size holes.
8. See what happens when you tilt the bottle after a vortex has formed.

What's going on?

The tornado you see is actually a vortex. In a vortex, the fluid on the outside has to move faster than the fluid on the inside to keep up. This is why strong winds can be felt far away from the tornado and the eye of a hurricane is calm.

Vortex in a Cup

Another experiment that you can do with vortices is quite simple and yet demonstrates an important principle of meteorology.

What you need:

- A large mug or a small pot
- A spoon
- Some ice

Try This:

1. Pour some very hot water into the cup or pot and stir it slowly in one direction so the water is rotating slowly (you may want to put some food color in so you can see the water better).
2. Next place a small ice cube at the center of the rotating water.
3. With a little luck you should see the ice cube start to spin faster and faster until it is turning much faster then the water around it.

What's going on?

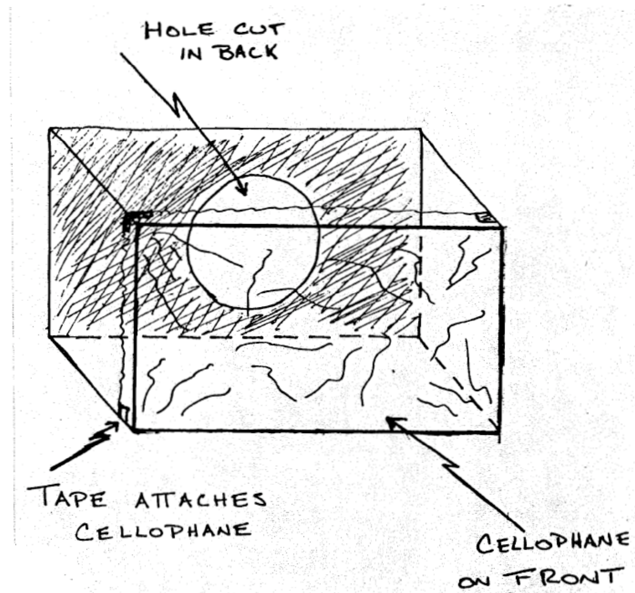
This occurs because the melting ice causes water to sink underneath it. This in turn draws in some of the warm water from the top edges. This water coming in from the edges is what spins the ice cube faster. This is the same principal that causes some tornados and whirlpools in rivers to spin up. You may have to experiment with the position of the ice cube to make this work well. But then, experimentation is half the fun!

[These experiments were suggested by Prof. David Houghton of the Meteorology Department.]

Heat

Smoke Rings

Have you ever seen someone make smoke rings? They have the scientific name vortices and are related to other vortices like the whirlpool in your tub or sink and even tornados. They look neat and they have some very interesting scientific properties, but since smoking is very bad for you it seems impossible to make them. Here's a way to make smoke rings without smoking.



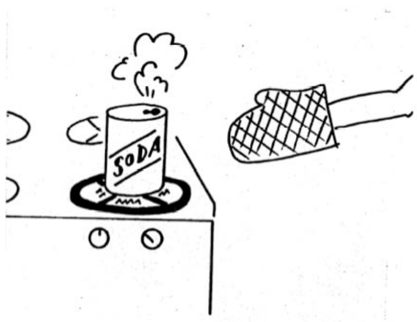
What you need:
- Cardboard Box (shoe box or tissue box works well)
- Plastic wrap
- Tape
- Baby powder or matches

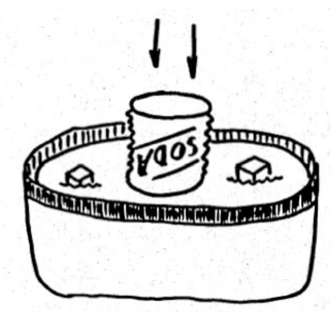
Procedure
1. Take a cardboard box (a shoe box or tissue box work well) that is open on one side only.
2. Cover the open side with some plastic wrap (like Saran wrap) and tape it on well.
3. On the opposite side of the box cut a round hole 3 or 4 inches across.
4. You now have your smoke-ring maker so it's time to load it with smoke. This part can be dangerous so please ask an adult to help. There are many ways to get "smoke" into your smoke-ring maker; you can put a piece of "dry ice" into the machine (don't touch the dry ice with your skin, it is very, very cold), you can use some baby powder, if it is fine enough, or you can use smoke (but be careful that you don't light your box on fire!). You don't need much smoke to make many rings.
5. Once your machine is loaded you are ready to start experimenting. To make a smoke ring just tap the plastic covered side. What would happen if the hole were square?
6. What happens when your smoke rings hit something like a stick? Try making two smoke-ring machines and then try sending the rings at each other. What happens when two smoke rings collide? (It's hard to make them collide so you may have to work at it for a while.)
7. Try different methods for making the rings easier to see (like shining a flash light on them). Can you think of more experiments for your smoke-ring machine?

What's going on?
The smoke ring is another vortex, just like the one in the tornado tube, except this time it has been bent into a donut shape called a torus. The air on the outside is moving faster than the smoke, so holds it in the ring shape.

Collapsing Can

Did you know that air has weight? In fact, a large amount of air can be very heavy. Here's a way to demonstrate the weight of air. You should do this with the help of an adult so you don't burn yourself.





What you need:
- Empty soda can
- Hot plate or stove
- An adult to supervise

Try This:
1. Get an empty soft drink can. Put about a quarter inch of water in the can.
2. Put several inches of water in a sink or large pan. Set the can on the burner of a stove and bring the water to a full boil. Let it boil for about a minute, but be careful not to let all the water boil away.
3. With a large pair of tongs or hot pads, remove the can from the stove. Don't touch the can; it's very hot! Place the can upside down in the sink or pan of cold water. The can should be instantly crushed!

What's going on?
When the water boils, the steam forces the air out of the can. When the can is placed in the cold water, the steam changes back into liquid water. This leaves a partial vacuum in the can. The can crushes because of the weight of the air outside the can. The total weight of the air can be as large as 700 pounds!

The weight is so large because we live at the bottom of an atmosphere that goes up many miles. All that air is very heavy and presses down on us all the time. Why aren't we crushed just like the can?

Have you ever gone down deep in a swimming pool and felt the pressure? That's because of the weight of the water above you. Do you think a fish notices the weight of the water?

Sound

The Doppler Effect

Have you ever stood along side a road while a car passed by with its horn blowing? If so, you probably noticed that the pitch of the sound was higher when the car was approaching than after it passed. This is called the Doppler effect.

What you need:

- Tape recorder
- Someone with a car

Try This:

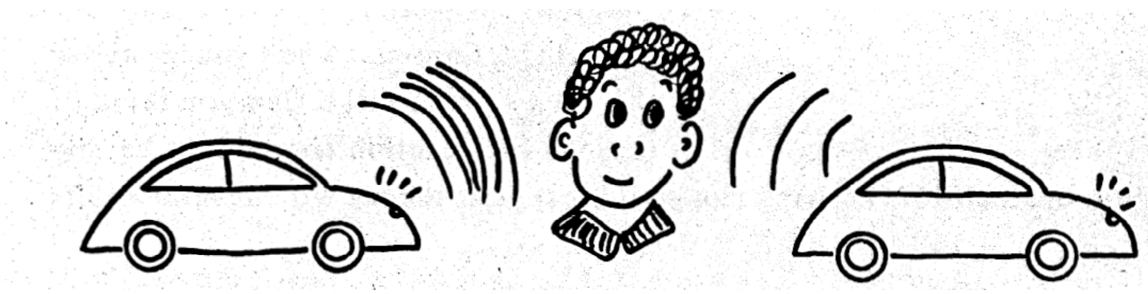
1. Go out in the country with someone who can drive a car. Take along a battery-operated tape recorder. If you have a pair of walkie-talkies, take them along too.

2. Find a long, straight road where there are no houses or other cars. Find a place where you can safely sit or stand off to the side of the road with the tape recorder.

3. Have the driver drive past you three times, once at 20, once at 30, and once at 40 miles per hour. Each time have the driver blow the horn for a few seconds as the car passes. Your job is to start and stop the tape recorder at the right times to record the sounds. You can also record on the tape in your own voice what's happening. Also make a recording of what the horn sounds like when the car is not moving. Have the driver drive past without telling you the speed. Can you estimate the speed from the pitch of the sound?

What's going on?

The Doppler effect occurs for all kinds of waves. It happens when either the source of the waves or the receiver of the waves is moving. The picture shows that the sound waves get compressed as the car moves toward you, creating a higher pitch sound. As the car moves away, the sound waves get spread out and you hear a lower sound. The speed of sound is only 769 mph, so a car going 50 mph would make a big difference! Could you observe the Doppler effect of water waves if you were in a moving boat?



The police use radar to measure the speed of cars. Radar works by the Doppler effect except that it uses radio waves instead of sound waves. Where do the radio waves come from?

String Telephones

Ever wonder if you can actually use tin cans to make a telephone? Let's try it and see!

What you need:

- Paper or styrofoam cups
- String
- Toothpicks

Try This:

1. Tie a toothpick on each end of a length of string.
2. Poke the toothpick through the end of the cup. Pull the string tight so the toothpick rests on the inside bottom of the cup. Put one cup at each end of the string. (You may want to experiment with different cups and strings to see what works best.)
3. Hold the string tight and talk into one of the cups. The person at the other end should be able to hear you. Why does the string have to be tight?
4. Try to make a party line by tying a third string and cup onto the middle of the string. Can everybody talk to everybody else?

What's going on?

Sound waves need something to travel through (called the medium). Usually they travel through air, but they can travel much faster and farther through a string. The string has to be tight or else the sound wave can't travel through it. The cup helps to amplify the sound on the other end.

Static Electricity Experiments

What you need:

- Balloon
- Plastic Pen
- Small scraps of paper (holes from a hole puncher work well)

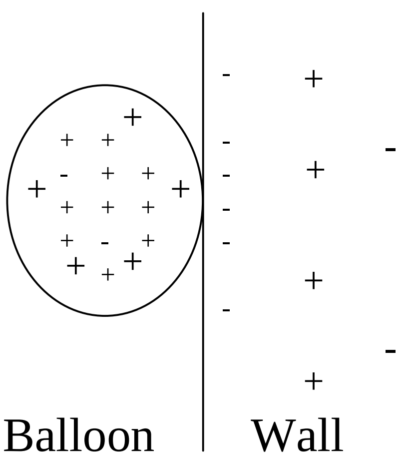
Try This:

1. Rub your hair on a balloon or wool sweater. What happens to your hair? Try to stick the balloon to the wall. Does it stick?
2. Rub a plastic pen on the wool sweater and hold it near a stream of water. What do you observe?
3. Rub the pen on the sweater again and try to pick up small pieces of paper. The holes from a hole punch work well.

What's going on?

In all of these experiments, we are manually moving electrons from one material to another. Your hair stands up because it is full of electrons. The electrons don't like each other and are trying to get as far away from each other as possible.

The balloon sticks to the wall because it creates an induced charge. The positive charge of the balloon attracts electrons from the wall and the balloon sticks! The same thing happens with the pen and the water and the pen and the paper.



Electricity

Plasma Ball Physics

What you need:

- Plasma Ball (available at toy stores and online)
- Fluorescent Light Tube
- Wooden chair or stool to stand on (or anything not metal)
- Pennies

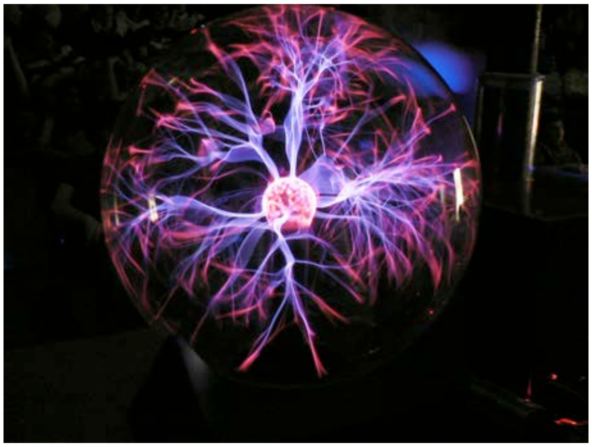
Try This:

1. Turn off the lights so that you can see the plasma ball glowing.
2. Put your hand on the plasma ball. What happens?
3. Now bring the fluorescent light tube close to the plasma ball. What happens?
4. This step requires a friend, so have one close by and ready to help. Stand on the chair or stool and put your hand on the ball. Now have your friend hand you the light tube. Do you see it light up? What happens if your friend lets go? **Be careful to not touch the ends of the light tube – it gets hot!**
5. Put a penny on the top of the plasma ball. Carefully touch the penny with another penny. **Don't use your finger – you'll get a shock!**

What's going on?

The plasma ball is a miniature Tesla coil. Inside the ball is a coil of wires that have electrons going through them oscillating at a very high frequency. This shakes the atoms around the wires so hard that their electrons start to fall off! Inside the glass globe is a partial vacuum. This just means that some of the air has been sucked out. Because there is not as much air in there, it is easier to make electric sparks that can be seen.

The electrons then travel out into the air from the glass ball. We know this because the plasma ball lights up the light bulb. If you touch the plasma ball, all of the electrons will go through you to the ground. You see only one big spark inside the ball where you put your hand. If you stand on a stool, you are insulated from the ground and get filled with electrons. This means you can light up a fluorescent light bulb!



Magnetism

Build an Electromagnet

What you need:

- Battery
- Insulated copper wire with ends stripped
- Large iron nail
- Small paper clips or staples

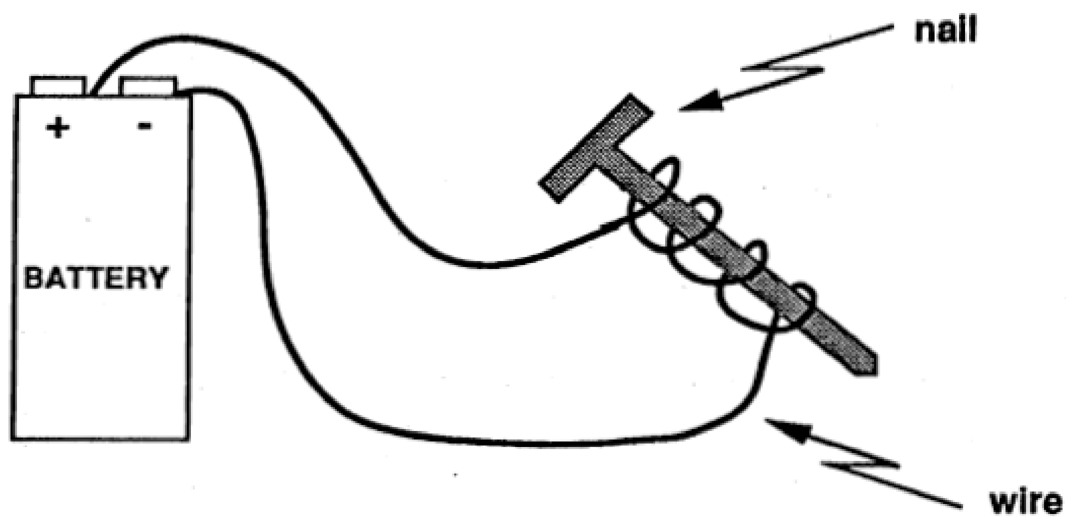
Try This:

1. Wrap the copper wire around the nail and touch the ends of the wire to the battery. Be careful to always wrap the wire in the same direction. Wrap it as tightly as you can. Try to pick up the paper clips. Does it work? **Be careful, the battery may get hot!**

2. Try the experiment again with more wire wrapped around the nail. Can you pick up more paper clips? What happens if you use a bigger nail? A nail made of a different material?

What's going on?

An electromagnet is a magnet that can be turned on and off. In this experiment, the battery is a source of electrons. When you connect the wire to the battery, the electrons flow through the wire. If there is not a complete circuit, the electrons will not flow. Electrons behave like little magnets and when they flow through a wire, they create a magnetic field, which turns the nail into a magnet that can pick up paper clips and staples!



Making a Pinhole Camera

What you need:

- Box (square or round – a Pringles can or oatmeal container work well)
- Wax Paper
- Small nail or thumbtack to make a hole
- Aluminum foil
- Sharp Knife or scissors
- Duct tape
- Bright light source (the sun works well!)

Try This:

1. Draw a line around the box about 2 inches from the bottom. Have a grown up cut the box in two pieces. Its easiest to cut if you lay the box flat and put it back together later.

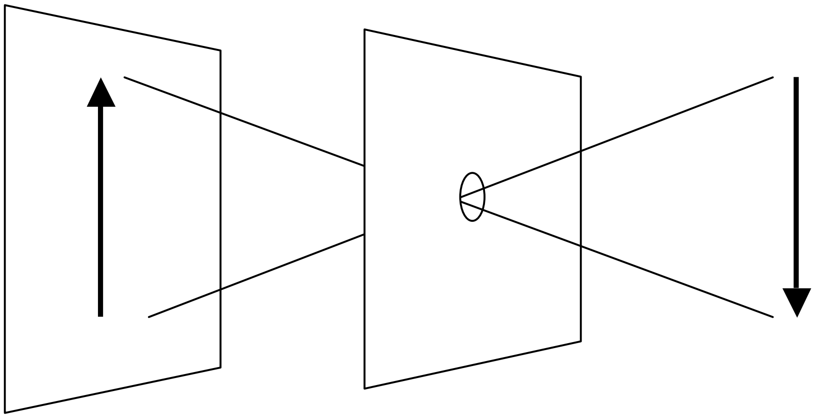
2. Tape up the small end of the box so it is box shaped again.
3. Cover the open end of that box with wax paper and tape it on the outside.

4. Tape the large part of the box back together. Cut the shape of your head in the top of the box.

5. Put the two parts of the box back together and tape them together.
6. Cover the whole thing with foil to make sure that no light can enter.

7. Once you are sure no light can get in, use the nail or thumbtack to make a hole in the middle of the bottom of the box.
8. Hold your hand below the box and slowly move it upward. If you look in the hole, you'll see the shadow move down!
9. Go out side on a sunny day and you'll be able to see an image upside down on your screen. Close the eye that's not looking in the box. You want it to be as dark as possible, so you may want to cup your hand around your "looking eye".

What's going on?
The pinhole acts like a lens and diffracts light as it passes through. We can see the image because light reflects off of everything. Only a small amount of reflected light traveling in a particular direction can go through the hole and that's what we see on the screen. This was originally called a camera obscura.



Measuring the Speed of Light

What You Need:

- Microwave
- Microwave safe dish at least 5-6 inches across (bigger is better)
- Mini-marshmallows
- Ruler
- Calculator

Try This:

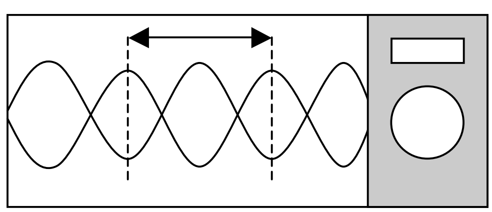
1. Place the mini-marshmallows in the dish one layer thick.
2. If your microwave has a rotating platform, remove it. We don't want the dish to rotate.
3. Put the dish in the microwave for 10 seconds.
4. When you remove the dish, you'll notice only certain parts are melted. (Time may depend on the microwave – if all or none of your marshmallows melted, adjust the time.)
5. Measure the distance between melted marshmallows using your ruler. Measure in centimeters. This is half the wavelength of a microwave.
6. Look for a sticker on your microwave that tells you its frequency in Hertz (Hz). Most microwaves are around 2450 MHz. Note: MHz = 10^6 Hz
7. Use the following equation to find the speed of light:

Speed of light = 2 x (distance between melted spots) x (frequency of microwave)

8. The actual speed of light is 3.00 x 10^{10} cm/s. How close were you?

What's going on?

Microwaves are a form of electromagnetic radiation, just like light, but they are beyond the visible spectrum so we cannot see them. A microwave oven works by creating a standing wave in the microwave.



The peaks of the wave heat faster and melt the marshmallows first. What you measure is half the wavelength of the microwave light. The arrow shows one full wavelength of microwave light.

Light

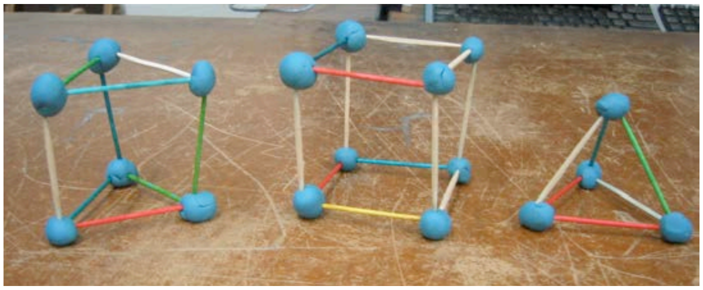
The Science of Bubbles

What you need:

- Dish soap
- Glycerin (available at some drug stores or order online)
- Water
- Wire, string, straws, modeling clay, toothpicks (to make bubble wands)

Try This:

1. First, you need to make the bubble solution. Here's the recipe:
   - ½ cup dish detergent
   - 4 ½ cups water
   - 4 Tablespoons glycerin
2. Make a funny shaped bubble wand using the wire, or string and straws.
3. Try to blow some bubbles. Can you make a funny shaped bubble?
4. Use the toothpicks and clay to make three dimensional bubble wands. Try the shape of a cube or a pyramid.
5. Dip the wand in the bubble solution and look at it BEFORE you blow. What shapes does it make?
6. Experiment with different bubble wands and make some observations.
7. You can also experiment with different recipes of bubble solution. See what it takes to make a better bubble!



What's going on?

The shape of the bubbles is determined by surface tension. This is what holds the bubble together. It's also what allows you to fill a cup with water over the brim without spilling. The bubble always tries to make the shape with the minimal surface area. In the free air, this is always a sphere. With the 3-D wands you may get some funny shapes. The edges have been set and the bubble fills in the least possible area inside the shape, which isn't always what you would expect.

You may also notice that the bubbles are pretty colors. The bubble is acting somewhat like a prism to break apart the colors of the rainbow. The colors in the bubble are formed when light diffracts as it hits the bubble. This just means that the light is interfering with itself. Imagine you throw two pebbles in a pond and see their ripples interact. The bigger waves or high points are constructive interference; the small waves or low points are destructive interference. The light waves behave in the same way, which creates patterns on the bubbles' surface and allows us to see the colors.