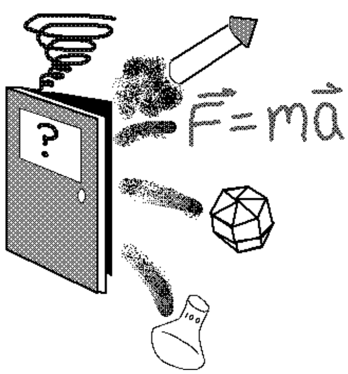
Physics From The Junk Drawer

Hands-On Physical Science Activities for Students, Teachers, and Anyone Interested in Science

Third edition



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THE SCIENCE HOUSE
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Introduction

There is a lot of interesting science to investigate in this world. Not all of the science in this world is done by men wearing white coats and working in laboratories. The entire world around us involves science. A child (or teacher) can investigate some pretty interesting stuff without requiring a laboratory or expensive laboratory equipment or dangerous chemicals.

These activities came from a teacher-training workshop - Physics From the Junk Drawer - that has been offered by The Science House for over a decade. Many teachers have taken the workshop and have applied the activities in their own classrooms - from first grade to high school.

We believe that students should be involved in active learning in which the teacher acts as a guide, not an answer machine. However, to be a good guide, the teacher has to have the road map in her/his head. So these activities include directions for doing the activities, suggestions on finding materials, and a little background on the science involved.

We realize that there are no new science demonstrations under the sun. Many of these are things that you may have seen before in another format. The point of this book is to assemble these in a rational format that encourages you, as a teacher or student, to try them out. A science demonstration in a book is useless, until someone actually does it and uses the experience to help their understanding.

The Science House is a science and mathematics learning outreach program of the College of Physical and Mathematical Sciences at North Carolina State University. The mission of The Science House is to work in partnership with K-12 teachers to emphasize the use of hands-on learning activities in mathematics and science classes. The Science House provides a variety of in-service training and enrichment activities that reach teachers and students across North Carolina and beyond.

We are located on the Centennial Campus at North Carolina State University, in Raleigh, NC. For more information on our programs please write us at The Science House, NC State University, Campus Box 8211, Raleigh, NC 27695-8211 or email: Science_House@ncsu.edu.

Acknowledgements

These activities are the results of contributions from a number of persons. David Haase wrote the first draft of the Physics From the Junk Drawer and Melissa Cole Brown the first draft of the Countertop Chemistry activities. After teaching these workshops many times and being the recipients of many helpful hints, we gratefully acknowledge the contributions of Bob Nance, Elizabeth Woolard, Anne Barefoot, Rebecca King, Mike Smith, Dr. Alton Banks, Dr. George Wahl, Todd Boyette, Bonnie Barnes Bordeaux, Keith Warren and Scott Ragan.

The inspiration of Ron Edge's "String and Sticky Tape Physics" is gratefully acknowledged, as well as many helpful conversations about physics demonstrations with Dick Patty and Chris Roddy.

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Activities and Demonstrations

There are many ways to use these experiments. Some of them are best done by the students themselves so the students can see the phenomena "up close and personal" and try out variations for themselves. Many of the activities are simple and cheap enough for the students to bring home and show their parents. Educating parents is just as important as teaching students!

You may wish to use some of the activities as demonstrations, in which you do only one setup of the activity and show it to the class. But make your demonstrations interactive! Education research shows that the way that you do a demonstration can increase or decrease the amount of learning that goes on. Here are some tips about how to make demonstrations more meaningful to your students

Use students as helpers. If the activity requires Chemical A to be poured into Beaker B, let Child C do the pouring, not the teacher.

Begin the demonstration by asking questions and by linking the demonstration you are about to do to the subject matter you were just discussing. This book has lots of questions for you to ask your students or yourself.

During the demonstration continue to ask questions of the students. "What did you see?" "What do you think will happen if we do...?" "Turn to your neighbor and explain what you just heard."

At the end of the demonstration ask students to write a three-sentence explanation of what happened in the experiment and what they learned from it. When you read these explanations after class you will learn how to improve your use of demonstrations and hands-on learning activities.

Each of the Physics From the Junk Drawer and Countertop Chemistry activities can be used at a variety of grade levels. Different grade students will learn different things from the activities. Therefore some of the questions included are quite appropriate for first grade, but not for twelfth grade. One of the authors has used almost all of the Physics From the Junk Drawer activities in introductory level college physics courses.

Each activity includes directions, questions, materials lists, and tips for carrying out the activity. There is a section at the end with a glossary of important science concepts as well as a list of references for other demonstrations.

In conclusion, there are two simple rules that we have learned about doing demonstrations or activities with students.

If it stinks, it's chemistry. If it's slimy, it must be biology. If it doesn't work, it must be physics.

If a demonstration works the first time, do not repeat it.
If a demonstration does not work the first time in front of your students, repeat it only once, then give up.

Mass in Motion (Can You Juggle?)

Physics Concept

Physics is about matter in motion.

Materials

Tennis balls, juggling bags, chain saws

Method

There is this great book, entitled "Juggling for the Complete Klutz, Cassidy, Rimbeaux, Waller." Get yourself a copy and find a closed room so you do not embarrass yourself as you learn this show-off demonstration. If you can't juggle let one of your students demonstrate and discuss the science in what they do.

Questions

Do the tennis balls go through the air the same way every time?
What affects how long they are in the air?
How high do they go?
How long a time does the juggler have to react to catch a ball?
What are some other objects in sports that move in the same way? How long do they stay in the air?

Applications to Real Life

A punter in football tries to kick the football so that it stays in the air for four seconds and travels forty yards downfield. This is the "Law of four and forty."
A gymnast who jumps in the air and turns a double somersault obeys the same laws of physics that the juggled ball does. The gymnast has about 0.5 seconds to jump up and somersault before gravity returns her to the floor.

Human Waves

Physics Concept

A wave is a disturbance that travels through a collection of objects. We see water waves at the beach. We hear sound waves. We see waves on strings or ropes or violin strings. In all of these waves some group of objects - water molecules or air molecules - are bouncing against each other and carrying energy from one to the other.

There are two types of waves in nature. In a compressional wave the objects move back and forth in a direction parallel to the motion of the wave. A sound wave in air is a compressional wave. When you talk your vocal chords push some air molecules back and forth. Those air molecules push their neighbors and the push is transmitted through the air until it pushes the eardrum of the hearer.

A good example of a transverse wave is the water wave you see when you throw a pebble in a pond. The wave travels horizontally along the surface of the pond. The water molecules in the pond, however, move up and down as the wave goes by. So the motion of the water is perpendicular, or transverse, to the motion of the wave.

Another neat transverse wave is the one you get when you walk out in the yard, pick up one end of the garden hose, and give it a flick of your arm. This produces one transverse wave that travels to the other end of the hose.

Materials

None except a group of cooperative students. We find that middle school students have to be encouraged to stand shoulder-to-shoulder with each other!

Method

To make compressional waves have about ten to fifteen students stand shoulder to shoulder in a straight line. Each should look straight ahead and have their feet a few inches apart. This is a collection of air molecules. The teacher stands at one end of the air molecules and gives a push.

The rest of the class should see the push transferred from student to student to the end of the line. The back and forth motion of each person is parallel to the direction of the wave. This is exactly the same way a sound wave travels in air, liquids, or solids.

To make a transverse wave have the students stand shoulder to shoulder as before and link arms at the elbows snugly. They should be touching at the shoulders and quite strongly linked. Now the teacher stands at the end of the line, holds the student by the arm and strongly shakes the student forward and backward. Again there will be a wave that travels to the other end of the line of students, but now the motion of each person is perpendicular to the direction of the wave. This is similar to water waves or waves on a string.

Questions

Ask the students in the line: Did the person at the end move to the other end of the line? Where did the energy come from to cause you to move? How did you move when the wave went by? What are everyday examples of these waves?

Reaction Time Chain
(Measurement)

Physics Concept

A person's reaction time is the time interval required to respond to seeing or hearing something. For instance, if you are driving an automobile, your reaction time is the time interval between seeing the cat run into the street and moving your foot to the brake.

Good athletes have shorter reaction times than most people. An average person's reaction time is about 0.2 to 0.3 seconds. That is a short time, too short to easily measure with a clock or even a stopwatch. On the other hand, an automobile traveling at 60 miles per hour (88 feet per second) moves about 26 feet in 0.3 seconds.

Materials

This activity requires a stopwatch or digital wristwatch with tenths of seconds.

Method

In this activity we measure the average reaction time of a group of ten to twenty students. Have the students form a chain holding each other's hands. Count the number of students. The teacher holds the hand of the student at one end of the line and watches the stopwatch. The teacher tells the students to squeeze the hand of the student next to them when their other hand is squeezed. When the student at the far end of the chain gets his hand squeezed he should shout, "Stop!"

The teacher squeezes the first student's hand and measures the time for hand squeeze to get passed on to the last student, who shouts "Stop." It is good to do this three or four times to get an average time.

To calculate the average reaction time of a student in the class divide the total time measured by the number of students in the chain. Remember to count the teacher!

Reaction time = total time / number of people in the chain

Example: It took 5.0 seconds for the hand squeeze to travel through a chain of 17 students.

Average reaction time per student = 5.0 seconds/ 17 students
= 0.29 seconds

Questions

What do you think your reaction time is?
What factors would affect your reaction time. What if you measure the average reaction time of the class first thing in the morning, or after lunch?
If we put more people in the chain would that change the average reaction time?

Pendulums - Length vs. Period

Physics Concept

Galileo discovered that pendulums (pendula) could be used to measure the passage of time. He found that if the pendulum does not swing too far the period of the pendulum increases as the length of the pendulum increases. A period is the time it takes for the pendulum to go through one complete cycle of its motion.

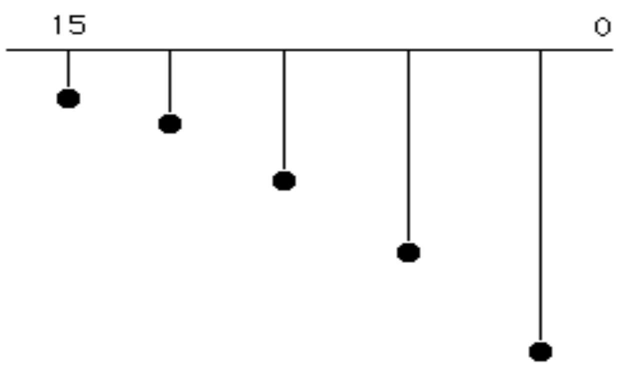
Materials

Anything that swings back and forth, like a child on a playground swing, is a pendulum. In this activity our pendulums are made with string and small weights, such as marbles or heavy washers, that can be attached to the string with a piece of tape.

Method

Students work in pairs to make a pendulum of length between 0.15 cm and 1.5 m and measure its length. At the teachers signal everyone starts their pendulums swinging at the same time. While the teacher counts off ten seconds the students count how many periods their pendulum goes through. One period is the time it takes for the pendulum to return to its starting point. The students should do the measurement more than once and average their results. Now mark across the top of the blackboard a horizontal scale (see figure) that goes from 15 to 0. Each student now tapes his pendulum to the board at the number that matches the number of periods counted in ten seconds.

The graph should look somewhat like this.



Questions

What happens if you put two or three marbles on the end of the pendulum without changing its length?
This is a good activity for talking about experimental error, because any "odd" measuring results will always stand out on the blackboard graph.

You can calculate the values to expect from:

$$\text{period} = 2\pi\sqrt{\frac{\text{length of pendulum}}{\text{acceleration of gravity}}}$$

where the acceleration of gravity is 9.81 meters/second^2.

This is a sample of the kind of data you might expect:

Pendulum Length (cm)	Period (seconds)	Number of periods in ten seconds
15	.78	12.7
25	1	10
35	1.24	8
50	1.43	7
75	1.76	5.7
100	2	5
125	2.27	4.4
150	2.48	4

Models of Matter

Physics Concept

All forms of matter are made of atoms and molecules. The difference between gases, liquids, and solids is how the atoms and molecules are arranged and move. In a solid the atoms do not move very much because they are relatively cold, since heat is energy that causes motion.

In a glassy material (glass, plastic) the atoms are just glued down in some random manner.

In a metal or a crystal like quartz or diamond, the atoms tend to sit in a very ordered arrangement, almost like students sitting in rows in a classroom. The simplest such arrangement is a close packed structure.

Materials

A plastic Petri dish with lid and bb's or similar size beads.

Method

Put the bb's into the Petri dish and tape on the lid. Shake the dish a little so that the bb's are shaken down to the bottom. They should have a regular hexagonal arrangement. Atoms in metals form solid structures that have the symmetry of hexagons, just as you get when you stack layers of spheres. This is called a close packed structure.

Shake the Petri dish steadily but not too hard. The bb's will move around among themselves but not jump out of the pile. This is what thermal motion does in a liquid. The atoms move around but very few leave the liquid or vaporize.

If you shake the petri dish very hard the bb's jump all over the Petri dish and become evenly distributed like the atoms or molecules of a gas that fills a room.

Questions

What phases of matter occupy the least volume?
Do materials occupy all of the volume that they "seem" to occupy?

Martian Hat
(Inertia)

Physics Concept

This is an eye-catching and silly demonstration of the principle of inertia. An object can balance in a stable position when its mass is distributed evenly and when the center of mass is below the point the object is balanced on. Inertia is the property of an object that makes it stay at rest until a force makes it move.

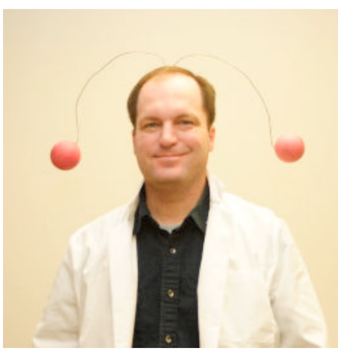
Materials

Two to three foot length of coat hanger wire or heavy gauge copper wire
Two blobs of modeling clay or play-doh.

Method

Bend the coat hanger into the shape shown in the figure and attach the two blobs of clay onto the ends of the hanger. Carefully place the balance point on the coat hanger onto the top of your head.

Turn your head rapidly to face left. This will show the effect of inertia, that is, the blobs do not move when your head does. Do not jump when you turn your head.



Questions

Why is the Martian Hat stable atop your head?
Why is the hat not stable when it is upside down?
Does it matter what kind of hair do you have?

Coke Bottle Inertia
(Inertia)

Physics Concept

Inertia. See previous activity.

Materials

Two glass bottles and a dollar bill.

Method

Place the bill on one bottle and carefully balance the other on top. It helps to rotate the bottles to find the right fit and then mark them for the next time you do the demonstration.

Hold the end of the bill with one hand and tap the bill with a finger of the other hand. Bring your hand down quickly and confidently.

Some brave people put water in the upper bottle. Can you figure out how to do that? Does that make the demonstration easier or more difficult?

Questions

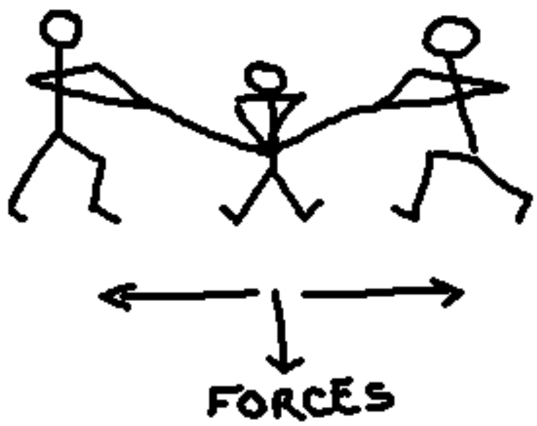
What will happen if you remove the bill slowly?
Does it matter how heavy the bottles are?

Tug of War
(Forces)

Physics Concept

A force is a vector - it has an amount (i.e. Newtons) and a direction. Both direction and amount of force are important.

In this demonstration the students at the ends of the rope are pulling in the horizontal direction, but the student in the middle is pushing downward. No one is opposing the force of the student in the middle.



Materials

Requires a long stout rope, the longer the better. Two strong, large students to pull at the ends and a smaller, but confident, student to stand at the middle.

Method

This is a tug of war between two strong people at the ends and a small person at the middle. The person in the middle tries to push the rope to the floor with one hand. The two at the ends try to hold the rope horizontal. They should not wrap the rope around their hands!

Questions

Who was exerting the most pounds of force, the students at the ends or in the middle?
Were the people at the ends of the rope pulling in the right direction to oppose the force of the middle student?
Why did the students at the ends have to pull so hard? (They were pulling against each other!)

Not Popping a Balloon With a Needle

Physics Concept

A balloon pops because the rubber is stretched. When it is nicked with a needle the rubber pulls away rapidly and the higher pressure inside the balloon causes the "POP!" If the balloon is nicked where it is not stretched, it will not pop. Some things that appear to be magic are really physics.

Materials

A balloon and a needle or a straightened coat hanger that has been sharpened at one end.

A little grease, glycerin or WD-40 on the needle helps.

Method

Blow up and tie the balloon. Using all of the showmanship you can muster, insert the needle into the balloon near where you tied it and out the "dimple" at the other end. Pop the balloon after you remove the needle.

Questions

An inflated garbage bag will not pop in the same way. Why?

Friction and Shoes
(Forces)

Physics Concept

Friction holds things together and keeps shoes from sliding. Gravity causes shoes to slide down an incline plane - the steeper the incline, the greater the gravitational pull down the incline. Shoe soles with a lot of friction will not slip on steep inclines because the force of friction is greater than the gravitational pull.

Materials

A board, some books to prop the board, a ruler, and shoes. Let each child measure his or her shoes and compare different brands and types.

Method

Put a mark across the board about three feet from the end. Put a shoe on the board with the heel on the mark. Lift the board slowly until the shoe begins to slip. Measure the height of the mark on the board when the shoe slips. This is a fairly reproducible measurement if one student lifts the board and one measures.

After all the students have measured the height at which their shoes slip, write on the blackboard all of the types of shoes and the heights that we measured. Compare the results for different types (street shoes, running, tennis, basketball, hiking) and brands of shoes.

Questions

What happens if you put a weight in the shoe? Does the slipping height change?
What kinds of shoes have the greatest friction?
What reasons do you use to choose shoes?
Do expensive brand name shoes have more friction than lower price shoes?

Egg and Sheet
(Forces and Momentum)

Physics Concept

You can stop a moving object with a small force if you take a long time to do it. This is the principle behind automobile air bags. If you hit the dashboard in an auto accident you receive a large force in a short time to bring you to a stop. An airbag stops you by exerting a smaller force over a longer time. The smaller force causes less damage to you.

Materials

Raw egg and a bed sheet.

Method

The students hold the sheet in a lop-sided "U".

Throw the egg at the sheet. Hard! Be sure to get the egg in the sheet and do not allow it to roll off the bottom of the sheet.

Ask a student to try to break the egg by throwing it into the sheet. At the conclusion break the egg into a clear glass to show that it was a real egg.

Questions

How is this like an automobile air bag?
Why does the egg crack if you throw it at the wall?

Collapsing Soft Drink Can
(Strength of Structures)

Physics Concept

The shape of an object can determine its strength. This demonstration shows the exceptional strength of the circular shape and how weak the can is if it is dented. Submarine hulls are circular in cross-section to maintain their strength against the pressure of the deep sea.

Look around you for examples of how the shape of an object is used to increase its strength.

Materials

Empty aluminum drink can, dent-free. You can usually stock up on these from the recycling bin. It pays to take the time to make sure the cans are empty or washed out. After you are finished put the cans back in the recycling bin.

Method

Have a student stand on one foot on the can. Don't try this on a carpeted floor. If the student balances carefully and the can is not dented, the can will hold the student up without collapsing.

Now all you need to do is to produce a small dent in the can to make it collapse catastrophically. You can snap one side of the can with your fingernail. You can tap it with a ruler. You can shoot the can with a rubber band.

Questions

What other objects use shape to produce strength? (bridges, corrugated boxes, pyramids, etc.)

Why does the dent weaken the can?

Is this the kind of force that a can is meant to withstand?

Falling Glass of Water (Weightlessness)

Physics Concept

The weight that you feel is really the force of the floor pushing up on you. Weightlessness is how you feel when you are falling freely through the air. Gravity always pulls on you but in free fall you feel weightless because the ground is not pushing you upward.

If you put water in a cup with a hole in it, the weight of the water pushes the water through the holes and out of the cup. When the cup and the water drop together the water is “weightless” with respect to the cup. Therefore it does not fall out of the holes.

Materials

Paper cup, water, and garbage can or bucket to catch the water.

Method

Put two holes in the lower sides of the cup. Put your fingers over the holes and fill the cup with water. Stand on a chair and hold the cup in front of you. Remove your fingers from the holes for a moment so that water starts to flow out of the cup. Then drop the cup into a trashcan. Notice that as soon as the cup drops the streams of water stop flowing. This looks very good in slow motion on videotape.

Questions

How does this apply to the way you feel in a descending elevator or at the top of a roller coaster ride?

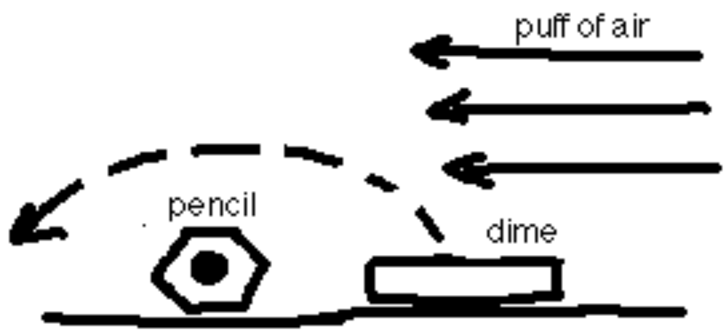
Shuttle astronauts feel weightless. Does that mean that the Earth's gravity no longer pulls on them?

Jumping Dime
(Air Pressure)

Physics Concept

Bernoulli's law says that fast flowing air has a lower pressure than still air. This is the principle that produces the aerodynamic lift on an airplane wing.

If you blow air over a dime sitting on a table the fast air above the dime has a lower pressure than the still air below it. This pressure difference is enough to make the dime hop up and then get pushed over the pencil



Materials

A dime and a pencil.

Method

Place the dime next to the pencil. Blow (puff) over the dime and make it jump over the pencil.

Questions

What practical applications could this have?
Where have you seen an example of this effect before?

Holding water in a Glass With a Card (Air Pressure)

Physics Concept

Air is pushing on us with the force of 14.7 pounds per square inch in all directions. It pushes down on your head and it pushes up on the bottoms of your feet. This oldie but goody demonstration shows that air pressure is really there even though we do not notice it.

Materials

A glass, water, and a stiff card or paper plate. If you are feeling lucky a sheet of notebook paper sometimes works in place of the card.

Method

Fill the glass half full of water. Place card on top of the glass and carefully and quickly turn the glass upside-down. Now remove the hand that was holding the card. The card should stay in place and the water should stay in the glass.

Questions

What is holding the water in the glass?
Would this work if there were no water at all in the glass? (No, it would not. The water acts as an air seal, like a gasket on a food jar lid.)
Does it matter how much water is in the glass? Does it matter how much air is in the glass? (You should let the students think about this and experiment with glasses that are nearly empty, half full and completely full of water.)
Does it matter if the cup is tall or short? (The cup must not be any more than 32 feet tall to get this activity to work.)

Center of Mass of Odd Shaped Objects

Physics Concept

The center of mass of an object is its balance point. When an object flies through the air it rotates about the center of mass. The center of mass travels in a parabolic path, just like a small rock.

Materials

Ten to eighteen inch diameter cardboard rounds and metal washers. The rounds can be cut out of cardboard or pieces sold for cake bottoms also work well.

Method

Use two identical circles of cardboard. Mark a large dot in the center of each. On one of the circles tape a washer near the edge. Throw each round into the air so they spin about their axes. Notice how the dot moves on each. The dot on the circle that has the washer should wobble as it goes through the air.

To find the location of the center of mass of the cardboard circle, balance the cardboard on a tripod of your thumb, first and second fingers. Slowly bring your fingertips together. They will converge under the center of mass of the object.

Now mark the center of mass on both circles with an X. Throw them through the air as before and notice the motion of the X.

Questions

Where is your center of mass?
Where is the center of mass of a hammer? Of a coat hanger? Of a tennis racket?
Use the tripod trick to find the center of mass of a book.
Glue a map of your home state on a piece of thick cardboard. Cut out the map to the shape of your state. Now use the tripod trick to locate the center of mass of your state.

14 Nails on One
(Center of Mass)

Physics Concept

Center of mass. See the Martian Hat for another example. This demonstration shows how an object is balanced if the center of mass is below the suspension point. Also demonstrates the virtues of patience and steady hands.

Materials

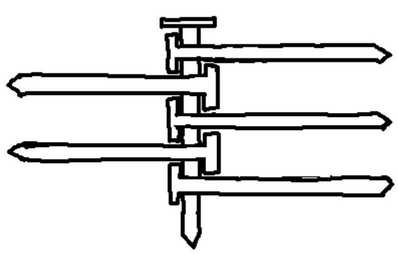
A small block of wood, for instance, a 4-inch length of 2 x 4.
Thirteen (or more) 16-penny nails.
16-penny nails come about 71 per pound.

Method

Nail one of the nails into the small block of wood so as to make a pedestal for the other nails. Take another nail and set it down on the table. Lay the next nail across the first nail perpendicularly with its head over the first nail. Lay the second nail in the opposite direction. Continue to do this until it looks like the remains of last night's fish dinner. Lay the last nail atop the others parallel to the first nail, but with its head at the other end. The top and bottom nails lock the arrangement in place. Carefully lift the arrangement by holding it at the ends of the top and bottom nails. Place it on the head of the nail in the block of wood.

Questions

What is holding the nails together?
Where is the center of mass of the nails? (It is located below the center of the arrangement of nails.)
How is this like a high wire walker and her balance pole?



Water Whirled in a Circle
(Centripetal Acceleration)

Physics Concept

When an object goes in a circle it experiences a centripetal acceleration. A force is needed to keep the object in the circle because it wants to go in a straight line.

Materials

Paper cup, string, and water

Method

Tie the cup to the string, put in water and whirl away.
Each student should try this, it is better to do than to watch and the worst that can happen is that someone gets wet. Make sure there is room to swing without hitting something, especially overhead lights.

Questions

How do you stop the demonstration without getting wet?
How is this like a roller coaster loop-the-loop?
What would happen if you put a small hole in the bottom of the cup? Where would the water go?
How is this like or not like the falling cup of water demonstration?

Picking Up a Marble With a Bottomless Cup

Physics Concept

More centripetal force and acceleration. The complete explanation is a proper problem for a high school physics class but younger students can understand how it works in simpler terms.

Materials

A paper cup that has sloping sides and a marble.

Method

More centripetal force and acceleration.

Cut the bottom from the cup. Put the cup on a flat table. Put the marble inside and holding the cup on the outside swirl the cup until you can lift the cup with the marble rolling around against the sides of the cup. The motion is all in the wrist.

Questions

Have you seen a ride at the state fair or an amusement park ride that uses the same principle?

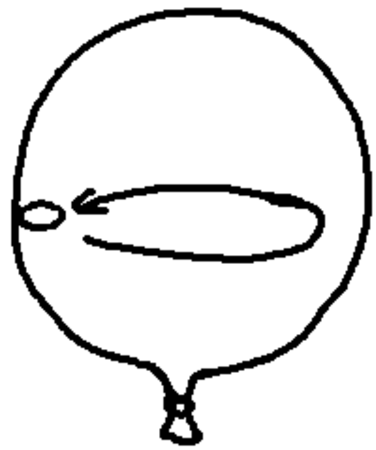
How does this relate to the banked turns on the Interstate Highway or at a car-racing track?

Would this trick work if the cup had sides that were exactly vertical?

The Penny in the Balloon

Physics Concept

More centripetal force and acceleration. This activity resembles the motion of a planet in orbit about the Sun.



Materials

Penny or a dime, a round balloon.

Method

Put a penny in a balloon and blow up the balloon.
Swing the balloon to get the penny rolling in a circle.
The penny rolls on its edge as it orbits inside the balloon. Because there is very little friction in rolling the penny will orbit the balloon for several seconds. As the penny slows down it will drop toward the bottom of the balloon.

Question

What happens if you stretch the bottom of the balloon?

Multiple Ball Drop
(Energy)

Physics Concept

Objects can lose or gain energy when they collide with other objects. The big basketball loses energy when it bounces from the floor. The little basketball gains energy when it hits the big ball. Two collisions occur the basketball hits the ground and then collides with the other ball. The smaller the second ball, the higher it should fly.

Materials

Basketball and other balls (softball, superball, golf ball, etc.)

Method

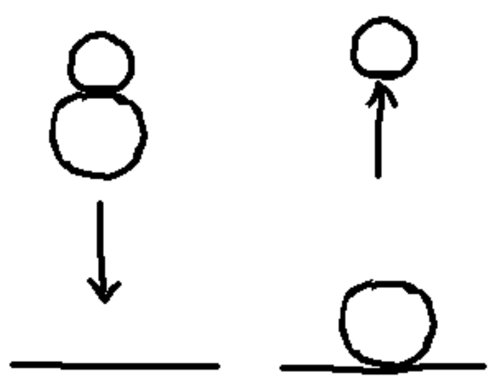
Drop the big ball and little ball individually. Discuss how a ball loses energy in hitting the floor and does not bounce back as high as the point where it was let go.

Now hold the big ball and little ball together as shown in the drawing and drop them. Try different combinations of balls.

Questions

Why does the big ball stay on the ground after hitting the little ball?

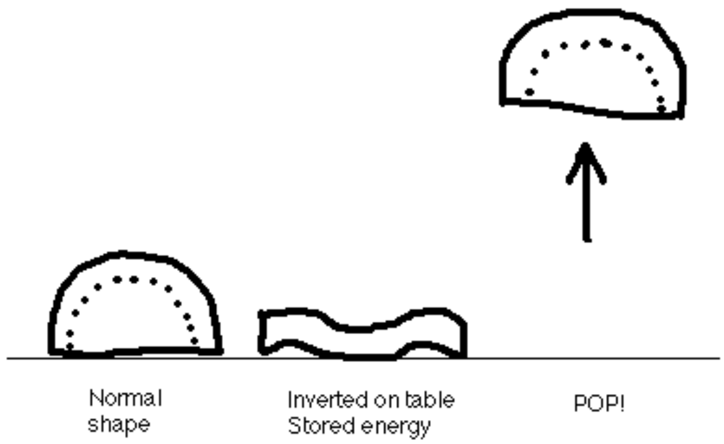
What happens if the big ball drops from on top of the little ball?



Popcorn Poppers

Physics Concept

This illustrates the storage of energy. Keep your eye open for the physics in toys! The reason most toys are fun is that they involve the principles of physics!



Materials

Popcorn poppers are half hollow spheres of rubber that can often be found at party stores or in the party favors section of stores. We have found two-inch diameter versions at Oriental Trading Company (www.orientaltrading.com). A homemade version can be made by cutting a blue racquetball in half.

Method

Turn the popper inside out and place on the table. After a moment the popper will pop back into its original shape and jump off the table. By turning the popper inside out you have stored potential energy, just like compressing a spring. The potential energy changes into motion energy when the popper reforms itself.

Questions

What happens if you "set" the popper and then drop it?
Where does the energy in the popper come from?

Electricity and Magnetism

An Electrometer
(Electrostatics)

Physics Concept

An electrometer is an instrument used to detect electric charges. Electrometers use the fact that like charges repel. There are many simple ways to make electrometers.

Materials

Paper cup, straw, paper clip, and a piece of the thin foil that is used to wrap a stick of chewing gum or a piece of chocolate candy (Hershey's Kisses).

Method

To make a very simple electrometer, hook two small pieces of foil from a paper clip so they can swing freely. Tape the paper clip to a soda straw or a paper cup. Touch a charged object to the paper clip. The foil pieces repel each other, showing that they have become charged.

A more elegant electrometer is described in “Teaching About Electrostatics,” by Robert A. Morse, available from the American Association of Physics Teachers. To make this tape an empty, clean, tab-top soda can horizontally to the top of a paper or plastic cup. Bend the tab out horizontally and hang a "U" of aluminum foil through the hole in the tab. When the can becomes charged the "U' will swing outward from the can.

Positive and Negative Charges

Physics Concept
Static electricity can be produced by rubbing objects together. This is called triboelectricity (electricity produced by friction). When the two objects rub, electrons from one object jump to the second object. The second object becomes negatively charged and the first, since it has lost electrons, becomes positively charged.

How do you know which object has the positive charge? Which combinations of objects produce large amounts of charge?

The charge transfer depends upon how strongly the electrons are bound to the object. Some materials give up electrons easily and are more likely to be left with a positive charge. Some materials hold strongly to electrons and are more likely to be left with a negative charge.

If you rub two pieces of the same material together neither piece becomes charged because they hold onto their electrons with the same strength.

If you rub a piece of styrofoam in your hair, the styrofoam picks up electrons from your hair and becomes negatively charged. Your hair becomes positively charged and after a few rubbings the hairs stand out and repel each other.

Some other combinations include: Glass (+) and silk (-), hair (+) and rubber balloon (-), and wool or fur (+) and hard plastic (-)

Materials
PVC pipe and nylon stockings, pieces of silk, glass beakers, sweaters, and Styrofoam blocks. Styrofoam is available in large sheets for house insulation (hardware store or home supply store). Cut the sheet into 4 inch by 6 inch pieces.

Method
Rub various objects together and see what kind of charges are produced. You can check the sign of the charge by seeing if they attract or repel a piece of Styrofoam or a rubber balloon that has been negatively charged by rubbing in your hair.

Questions
Do the charges move on the balloon or Styrofoam? Does the entire piece of Styrofoam become charged or only a part of it?

Jumping Grains
(Electrostatics)

Physics Concept

Different materials respond in different ways to electric fields depending on their ability to hold a charge. An uncharged grain of salt becomes polarized when another charged object is held near it. That is, the grain builds a positive charge on one side and negative on the other. Some materials become polarized more easily than others. Also some materials can pick up or lose charge easily. These properties can be used to separate different materials. Charged objects can join be attracted to each other by having positive charge on one end and negative charge on the other.

Materials

An aluminum pie pan, dry unflavored gelatin powder, grits (or cornmeal), black pepper, and salt. A piece of Styrofoam to charge by rubbing in your hair.

Method

In the pie pan put separate teaspoonful-sized mounds of the gelatin, grits (cornmeal), pepper, and salt. Hold the charged Styrofoam above each mound and carefully observe what happens. The grits and pepper should jump up to the Styrofoam and stick to it. The salt grains may jump up and then jump back to the pan when they pick up charge from the Styrofoam. The gelatin grains will form tiny chains or fingers as they climb toward the Styrofoam. Each particle of gelatin becomes polarized and develops a plus and minus charge on opposite ends. These ends link up to form the chains you see.

Questions

Which of the materials loses its charge the most easily?
If you mix the salt and pepper can you separate them using charge?

An Electrostatic "Compass" (Electrostatics)

Physics Concept

An insulator can still have a charge induced on it. Every object has positive and negative charges. The proximity of another charged object causes these charges to move so that there is an attraction. This activity demonstrates polarization and induction.

Materials

Small scale - a soda straw, a piece of cardboard and a paper clip.
Large scale - a three-foot long wood two-by-four and a watch glass to balance it on.

Method

Unfold the paper clip half way and stick the straight end through the center of the cardboard and tape it in place so that the wire sticks up when the cardboard is set on the table. Make a small hole on one side of the center of the straw for the wire to go through. Balance the straw on the end of the clip. The straw must be able to swing freely like a compass needle. Hold a charged object near one end of the straw. The straw should turn like a compass needle.

Put the watch glass on a table with the curved end upward. Balance the wood two-by-four on the watch glass and hold a charged object near one end to make it rotate.

Question

Sketch where the charges are located on the compass. How can something that has no charge become attracted to a charged object?

An Electrostatic "Slime"

Physics Concept

Electrical forces between atoms hold all materials together. In a few cases the properties of a material can be changed drastically by using a static electric field. An electrorheological liquid is a liquid whose viscosity is changed by electric fields. In this demonstration the starch grains become charged, link together, and slow down the flow of the oil. This type of liquid may have applications for making components in micromachines.

Materials

A piece of Styrofoam to produce a charge.
Two glasses, cornstarch and vegetable cooking oil.

Method

Pour a few tablespoons of cornstarch in one of the glasses and slowly stir in cooking oil until the mixture has the consistency of thick gravy.
Now rub the Styrofoam in your hair to put an electrical charge on to it.
Slowly pour the liquid from one glass to the other. While doing this move the charged Styrofoam near the liquid. The liquid should stop flowing and seem to solidify. A chunk of the stream may even break off and fly onto the Styrofoam.

Reference

See "Electrorheological Liquids," David G. Haase, *The Physics Teacher* 31, 218 (1993).

Making a Magnet and a Magnetic Field Detector (Magnetism)

Physics Concept

Making a simple compass. The paper clip always lines up parallel to the magnetic field lines.

Materials

Nail and a magnet, paper cup, thread and a paper clip.

Method

Stroke the paper clip a few times with the magnet to magnetize it. Tape it to a thread and hang from the paper cup support.
Stroke the nail with the pole of the magnet and then hold it near the paper clip.
Stroking the nail lines up the internal magnets in the iron.

Question

How do you figure which is the North and which is the South pole?

Floating Needle Magnetic Field Detector

Physics Concept

This is a simple compass that uses the surface tension of water to provide a support. It is *very* sensitive so do not move a magnet too close to it.

Materials

Needle, magnet, fresh water and a clean cup.

Method

Fill the cup almost full with water. Magnetize the needle by rubbing it a few times with one pole of a magnet. Use piece of paper as a cradle to carefully lower the needle onto the surface of the water in the cup. The needle should float in the middle of the cup and should point along a north - south line.

In a wax-coated cup the meniscus of the water is curved like a hill, the needle sometimes goes to the side. In a ceramic cup the meniscus of the water is like a valley, the needle stays in the middle.

Wave a magnetized nail near the needle.

Questions

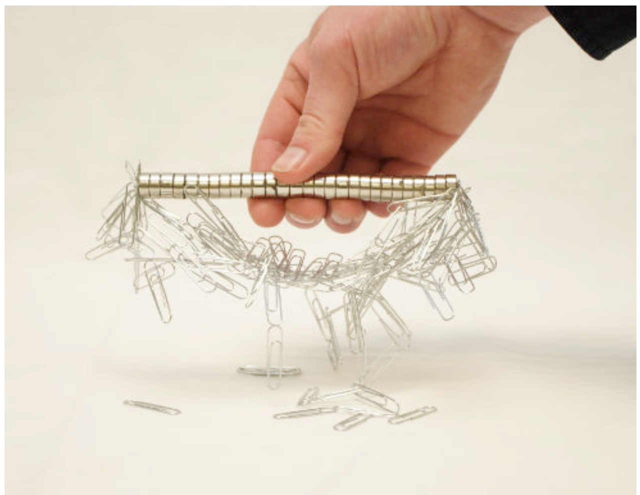
What happens if you put two needles on the water?

Is this a practical compass? Would it have worked for Christopher Columbus?

Strength of a Bar Magnet - Concentration of Magnetic Force

Physics Concept

Most of the strength of a magnet is at the poles. The rest of the magnet does not exert a magnetic force.



Materials

Magnet and paper clips

Method

Hang paper clips on a bar magnet. Where do they stick and where do they fall off?

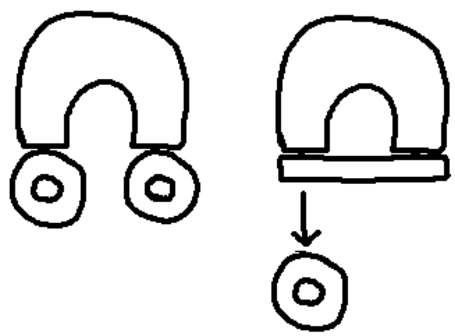
Riddle

There is an old riddle. If you have two identical looking iron bars, one of which is a magnet and the other is a non-magnetized piece of iron. How do you determine which is which? You cannot use any other devices except for the two iron bars.

Horseshoe Magnet and a Keeper - Why don't other things stick?

Physics Concept

A new horseshoe magnet is usually are supplied with a keeper, a piece of soft iron that is held across the north and south poles. The keeper has two purposes. It helps the magnet last longer before it becomes demagnetized and it keeps the horseshoe magnet from sticking to other iron or magnetic objects. How does the keeper accomplish these tasks?



It takes energy for a magnet to produce a magnetic field in air. Eventually the magnet becomes demagnetized because of having to expend energy on this "outside" field. It takes less energy for the magnetic field to go through a piece of iron like the keeper. So when the keeper is in place all of the magnetic field from the horseshoe magnet goes through the keeper and none goes into the air.

Materials

Horseshoe magnet, keeper, and an iron washer

Method

Hang two or more iron washers from the horseshoe magnet. Locate the poles of the magnet and the parts of the washers that now have a strong magnetic field.
Remove the washers and put the keeper on the magnet. Try to hang washers from the magnet now.

Questions

Where did the north and south poles go when the keeper was in place?
What will happen if the keeper is placed across the south pole but does not touch the north pole?

Magnetic Field Around a Coil of Wire

Physics Concept

An electric current produces a magnetic field. A current through a coil of wire make a field that goes straight through the center of the coil, and outside of the coil the field is like that of a bar magnet. The nail enhances the magnetic field of the coil by using that field to line up the magnetic moments in the iron.

Materials

Battery, about 6 feet of #26 copper wire (exact size not critical), soda straw and nail, sandpaper to remove insulation, magnetic field detector (i.e. compass)

Method

Remove the insulation from one inch at each end of the wire. Wire can be stripped with a flame, a knife, or sandpaper. Wind the wire into a coil at the end of the soda straw. Hold the coil near the magnetic field detector and see if it reacts. Put the nail in the soda straw and repeat. Touch wire to battery briefly. The sparks are not dangerous; the heat is.

Questions

What would happen if you put a piece of wood or an aluminum nail in the straw instead of an iron nail?
What can you change to make a more intense magnetic field? (Number of turns of wire, more batteries, more nails?)

Iron in Breakfast Cereal (Magnetism)

Physics Concept

Some foods are fortified with iron by adding elemental iron, sort of like iron filings. Iron filings may not seem very digestible but they taste better than chicken liver in your breakfast cereal. Your body does assimilate part of the iron added to the cereal and passes the rest.

You can separate out some of the iron particles by mashing the cereal and pulling the particles out with a magnet. A plastic bag is used to allow the particles to be separated from the magnet.

Materials

Magnet, a breakfast cereal fortified with iron, plastic bag, water, sheet of white paper. You might try some consumer physics by comparing different types or brands of cereals.

Method

Put a little cereal and water in a cup and pulverize into mush. Put the magnet in a plastic bag and stir the mush with the magnet. Remove the magnet from the bag and wipe the bag on the white sheet of paper. The black motes are iron filings. You can demonstrate this by picking them up again with the magnet.

Application in Real Life

You may not want to do this everyday with your cereal, but the use of magnets to reclaim iron from junk metal is a very common process.

Refrigerator Magnets
(Where is the North Pole?)

Physics Concept

Where is the North pole on a flat magnet of the type that you use to post notes on the refrigerator at home? The answer is that there are several north and south poles. You can learn about them by using two magnets or better, cutting one magnet into two parts.

Materials

Flat refrigerator magnets of the type used for advertising. They usually are thin and rubbery. Thick magnets will not work.

Method

Hold the flat surfaces of the two pieces of magnet together and slide them across each other. Now rotate one of the pieces 90 degrees and do the same thing. Do the magnets stick to each other? Do you feel bumps when you slide one across the other? Hold the pieces end to end. Are there some ways that they are attracted to each other now?

Questions

Make a drawing of how you think the north and south poles are arranged on the magnet.
How can you decide which are the north and which are the south poles?
If you hang a refrigerator magnet from a thread will it line up with the Earth's magnetic field? Why or why not?
How can a refrigerator magnet always stick to a refrigerator even though the magnets cannot always stick to each other?
Can you pick up a refrigerator magnet with the north pole of a bar magnet or horseshoe magnet?

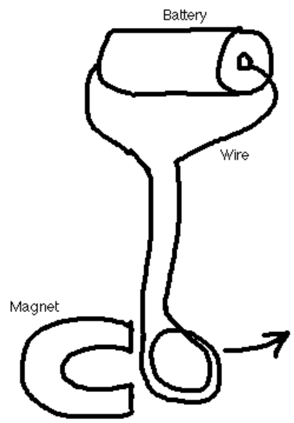
Reference

"The Mysterious Magnets," David G. Haase, The Physics Teacher 34, 60 (1996).

Magnetic Force on an Electric Current

Physics Concept

All magnetic forces come from moving charges. The electrons moving around iron atoms make iron magnetic. An electric current through a wire also produces a magnetic field and can be attracted or repelled by another magnet. This force is used to produce motion in an electric motor.



Materials

Strong magnet, long piece of wire, or a long 1/2 wide strip of aluminum foil, battery

Method

Hold a loop of wire near the pole of a magnet and touch the ends of the wire to a battery to put a current through it. The direction the wire jumps depends on the direction of the current flow.

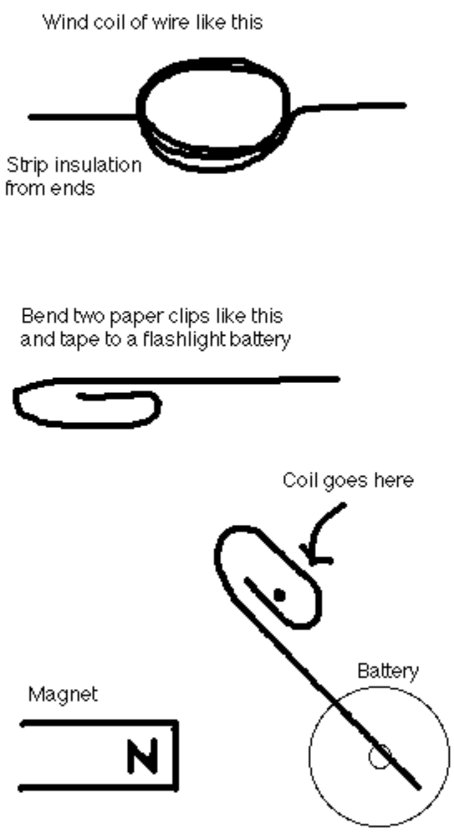
Questions

How could you arrange things so the wire jumps further?

Simple Electric Motor
(Electric/Magnetic Forces)

Physics Concept

Magnetic fields exert forces on electric currents.



Materials

Battery, 2 feet of copper wire, magnet, paper clips, tape, felt tip marker

Method

Tape the paper clips to the ends of the battery to make a cradle for the coil. Wind the wire into a coil of about 10 turns. Clean the ends of the wire. Mark one side of one of the clean ends with the felt tip pen. Place with the magnet as shown.

To get the motor to turn you may have to adjust the position of the magnet and the balance of the coil of wire. Give the coil a little spin to start it off.

Questions

If you have an old motor that you can disassemble this is a good opportunity to compare the direct current motor here, with an alternating current motor. Both types have wires, coils and a rotating electric connection to the axle. Some alternating current motors do not have permanent magnets but use electromagnets instead.

Electrolysis - Hydrogen and Oxygen Production (Electricity and Chemistry)

Physics Concept

Water is a molecule made of oxygen and hydrogen. Electrical forces hold the molecule together and electrical forces can be used to tear it apart.

Materials

Cup of water, salt, paper clip, copper wire, flashlight battery.

Method

Tape the paper clip to the positive end of the battery and the copper wire to the negative end. Put salt into water in a cup until the salt does not dissolve any more. Insert the clip and wire into the water. Observe.

Questions

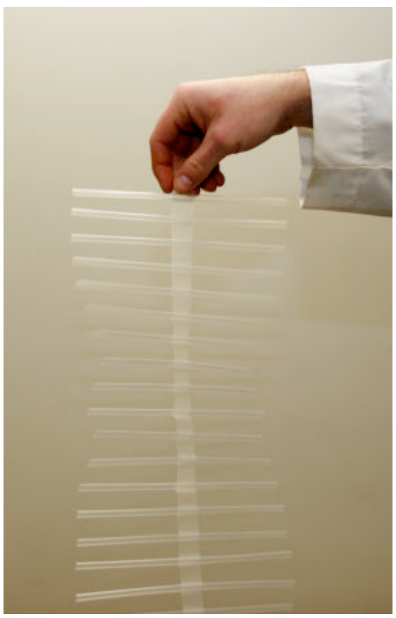
What are the bubbles made of?
What is the stuff collecting on the paper clip?
What happens if you put the paper clip on the negative end of the battery and the copper wire on the other?
You should try other combinations of materials for the electrodes - aluminum foil, graphite pencil leads, pennies, nickels or dimes. Note what happens to the electrodes, where the bubbles form, how does the salt water change.

Sound and Optics

Soda Straw Torsional Waves (Oscillations)

Physics Concept

This is an illustration of a type of wave in which each object rotates. It is also a model for how the ribs are mounted on a person's spinal column, or the ribs of a fish. Torsional oscillations are used in old-style mechanical watches and in the shock absorbers of some automobiles ("torsion bars")



Materials

Plastic soda straws, cellophane tape, paper clips.

Method

It pays to be neat and methodical in preparing this. Lay a two to three foot long piece of transparent tape sticky side up on a table. Tape the ends down to the table. Lay the straws across the tape as shown, leaving about one inch between the straws. If this is to be a "permanent" demonstration put another piece of transparent tape over the top of the straws. Then carefully lift the ends of the tape from the table.

Hold the tape at one end and let the straw assemblage dangle. Push the end of the top straw and let go. You should get a nice wave, like a corkscrew, that travels down the straws.

A six-foot long version of this works well for hanging from the ceiling of your classroom, but is somewhat fragile.

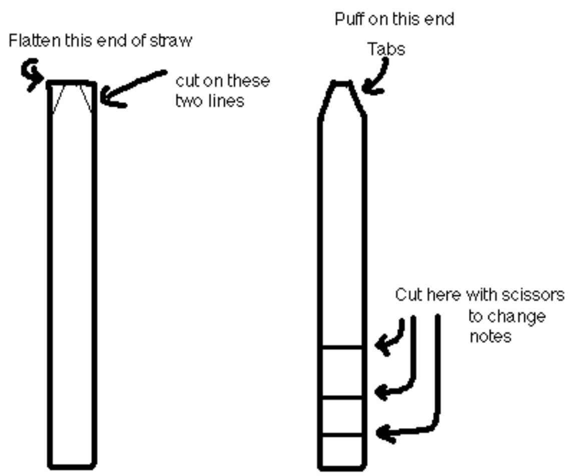
Question

How do you change the speed of the waves?
What would happen to the waves if you space the straws closer together on the tape?
Can you see waves reflect as they reach the end of the soda straw ladder and then bounce back?

Soda Straw Flute or Oboe
(Sound)

Physics Concept

All musical instruments involve something that vibrates the same way over and over again. In this case the air in the soda straw produces the sound. The tabs on the straw act like the reeds on an oboe to make the air column vibrate. The longer the straw the lower the pitch of the note.



Materials

Soda straws and scissors. The big fat soda straws from MacDonald's give a very mellifluous tone.

Method

Chew the end of the straw to flatten a one-inch section at the end. Make two diagonal cuts across the end of the straw as shown. These cuts produce the two reeds of the soda straw oboe. Puff hard on the straw. You can increase the pitch of the note by cutting across the straw at the other end to make the length of the air column shorter.

Question

How do other horns and woodwinds produce notes?
What would happen if you connect one or two other straws to the end of the first straw?

Corruga Horn
(Sound and the Bernoulli Effect)

Physics Concept

The corruga horn works like the soda straw oboe except that the Bernoulli effect draws the air through the horn, and the corrugations, not reeds, cause the air column to vibrate.

Method

Swing the corruga horn around your head. As you swing the tube you will hear the pitch of the sound change from a lower note to higher notes. The notes should sound familiar. They are the same notes that are produced by a bugle. Try playing "Taps."

The Bernoulli effect causes the air to flow through the horn because one end of the horn is moving quickly and the end of the tube in your hand is not moving. Where the air moves fast the air pressure is lower, so the pressure drives air from the end of the tube in your hand through to the end of the tube that is swinging.

Now put your hand over one end of the tube as you swing the other end. This stops the flow of air, and stops the sound, too.

Another Thing to Try

Take a plastic garbage bag, fill it with air and then hold the open end tightly around one end of the corruga horn. Swing the other end of the horn around and notice that the motion of the horn and the Bernoulli effect draw the air out of the bag until it is totally deflated.
Because the sound is produced by the corrugations you can do the same thing with a ten-foot long, 6-inch diameter plastic drainage pipe and also with long lengths of two inch diameter flexible plastic sump tubing. However, you cannot get sounds by swinging a soda straw, a smooth golf club tube or a smooth PVC pipe.

Perception of Direction with Sounds (Speed of Sound)

Physics Concept

We are able to determine where sounds come from because we have two ears, a smart brain, and because sound travels at 330 m/s (about 1000 feet/second)
Most people can determine a time span of less than 1/1000 second with their hearing.

Materials

A 1/4 inch diameter rubber tube about 4 feet long. A pencil.

Method

Have a student hold one end of the tube to each ear with the tube passing behind her back. Another person stands behind her and taps on the tube with the pencil. This produces a sound that goes independently from the point where the tube was tapped to each ear. If the tap is closer to the right ear, the listener hears the sound as coming from the right side. If the tap is closer to the left ear, the listener hears the sound as coming from the left side. If the tap is made near the center of the tube the listener cannot tell the direction of the sound.

For most people there is a section of the tube about four inches long where the listener cannot tell the direction. This is because the listeners brain cannot separate sounds that are closer together than the time it takes for sound to travel about four inches or about 3/10,000 of a second.

Question

What happens to your hearing sense of direction when you are underwater? Sound travels through water at 1480 m/s. You might want to try this at a swimming pool, using a metal pan or a bell to make sounds underwater.

Disappearing Test Tube in Salad Oil (Optics)

Physics Concept

Light is bent by the shape of a transparent object and by its index of refraction. The index of refraction of a material = (speed of light in vacuum)/ (speed of light in the material).

Glass objects may seem to disappear because the index of refraction of the oil is the same as the index of refraction of the glass.

This is a great demonstration to do in steps and to ask the students at each step "What do you see? Why do you think you see this?"

Materials

A glass or beaker, salad oil, and a Pyrex test tube.

Method and Questions

Put the tube in the beaker as shown in the drawing. Ask the students to describe what they see. How is it that they can see both the test tube and the beaker even though both are clear and do not absorb light? Remind the students about reflection and refraction. Do you see any reflections? When you look through the tube and beaker how do the objects on the other side look? How do reflection and refraction help you see the test tube and beaker?

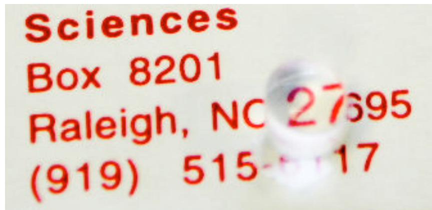
Now pour salad oil into the beaker. Ask the same questions. What do you see? Do the test tube and beaker look different than before? How have the reflections and refraction changed?

Now pour the salad oil into the test tube. Be careful to avoid bubbles. Ask the same questions as before. If reflection and refraction (distortion of images) helped you see the test tube before, why can't you see the test tube now?

Did the test tube really disappear or is it still there?

You could also do the same demonstration with another beaker, test tube and water and have the students notice the differences when you go through the steps. The index of refraction of water is not equal to the index of refraction of glass.

Soda Straw Magnifying Glass
(Optics)



Physics Concept

This uses a drop of water instead of a curved glass to make a magnifier - or demagnifier. If the water meniscus is above the top of the straw you have a magnifying glass.
If the meniscus curves downward you have a diverging or reducing lens.

Materials

A 1/4 inch long piece of soda straw, water, and cellophane tape, a piece of paper towel

Method

Put a piece of the tape over the end of the straw. Put a drop of water in the straw. Place over a printed letter to read the letter.

Question

What happens if you use salad oil instead of water?
How does the shape of the meniscus of the droplet affect the magnification of the "lens”?

Oil on Water
(Optics)

There is an interesting related magnifier effect when you put some oil into a pot for boiling spaghetti. Put a few drops of clear cooking oil into a pan that has about an inch of water in it. Then look through the oil drops that are floating on the surface of the water to the bottom of the pan. The bottom of the pan is magnified because the oil drops form lenses. The oil drops have a slightly domed shape and the index of refraction of the oil is different from the index of refraction of the water. Notice how the size and shape of objects on the bottom of the pan change when you stir the oil drops with a fork.

Pin Hole Lens
(Optics)

You can make a simple magnifier with just your fingers. Pinch together both of your thumbs and forefingers so a small hole is formed at point where they pinch together. Put a book with small print on the table, hold your head about 10 inches above the book, and put your hand lens about half way between the book and your eye. Look with one eye through the pinhole to the small print. By adjusting the position of your hand and eye you should see the print doubled in size.

Where is It?
(Optics)

Physics Concept

Your depth perception depends on the use of both eyes. Each eye sees a different image and your brain combines those images into one. At the same time your eyes triangulate the distance to what you see. This is exactly the same way astronomers at different telescopes triangulate the distance to a nearby planet.

Materials

A card and a pencil.

Method

Punch a hole in the card with the pencil. Hold the card and pencil at arms length. Turn the card so that its edge is towards you. Close one eye. Try to put the pencil through the hole.

A variation of this is to hold the eraser end of the pencil, close one eye and try to touch the corner of a table with the point of the pencil.

Questions

Would there be any advantage to having three eyes or four eyes?

Are there other clues that help you tell distances even if you only see through one eye?

References for Demonstrations

The Physics Teacher (especially the String and Sticky Tape column)

The American Journal of Physics

"The Amateur Scientist" column in Scientific American.

String and Stick Tape Experiments, R. D. Edge, available from the American Association of Physics Teachers, 5112 Berwyn Road, College Park, MD 20740-4100

The Flying Circus of Physics (With Answers), Jearl Walker, John Wiley and Sons, Inc.

Instructors Manual for Physics by Tipler
Worth Publishers, Inc. 444 Park Ave. South, NY 10016

Physics Demonstration Experiments, Harry Meiners, ed., two volumes, Ronald Press Co. NY, 1970. (mostly college level demonstrations, but inspiring to read through).

A Demonstration Handbook for Physics, G. D. Freier and F. J. Anderson, available from the American Association of Physics Teachers.

Resource Kit for the New Physics Teacher (for the high school teacher) available from the AAPT.

"Fun With Physics," videotape available from Carolina Biological Supply, 2700 York Road, Burlington, NC 27215 (1-800-334-5551).

(Hint to physics teachers - Join the American Association of Physics Teachers)

Physics Concepts and Terms

Force - a push or a pull - measured in pounds or Newtons.

Mass is the amount of stuff in an object, measured in slugs or kilograms. The gravitational force (weight) of one slug of mass is 32 pounds. The weight of one kilogram of mass is 9.8 Newtons.

Inertia - an object at rest tends to stay at rest, an object moving in a straight line tends to move in a straight line - until acted on by a force.

Acceleration - the rate at which the velocity changes. Forces cause an object to accelerate.

Centripetal acceleration - the acceleration of an object when it is going in a circle. Its velocity is always turning toward the center of the circle.

Centripetal force - the force that causes the centripetal acceleration.

Work = a force exerted to move an object a distance

Potential energy - the ability to do work
The P.E. of a mass due to gravity = mass x height

Kinetic energy - energy due to motion
K. E. = (1/2) mass x $(\text{velocity})^2$

Momentum - the quantity of motion. Momentum (p) = mass x velocity.

Bernoulli's Law - the faster a gas is flowing the less its pressure.

Speed of sound in air = 330 meters/sec. = 1000 ft/sec.

Electric current - the motion of charges in a wire.

Coulomb's Law - basic law of electricity - like charges repel, unlike charges attract.

Wavelength - the distance between two peaks in a wave.

Period - the time it takes for a pendulum or oscillator to go through one complete cycle of motion.

Frequency - the number of periods per second.

Index of refraction - light travels slower in materials than it does in space. The speed of light in space divided by the speed of light in a material is the index of refraction of the material. The speed of light in space is about 186,000 miles/sec. The index of refraction of water is 1.33, so light travels at 186,000/1.33 = 140,000 miles/sec through water. The index of refraction of diamond is 2.42.

Temperature - a measure of the thermal motion of atoms in a material. Absolute zero is -273.15 Centigrade, which is designated to be zero Kelvin. Room temperature is about 27 Centigrade or 300 Kelvin.