Beyond the 4 Activities

Suggested extension activities on the physical science concepts introduced in PhysicsQuest

About the Extension Activities

The extension activities are supplements to PhysicsQuest 2007: Marie Curie's Floating Classes. Each of the four PhysicsQuest activities has its own set of extensions, which can be used to create more in-depth lessons on the topics introduced in the PhysicsQuest activities.

The extensions vary in both difficulty of execution and of the scientific concepts involved. Some are simple to construct and use but teach more complex scientific concepts. Others are difficult to construct and use but demonstrate simple ideas. Please try each extension before using it in class so that you can adjust the procedure to fit your students' needs.

Some extensions are best performed as demonstrations, some as whole class experiments, and others as hands-on group activities. The instructions and discussion questions for most of the activities are on a separate page from the logistical information and background, so that you can copy and distribute the instructions to students if desired. We hope that you will use these ideas to create fun, science-rich lessons for your students. For additional background on the concepts shown in the extensions and for references, see the "Suggested Resources" section at the end of each extension activity.

About the Materials

Most of the materials needed for the experiments in this guide are not included in the PhysicsQuest kit, but are inexpensive and available at grocery or hardware stores. If you need more liquid crystal thermometers, they are available in the aquarium section of any pet store. Links to suppliers for hard to find items are included within the instructions.

The materials list for each experiment provides the items necessary for one set-up of the activity. If you have students working in groups, you will need to multiply the amount of materials needed by the number of groups that will be performing the activity.

Activity 1 — 1 Visualizing Conduction

Watch as heat travels along a piece of metal.

Caution: Be careful when handling hot water!

Materials

Liquid crystal paper

Piece of metal

Styrofoam cup

Hot water

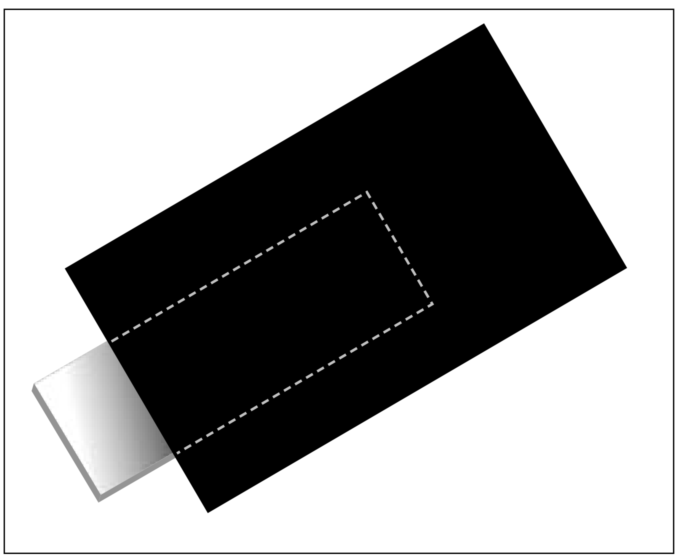
Scissors

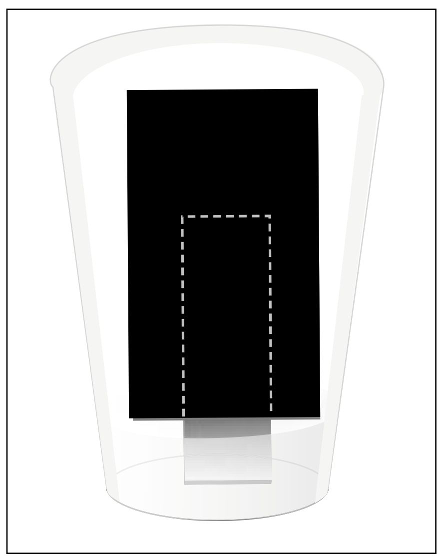
Ruler

Tape or glue

Instructions

1. Cut a piece of liquid crystal paper about 2" x 4".
2. Touch the liquid crystal thermometer with your fingers. What happens? If nothing happens, rub your hands together for a few seconds and try again.
3. Tape or glue the piece of liquid crystal paper to one end of the metal, as shown in the picture. Make sure some of the metal is left uncovered.
4. Fill the cup with very warm water until the water is about an inch deep.
5. Put your apparatus in the cup, metal end first. Be careful not to let the water touch the liquid crystal paper.
6. Watch what happens to the liquid crystal paper. Write down the colors changes that you see.





Discussion Questions

What do you think the different colors mean? What causes the colors to change?

Look for a specific shape or pattern that the colors made on the thermometer. Repeat the experiment until you are sure you have seen it!

Try replacing the metal with a different type of metal or another type of material. What can you learn about a material from this experiment?

Activity 1

FOR THE TEACHER

Visualizing Conduction

Discussion

Liquid crystals are a unique type of material — they flow like a liquid but are orderly arranged like the crystals. They are used in displays and as thermometers because they reflect different colors of light depending on their temperature.

When hot water comes in contact with the aluminum, thermal energy begins making its way up the metal — and an observer can see this happen in real time through the changing colors. Under close inspection you can see that the heat starts at a point at the bottom of the piece of liquid crystal and, as the energy travels upward, takes the shape of a flame. Eventually the temperature evens out across the metal and the colors all change together.

Most metals are good heat conductors, meaning that heat can pass through them easily. Insulators are the exact opposite of conductors; they keep heat from passing through. Insulators like foam, felt, and cotton are used to shield houses and people from cold temperatures because they keep the heat inside (or near the body). A metal jacket would not keep you very warm in the winter!

Materials

Liquid crystal sheet (Postcard Size)
You can purchase liquid crystal sheets at most science supply stores, such as Educational Innovations, http://www.teachersource.com, part number LC-3035A. $22.95 for a 12-inch square.

Piece of metal approximately 1” by 4”
Aluminum flashing works well for this and is available in the hardware store in the roofing section. Approximate cost: $10 - $15 for a 14” x 10’ roll. Smaller sections may be available upon request.

Styrofoam cup

Very warm water

Scissors

Ruler

Tape

Note: You may wish to provide other materials such as plastic, glass, or wood so that students can compare how the experiment proceeds with materials of different thermal conductivities (discussion question 3).

Suggested Resources

Liquid Crystal Thermometer:
http://en.wikipedia.org/wiki/Liquid_crystal_thermometer

Heat:
http://en.wikipedia.org/wiki/Heat_%28thermodynamics%29

Heat Conduction:
http://en.wikipedia.org/wiki/Heat_conduction

Bibliography

Liquid Crystal Thermometers:
http://www.exo.net/~pauld/activities/liquidcrystal/liquidcrystal.html

Activity 1

2 Visualizing Convection

Observe a temperature change through color using liquid crystal thermometers.

Safety: Be careful when handling the hot water and when using the lamp.

Materials

Liquid crystal thermometer

Ice cube

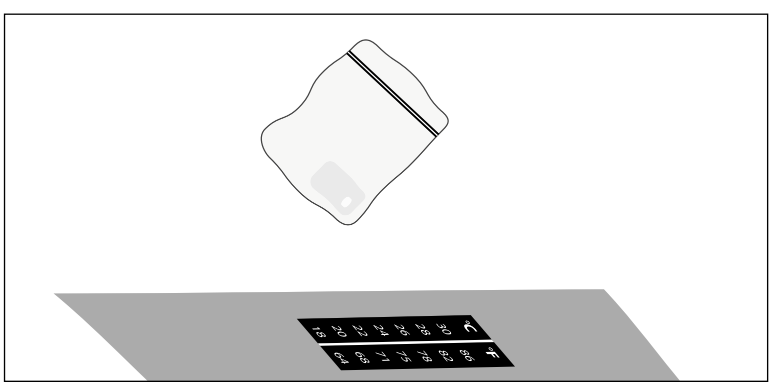
Small plastic bag

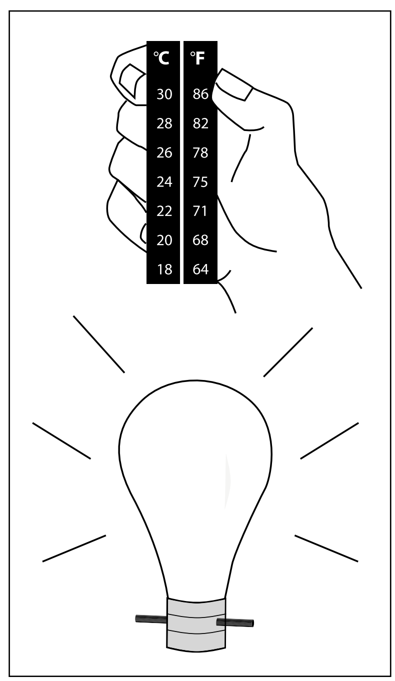
Lamp with working light bulb

Pencil and paper

Instructions

1. Observe and record the temperature shown on the liquid crystal thermometer. Make sure no one has touched it for at least a minute before you write down the temperature.
2. Turn on the lamp.
3. Hold the liquid crystal thermometer by its edges about 1cm above the light bulb. The lampshade may need to be removed.
4. For at least 30 seconds, observe how the temperature indicated by the thermometer changes. On your paper, record how the temperature changed.
5. Turn off the lamp and move the thermometer away from the lamp. Set the thermometer on a desk or table until it returns to the temperature you recorded at the beginning of the experiment.
6. Place the ice cube in the plastic bag and hold it above the thermometer.
7. Observe what happens to the thermometer and describe any changes on your paper.





Discussion Questions

What is causing the liquid crystal thermometer to change colors when it is not touching the light bulb?

Why is the liquid crystal thermometer held underneath the ice cube, and on top of the light bulb?

Activity 2

FOR THE TEACHER

Visualizing Convection

Discussion

Convection is when heat moves because of the movement of hot or cold fluids, such as air or water. The fluid motion can be caused by an external source such as gravity, which is known as natural convection or free convection. Forced convection is the circulation of fluids by a fan or a pump.

When the lamp is turned on, it begins to warm the air next to the light bulb through conduction. The warm air molecules move more quickly, which forces them to spread out. This causes the air to become less dense, so the warmer air rises. When the warm air reaches the liquid crystal thermometer the thermometer starts to change color because it detects the change in temperature. This process is convection because the heat is transported by the movement of the air.

When the ice is placed above the liquid crystal thermometer, it begins to cool the air around it. The cold air does not expand like warm air and instead becomes more dense than the surrounding air. The dense cold air flows downward, cooling the liquid crystal thermometer and causing it to change color again.

Materials

Liquid Crystal Thermometer *(included in your PhysicsQuest kit)*

Ice cube

Small plastic bag *(snack or sandwich size works well)*

Lamp with working incandescent *(not fluorescent)* **light bulb**

Pencil and paper

Note: If you have enough thermometers, it is more time-efficient to give each group two thermometers. This eliminates the wait-time while the thermometer returns to room temperature after being heated by the light bulb.

Suggested Resources

Heat:
http://en.wikipedia.org/wiki/Heat_%28thermodynamics%29

Convection:
http://en.wikipedia.org/wiki/Convection

Forced Convection:
http://www.answers.com/topic/forced-convection?cat=technology

Natural Convection:
http://www.answers.com/topic/natural-convection?cat=technology

Bibliography

Liquid Crystal Thermometers:
http://www.exo.net/~pauld/activities/liquidcrystal/liquidcrystal.html

Activity 1

3 Visualizing Sun Radiation

Watch as radiation from the Sun warms a thermometer.

Safety: Be careful when handling the hot water and when using the lamp.

Materials

Liquid Crystal Thermometer

Bright sunlight

Instructions

1. Place the liquid thermometer in the sunlight. Do not touch the thermometer once you have finished putting it down.

2. Observe how the indicated temperature changes over a period of about five minutes. You may wish to record the changes in order to track the temperature more accurately.

3. Remove the thermometer from the sunlight until it returns to its original temperature.

4. Repeat steps 1-3 tilting the thermometer at different angles or putting it in different locations. You may also want to try shading part or the entire thermometer to see what happens.

Discussion Questions

Why did the temperature reading of the thermometer change when it was placed in the sunlight?

Did you observe any differences in the way the temperature changed when you tilted the thermometer at different angles? What could have caused these differences?

What happened to the thermometer when it was kept in the shade? Use these results to predict how the high temperature on a cloudy and a clear summer day might differ.

Activity 1

3 FOR THE TEACHER
Visualizing Sun Radiation

Discussion

Radiation is a form of heat transfer that does not require any medium, such as air, for a means of travel. Radiation can come from many different sources such as the sun, an incandescent light bulb, or a radiator. Thermal radiation involves the motion of atoms and molecules. Proton and electrons are charged particles that make up atoms and molecules. Electromagnetic radiation is emitted when the charged particles move around. This is a wave that carries the thermal energy away from the surface.

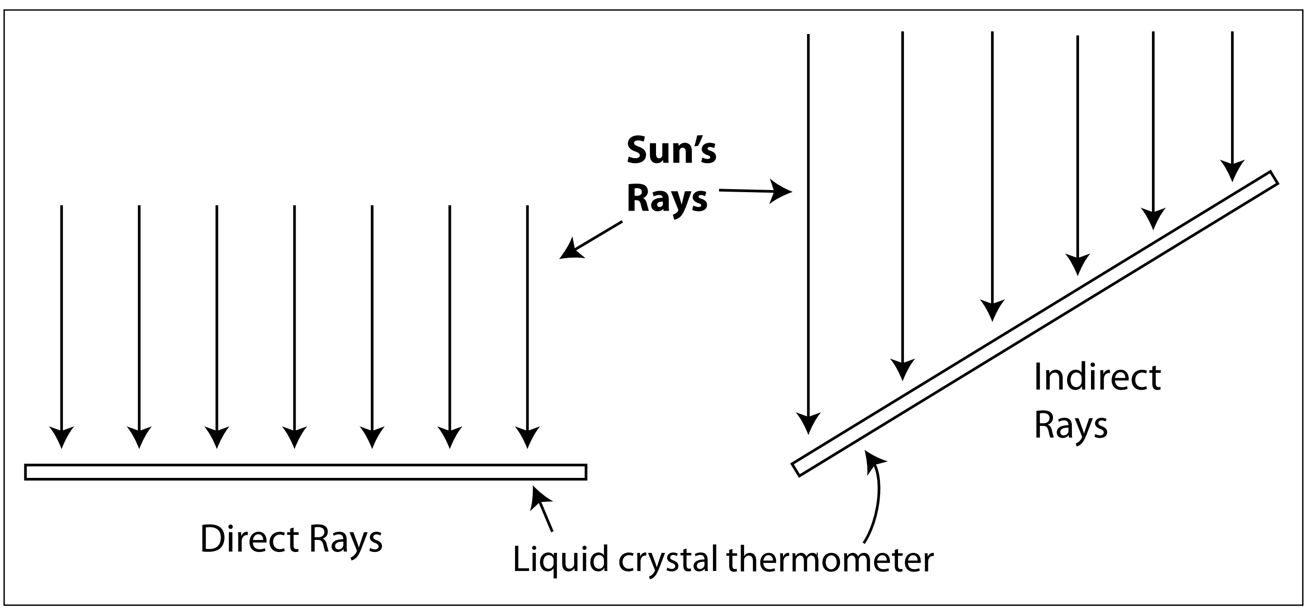
The Sun radiates light, heat, and energy. The Sun is about 93 million miles away from the Earth, so the Sun's thermal radiation must travel through space to reach the Earth. About half of the radiation reaching the Earth from the Sun is in the visible part of the electromagnetic spectrum, meaning that it has a wavelength between 400 nanometers and 700 nanometers. Most of the rest has a slightly longer wavelength and is in the near infrared portion of the spectrum. We sense this type of radiation as heat. A smaller amount has a shorter wavelength within the ultraviolet portion of the spectrum. This is the radiation that is mostly absorbed in the atmosphere, and causes sunburn from prolonged exposure.

Materials

Liquid Crystal Thermometer
(included in your PhysicsQuest kit)

The temperature of the location where you plan to conduct this activity should be within the temperature range of the thermometer.

Bright sunlight



The students should notice that the sun's radiation warms up the card faster when it is perpendicular to the sun's rays (directly facing the sun) than when the card is tilted at an angle relative to the sun's rays. In the picture above, you can see that fewer of the Sun's rays hit an angled piece of liquid crystal paper than a piece directly facing the Sun. Since fewer rays hit the angled paper, it absorbs less heat and its temperature increases slower. This result can lead to a discussion of the cause of the seasons. In the northern hemisphere the Sun's rays are more direct or "straight on" in the summer, so weather is warmer than in winter, when the rays are less direct.

When the students cast shadows on the liquid crystal thermometers, they should take note that the sun's radiation does not travel through them. This could lead to a discussion of the role of clouds in blocking solar radiation and the effects this could have on weather.

Suggested Resources

Heat:
http://en.wikipedia.org/wiki/Heat

Thermal Radiation:
http://en.wikipedia.org/wiki/Thermal_radiation

Solar Radiation:
http://en.wikipedia.org/wiki/Solar_radiation

NASA, Electromagnetic Radiation:
http://www.nasa.gov/worldbook/sun_worldbook.html

Bibliography

Liquid Crystal Thermometers:
http://www.exo.net/~pauld/activities/liquidcrystal/liquidcrystal.html

Thermal Radiation:
http://en.wikipedia.org/wiki/Thermal_radiation

Activity 2

1 Hot Leaks

See how the temperature of liquids changes the way they flow.

Safety: This experiment requires using the hot water tap and straight pins. Ask an adult to help you with this part of the experiment.

Materials

2 Styrofoam or paper cups

Paper cup

Straight pin

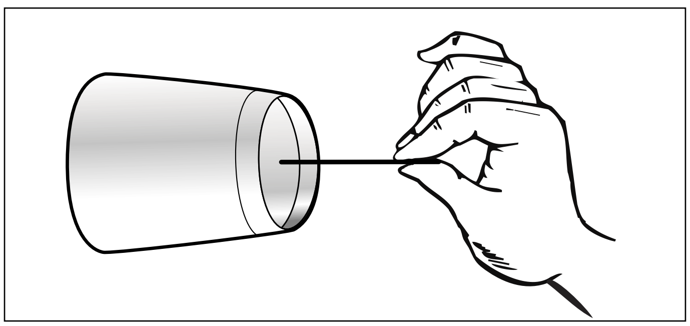
2 small clear cups

Hot water

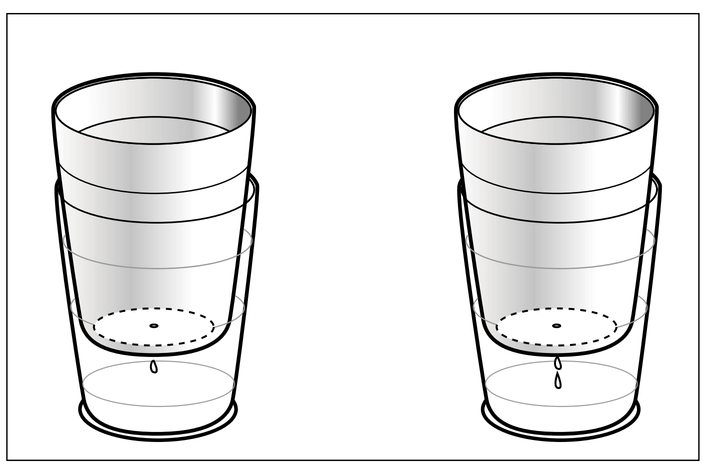
Cold water

Instructions

1. Fill the paper cup half full of cold water and then place it in a freezer for 45 minutes or until a thin icy layer forms along the surface.
2. Use the straight pin to poke a small hole in the bottom of each of the Styrofoam cups. Place each Styrofoam cup in one of the small clear cups.



3. After the 45 minutes are up, take the icy cold water out of the freezer and carefully pour the part that is still liquid into one of the Styrofoam cups making sure not to pour the part that has turned to ice in as well.
4. Turn on the hot water tap and let it run until the water is hot.
5. Place the second set of cups underneath the hot tap water and fill to same level as the cold water.
6. Set the cups side by side and observe what is taking place.



Discussion Questions

Which cup of water is dripping faster?

What is the difference between the two sets of cups?

Why might this cause a difference in how quickly the water drips out?

Activity 2

1

FOR THE TEACHER

Hot Leaks

Discussion

There is a direct relationship between the motion of molecules and their temperature. Molecules are constantly moving around, which means they have kinetic energy, and the temperature of a substance is the average kinetic energy of its molecules. Molecules with low kinetic energy move slowly and are at a low temperature. A high kinetic energy means the molecules move faster and have a higher temperature.

The hot water leaks faster than the cold water because the hot water molecules are more active and flow out of the hole at the bottom of the cup more often. The cold water molecules are moving more slowly and therefore do not flow out of the cup as fast as the hot water – or sometimes even at all!

Another way to help students understand the concept of molecule motion is to ask them to imagine themselves running around inside a room. They are just like the fast moving molecules and have a high kinetic energy. If the room had a small door, they would all be going through the door quickly. If they were moving slowly, with less kinetic energy, it would take them much longer to get out.

Materials

- 2 Styrofoam or paper cups
- Paper cup
- Straight pin
- 2 small clear cups
- Hot water
- Cold water

Suggested Resources

"Gas Molecule Motion":
http://id.mind.net/~zona/mstm/physics/mechanics/energy/heatAnd-Temperature/heatAndTemperature.html

Bibliography

Churchill, E. Richard, Loeschnig, Louis V., Mandell, Muriel, "730 Easy Science Experiments," Sterling Publishing Company, 1997.

Activity 2

2 Hot Air Balloon

Watch what happens as a balloon on a bottle is heated and cooled.

Safety: Ask an adult to help you with boiling water. Be careful not to burn yourself.

Materials

Small glass bottle

Stove top burner

Water

6 to 8 inch latex balloon

Small- to medium-sized stove pot

Potholder

Instructions

1. Pour water into the pot until it is about half full and place on burner.
2. Turn the burner on to medium-high heat.
3. Stretch the neck of the balloon and then place it over the bottle opening.

4. Once the balloon is secure and the water is boiling, carefully place the bottle in the pot with the water.
5. Observe what happens to the balloon for about the next two minutes.
6. Turn off the burner and use a potholder to remove the pot from the heat source.
7. Carefully remove the bottle from the pot or pour out most of the water.
8. Observe the balloon for about another two minutes.

Discussion Questions

What happened to the balloon when it was placed in the boiling water? Why?

What happened to the balloon when it was removed from the boiling water? Why?

What do you think would happen to the balloon if you put the bottle and balloon into the freezer? Why?

Using what you observed in this experiment, can you explain why hot air balloons seem more “full” when the flame is on at the bottom of the balloon?

Activity 2

2 FOR THE TEACHER
Hot Air Balloon

Discussion

When the balloon is placed on the opening of the bottle some air is sealed inside. During the experiment, air does not enter or exit the balloon and bottle system. As the bottle is heated in the boiling water, the temperature of the air inside the bottle increases. This temperature increase means that the molecules of warm air in the bottle move faster on average than they did at room temperature. Since the molecules are moving faster, they strike the sides of the balloon faster and more often, causing the balloon to expand.

After the pot is removed from the burner, the temperature of the air inside the bottle and balloon decreases. As the air molecules cool, they move more slowly. This makes the molecules hit the walls of the balloon less often and at lower speeds. When this happens there is less force holding the balloon in its expanded shape, and the balloon contracts back to its original size.

Students may propose that air is created inside of the bottle or that more air got into the bottle and that is what caused it to inflate. It is important to address this misconception and clarify that air neither enters nor is created in the bottle at any point in the experiment. The changes in the balloon are caused by the changing temperature of the air.

Materials

Small glass bottle

Stove top burner

Water

6 to 8 inch latex balloon

Small- to medium-sized stove pot

Potholder

Suggested Resources

Gas Molecule Motion:
http://id.mind.net/~zona/mstm/physics/mechanics/energy/heatAndTemperature/gasMoleculeMotion/gasMoleculeMotion.html

Bibliography

Churchill, E. Richard, Loeschnig, Louis V., Mandell, Muriel, "365 Simple Science Experiments with Everyday Materials," Sterling Publishing Company, 1997.

Activity 2

3 Molecular Motion

Make a model of the way molecules move in different states.

Safety: Ask an adult to help you when using the scissors.

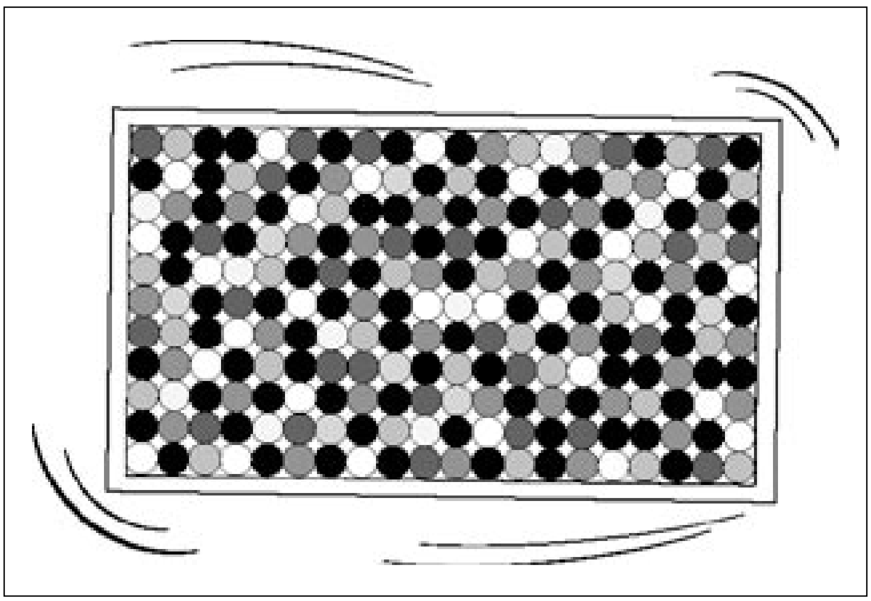
Materials

Box lid from a shoe box or something similar

Enough marbles to cover the box lid

Instructions

1. Place the marbles in the lid until they are packed tightly and cover the bottom.



2. Shake the lid back and forth. Observe how the marbles move.
3. Remove a handful of marbles and shake the lid again. Observe how the marbles move.
4. Remove all but about ten marbles and shake the lid again. Observe how the marbles move.

Discussion Questions

Which state of matter is best represented by the lid packed with marbles? (solid, liquid, or gas) Why?

Which state is best represented after some of the marbles have been removed and move around a little easier in the box lid? What about when you remove even more?

Can you think of any differences between this model of states of matter and the way molecules move in the real states of matter?

Activity 2

3 FOR THE TEACHER
Molecular Motion

Discussion

This model is good for showing the differences in how molecules move in various states of matter. At first, when the box lid is completely covered with marbles, the students should notice that the "molecules" do not have the freedom to move very much. They can vibrate and rotate, but cannot change places with other molecules. This is similar to the motion of molecules in a solid, where each molecule has a location in a lattice or organized pattern, but may rotate or vibrate at that position.

After some "molecules" are removed the marbles can move about more freely. In this case they collide often and can vibrate, rotate, and move about the box lid. This part of the model is like a liquid, because the marbles are still close together, but can now move about the box. One difference between this model and a real liquid is that if the marbles were put into a bigger box lid they would still move about the whole lid, but a real liquid has a definite volume, and only takes up a finite amount of space.

The model represents a gas when most of the marbles are removed in the last step. Here the "molecules" are very spread out, and most of the lid is empty space. The molecules can still vibrate, rotate, and move about, but they run into each other far less often. One difference between the model and a real gas is that a real gas would not be confined to the box lid, but would instead take up the space around the lid as well unless contained on all sides.

Materials

Box lid from a shoe box or something similar

Enough marbles to cover the box lid

Suggested Resources

States of Matter:
http://www.chem.purdue.edu/gchelp/atoms/states.html

States of Matter Plus Exotic States (states other than solid, liquid and gas):
http://en.wikipedia.org/wiki/List_of_states_of_matter

Activity 2

4 Float or Sink?

Watch water's strange behavior in a container with oil.

Materials

Water

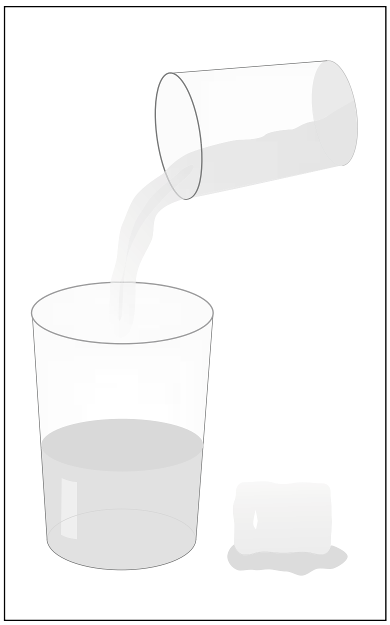
Ice cube

Vegetable Oil

Clear Plastic Container

Instructions

1. Pour oil into the container until there is enough to cover an ice cube.



2. Add about the same amount of water to the container.
3. Let the container sit for a few minutes and observe what happens.
4. Add an ice cube to the container. Observe how the ice cube's position differs from the water.

Discussion Questions

Is liquid water more or less dense (more or less heavy if you weighed the same volume of each one) than the cooking oil? How do you know?

Is the ice cube more or less dense than the cooking oil? How do you know?

If you could cool the oil enough to freeze it and form an "oil cube," where do you think it would settle in the container? Why?

Activity 2

4 FOR THE TEACHER Float or Sink?

Discussion

Layering in fluids is controlled by the density of the fluids, just as the density of a solid determines whether it will sink or float in a liquid. Density is determined by the amount of mass a material has in a predetermined volume, usually by measuring the mass and dividing the result by an objects' volume. If two objects that take up the same amount of space (have the same volume) are compared, the object with a higher density will weigh more. In this experiment, students should see the cooking oil move to the top of the container as a layer above the water. This indicates that the oil is less dense, or weighs less than water when equal volumes of each liquid are compared.

The ice cube, however, will float in the oil. Students will probably be familiar with ice floating in water, which demonstrates that the ice formed has expanded to become less dense than liquid water. The result of this experiment shows that the ice is not only less dense than liquid water, but even less dense than oil. This property of water is actually quite unusual. Most liquids become denser when cooled and frozen. Water, on the other hand, becomes more dense (contracts) as it is cooled until it reaches about 4°C, but then expands until the water freezes near 0°C. The final discussion question, which asks where an "oil cube" might settle, can help introduce this unusual property of water. Oil, like most liquids, is denser when frozen and an "oil cube" would sink to at least the bottom of the oil layer, possibly to the bottom of the water as well. It is not possible to try this experiment because oil needs to be very very cold in order to freeze.

Tips: Students may notice the curved surface of the interface between the water and oil. This is called the meniscus, and is caused by water's tendency to be attracted to the sides of containers. See the "meniscus" resource below for more information.

You may wish to have the students predict what will happen both before the water is added and before the ice cube is added. Comparing the predictions with observation can lead to a lively discussion!

Materials

Water

Ice Cube

Vegetable Oil

Clear Plastic Container
(disposable cup, plastic graduated cylinder, or other small container large enough to hold an ice cube)

Suggested Resources

Density:
http://en.wikipedia.org/wiki/Density

Meniscus:
http://en.wikipedia.org/wiki/Meniscus

Freezing oil:
http://van.physics.uiuc.edu/qa/listing.php?id=1600
http://www.newton.dep.anl.gov/askasci/chem03/chem03265.htm

Activity 3

1 Happy/Unhappy Spheres

Observe the effect of temperature on two similar, but not identical, spheres.

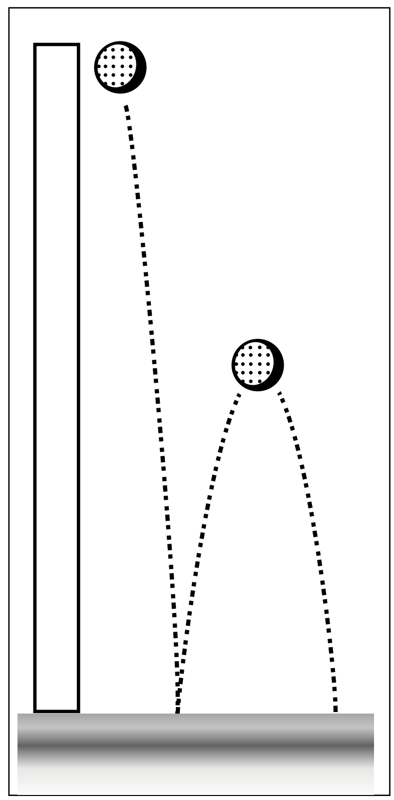
Safety: Be careful when handling the hot water. Ask an adult to help you do this part.

Instructions

1. Record the temperature of the room. The spheres should not be handled for a few minutes before the experiment so that they are at the same temperature as the room. Drop each of the spheres once to decide which spheres are happy and which ones are unhappy. (It is important that they do not get mixed up.)
2. Drop each sphere from a height of one meter onto a hard, smooth surface. Record the maximum height of first bounce of each sphere. Do this three times for each sphere.
3. Place the spheres in a bowl of near-freezing temperature water and wait about two minutes for the spheres cool to match the temperature of the water.
4. Record the temperature of the water.
5. Drop each sphere three times from one meter and record the bounce heights as in step 2.
6. Place the two spheres into the water again and add warm water or wait until the temperature of the water increases by about 5 degrees Celsius.
7. Repeat steps 4-6 until the water and spheres reach room temperature.
8. Place the spheres into the bowl of hot water. Water from the tap is fine, as long as it is considerably warmer than room temperature. Wait about two minutes for the spheres to warm to the temperature of the water and then record the water's temperature
9. Drop each sphere using the procedures from the above steps.
10. Place the spheres in the water again and wait for a decrease in temperature. Repeat the drops until the water and spheres reach room temperature.

Materials

- One pair of happy/unhappy spheres
- Thermometer
- Meter stick
- Two bowls
- Hot water
- Ice cold water
- Pencil
- Paper



Discussion Questions

What happened to way each sphere bounced when it was heated?

What happened to way each sphere bounced when it was cooled?

Make a graph of the height versus temperature for each sphere and compare the results.

Activity 3

1 FOR THE TEACHER
Happy/Unhappy Spheres

Discussion

The two black balls have the same shape and diameter, but there is a distinct characteristic that is not so noticeable at first. When the balls are dropped onto a flat, hard surface, they behave very differently. This is because the happy ball is made of neoprene, a common synthetic rubber used in wetsuits and laptop sleeves, and the unhappy ball is made of a polymer called Norbornene. This material, which is sometimes used in artificial leather, has a low restitution elasticity, which means that the ball absorbs much of its kinetic energy, or energy of motion, upon impact. When the unhappy ball hits the ground, its kinetic energy is converted into other forms of energy such as deformation of the ball, sound, and heat.

When testing the temperature dependence on the bounce of both balls, each ball should behave very differently. When the balls are warmed, the happy ball bounces higher and the unhappy ball remains the same: it hardly bounces at all. When the balls are placed in the near-freezing cold water, the happy ball bounces less high and the unhappy ball bounces much higher than before! We don't fully understand why this occurs; perhaps the next generation of scientists will investigate further and figure it out!

After the experiment is complete, the students should recognize that the way each ball bounces depends on the temperature. The happy ball behaves as many scientists would predict: it becomes more rigid as the temperature decreases and the height of its bounce decreases. The unhappy ball, however, behaves in exactly the opposite way, showing that predictions should be questioned and tested.

Materials

One pair of happy/unhappy spheres
Happy/Unhappy Spheres may be purchase at Educational Innovations: http://www.teachersource.com/catalog/index.html

Thermometer

Meter stick

Two bowls

Hot water

Ice cold water

Pencil

Paper

Suggested Resources

Happy/Unhappy Balls may be purchased at Educational Innovations:
http://www.teachersource.com/catalog/index.html

Elasticity:
http://www.physlink.com/Education/AskExperts/ae469.cfm

Bibliography

Sock User's Guide:
http://www.spsnational.org/programs/socks/2006sock_guide.pdf

Activity 3

2 Soda Bottle Collapse

Materials

20oz plastic soda bottle (empty, label removed)

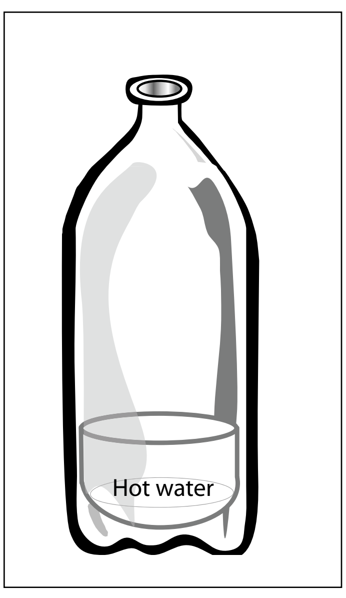
Hot water

Watch what happens as a soda bottle cools.

Safety: Be careful not to burn yourself with the hot water.

Instructions

1. Fill the empty bottle one quarter of the way with very hot tap water.
2. Cap the bottle and swirl the water around for a few seconds to warm the whole bottle.
3. Undo the cap and pour the water into the sink. Quickly recap the bottle.
4. Observe what happens to the bottle.



Discussion Questions

What happened to the temperature of the air inside the bottle after it was recapped?

Would you have seen the same results if the cap was not on tight enough to seal the bottle?

If you assume the cap was tight enough that no air went in or out of the bottle, what made it collapse?

What happened to the pressure inside the bottle after pouring out the water and putting the cap back on?

Activity 3

2

FOR THE TEACHER

Soda Bottle Collapse

Discussion

When the water is swirled around the inside of the bottle, the air inside and the bottle itself is heated. This hot air is trapped inside when the students pour out the water and recap the bottle. Left to sit on a desk or table, the bottle and the air inside it cool, eventually returning to room temperature. The collapse of the bottle is caused by the cooling of the air inside. As the air gets cooler, the molecules in it move more slowly. This makes them run into the side of the bottle less often and with less force than when the air was hot. We call this a change in pressure. Pressure is the amount of force per unit area, so the result of fewer collisions combined with less force on the wall from each collision is a decrease in pressure.

The results of the experiment can also be explained by the ideal gas law: $pV = nRT$. In this case the temperature is decreasing. The bottle collapses until the pressure is (almost) the same on both sides of the bottle. The result is a change in volume due to temperature change.

Students might benefit from the analogy of bouncing tennis balls off an unsupported wall from both sides: if one side throws the balls much faster, or throws more balls per minute, the wall will fall away from that side. This is like comparing the inside and outside of the bottle in the experiment. Before the bottle is capped the fast moving hot air molecules can leave the bottle quickly, just like the hot water dripping quickly out of the cup in the Hot Leaks activity in section 2. When the bottle is capped the fast moving (hot) air molecules are trapped inside. For some time the fact that they are moving faster makes up for there being less molecules inside, but as the molecules cool they get slower and no longer hit any faster than the room temperature molecules on the outside of the bottle. When this happens the pressure inside the bottle is lower than outside, and the bottle collapses.

Materials

20oz plastic soda bottle
(empty, label removed)

Hot water

Tips

Try this activity yourself before presenting it to your class to make sure the water in your classroom is sufficiently hot to show the desired results. If you want to convince your class that no air escaped after the bottle was capped run the collapsed bottle under hot water to bring it back to its normal size.

Put a balloon in the freezer to show another example of volume change with temperature. If the balloon is blown up with warm air and then cooled in the refrigerator or freezer it should shrink noticeably. To demonstrate that no air has escaped you can warm the balloon in your hands and let it expand back to its original size. Be sure not to leave the balloon in the freezer too long, or some air will have leaked out and the last part of the demonstration will be unconvincing.

Suggested Resources

Ideal Gas Law:
http://en.wikipedia.org/wiki/Ideal_gas_law

Kinetic Theory of Gases:
http://en.wikipedia.org/wiki/Kinetic_theory

Activity 3

3 Greenhouse Effect

Observe how the atmosphere keeps the Earth warm using household materials.

Safety: Never look directly into the sun.

Materials

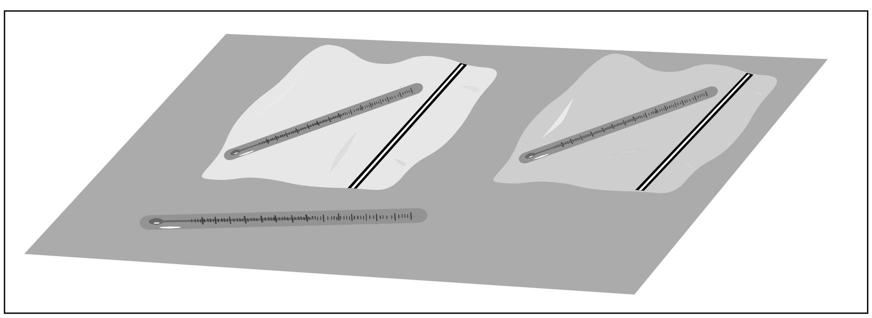
3 Thermometers
(any type that can show differences of 2°F or more, such as those included in PhysicsQuest kit)

2 Clear plastic bags
(sealable top type bag such as Ziploc® quart bags)

Grey cellophane

Instructions

1. Check that both thermometers read the same temperature before beginning the experiment.
2. Place one thermometer in a clear plastic bag. Seal it most of the way and then blow into it to trap more air and seal it completely.
3. Do the same with the second bag, but once it is blown up, cover it with the grey cellophane.
4. Wait a few minutes until the thermometers read the same temperature again.
5. Place the bags with thermometers and the free thermometer in the sun.



6. Wait about 10 minutes and then record the temperature on all three thermometers.

Discussion Questions

How did the final temperatures of the three thermometers compare?

Can you explain why the end temperatures were different? Think about heat entering and leaving the bag.

How did the cellophane wrapped bag compare to the clear bag? What practical uses can you think of for this result?

How is the experiment you preformed related to the effect that the atmosphere has on the climate of the Earth?

Why do you think this experiment is titled "Greenhouse Effect"?

Activity 3

3 FOR THE TEACHER
Greenhouse Effect

Discussion

In this activity students are observing the effect that the atmosphere surrounding the Earth has on the temperature of the Earth on a very small scale. The light from the sun easily penetrate the clear plastic bag, so that both thermometers receive about the same amount of light. When the light hits the thermometer, some of this energy is converted to heat energy. This heat energy cannot penetrate the bag as easily and is trapped inside. The heated air surrounding the thermometer that is not in a bag, however, moves away from the thermometer through conductive currents in the air as well as radiation. Think back to the extension activities in section 1. This is why the temperature inside the bag increases more than the temperature outside of the bag. In the cellophane wrapped bag not as much sunlight is getting through so the air remains a bit cooler.

We see the greenhouse effect in many everyday experiences. In the summer, cars get hot when parked with their windows up because of this very phenomenon. The sun's light can enter easily through the glass windows, but is then trapped inside the car causing the temperature to increase to as hot as 49°C (120°F). People can lessen this effect by tinting their windows, which is represented in this activity by the cellophane covered bag. Enclosed porches also warm up because of the greenhouse effect, just as the greenhouses the phenomenon is named for trap heat to help plants grow.

Students may have heard of greenhouse gasses in the negative context of human caused climate change. This may be a valuable topic to explore with your students. However, many will carry with them the misconception that the greenhouse effect is always a bad thing. This activity can help them realize that the greenhouse effect helps regulate Earth's climate and that without it the Earth would be much colder. However the greenhouse effect could also make the Earth too hot which is why it is currently seen as negative.

Materials

20oz plastic soda bottle
(empty, label removed)

Hot water

Suggested Resources

The Greenhouse Effect:
http://en.wikipedia.org/wiki/Greenhouse_effect

Greenhouse Effect Background Material:
http://www.ucar.edu/learn/1_3_1.htm

Activity 4

1 Smashing Spheres

Watch as energy changes form when steel spheres are smashed together.

Safety: Be careful when smashing the spheres. Do not smash your fingers or your friend's hand!

Materials

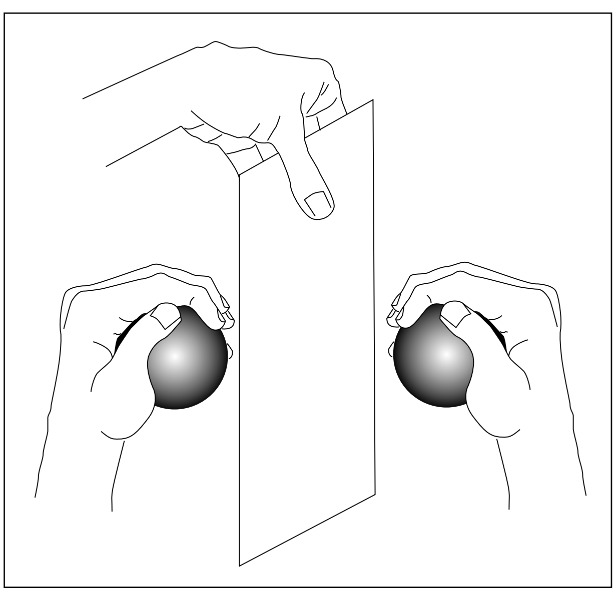
A set of smashing steel spheres

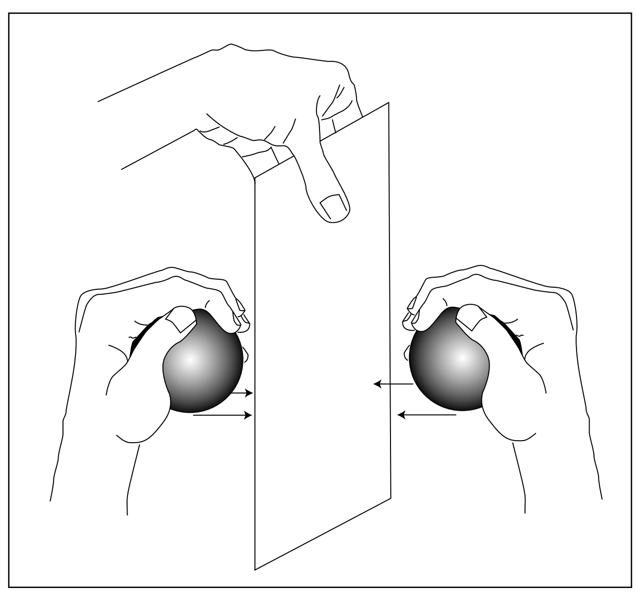
Pieces of paper

A friend

Instructions

1. Hold a steel ball in each hand
2. A second person should hold a piece of paper vertically in front of their body.
3. The person with the spheres should hold one sphere in each hand and place their hands on each side of the paper.
4. When both partners are ready, the person with the spheres can smash them together with the paper in between!
5. Observe what happened to the paper and repeat as desired.





Discussion Questions

What happened to the paper after the spheres were smashed? Is this what you expected?

What do you think caused this result? Where did the energy come from to cause this change?

What might happen if you used thicker paper or different sized spheres in this experiment? Why?

List some other types of energy. Use examples from your experience.

Activity 4

1 FOR THE TEACHER
Smashing Spheres

Discussion

The smashing spheres provided in the kit from Educational Innovations, Inc. weigh one pound and are two inches in diameter. When smashed together, the energy from their motion is converted into enough heat to burn a hole in a piece of paper!

In this experiment kinetic energy is converted into thermal energy, or heat, which causes the paper to burn at the place of contact. Some energy from the balls' motion is also converted into sound waves as the spheres collide, which results in the loud crack you and your students hear.

The energy in the system (spheres and paper) is initially in the form of kinetic energy, or the energy of motion. In this case the kinetic energy is in the form of translational motion, since the entire sphere is moving toward the paper. Kinetic motion can also be vibrational, as in molecules vibrating within a material, or rotational, like when a wheel spins around its own center while the entire wheel does not change its position.

When the two spheres collide they stop, which means they no longer have translational kinetic energy. This energy must go somewhere because energy is conserved overall. Some of the energy from the collision is converted to thermal energy, or heat. This heat changes the temperature of the paper and warms it enough to burn a small hole. The rest of the energy creates sound waves, which we hear as a crack. Some energy may also remain in the balls and cause them to vibrate when they collide.

The smashing spheres are just one example of conversion from one form of energy to another. To extend the concept of conservation of energy farther you may wish to discuss where the energy one partner used to move the spheres came from. The food chain can be used to illustrate that our energy comes from food, while the energy in our food comes from plants and ultimately from the Sun.

Materials

A set of smashing steel spheres
Smashing steel spheres may be purchased from Educational Innovations, Inc. here: http://www.teachersource.com/Energy/EnergyConversion/Smashing_SteelSphereDemoKit.aspx

Pieces of paper

A friend

Suggested Resources

Smashing steel spheres may be purchased from Educational Innovations, Inc. here:
http://www.teachersource.com/Energy/EnergyConversion/Smashing_SteelSphereDemoKit.aspx

Mechanical Energy:
http://en.wikipedia.org/wiki/Mechanical_energy

Activity 4

2 Cold Wave

Observe a chemical reaction that lowers the temperature of water.

Safety: Be careful when handling the Epsom salt solution.

Materials

Thermometer

Epsom Salt

Tap water

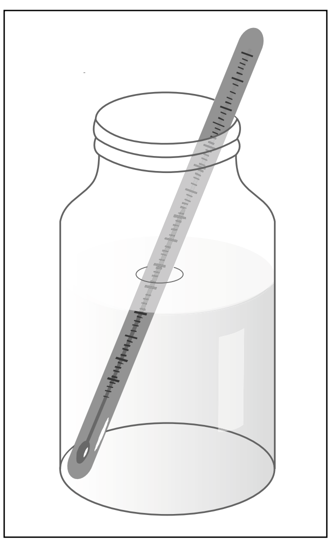
Spoon

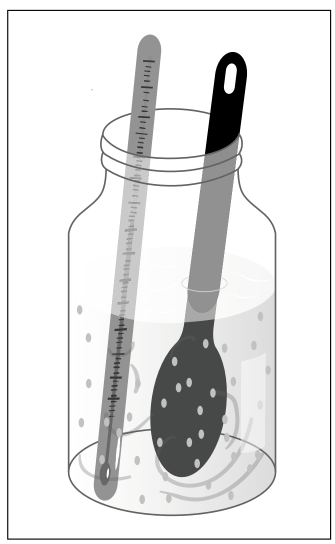
Medium glass jar

Pencil and paper

Instructions:

1. Wash the glass jar thoroughly and then fill it ¾ of the way with tap water. Allow the jar to sit for a few minutes so it can reach room temperature.
2. Feel the sides of the jar and take note of the temperature.
3. Place the thermometer inside the jar and wait for a couple of minutes. Record the temperature of the water in the jar.





4. Use the spoon to carefully add 4 spoonfuls of Epsom salt to the water. Being careful to avoid hitting the thermometer, stir the solution until the salt is completely dissolved.
5. Feel the sides of the jar and then record the temperature of the water.

Discussion Questions

What happened to the temperature of the water inside the jar?

Is heat absorbed or produced by this reaction?

Where did the heat go?

What uses can you think of for this solution?

Activity 4

2 FOR THE TEACHER Cold Wave

Materials

Thermometer
(Included in PhysicsQuest kit)

Epsom Salt

Tap water

Spoon

Medium glass jar
(canning jars, pasta sauce jars, or beakers work well)

Discussion

When the Epsom salts are added to the room temperature water, a chemical reaction takes place. This reaction absorbs heat from the water, so the water gets colder. The heat is used to break the bonds in the salt. Such a reaction, where heat is absorbed and cools the surroundings, is call endothermic. Students can remember this word because “endo-” means “inside” and “-thermic” means “heat” so the heat goes in from the surroundings.

Epsom salt baths are used for several medical purposes. Many people soak their feet in an Epsom salt bath to reduce soreness and swelling due to athletic injury or for improvement in circulation and nerve function. The low temperature bath helps to absorb heat from the injury while allowing the healing process to take place.

Some other examples of endothermic processes reactions include combining vinegar and baking soda, as in many science projects simulating volcanoes, and photosynthesis, the process by which plants produce food. In both of these, just like in the experiment, heat goes into the materials reacting (vinegar and baking soda solution in the case of the first reaction, and the plant in photosynthesis) and the surrounding material gets colder.

Suggested Resources

Endothermic:
http://en.wikipedia.org/wiki/Endothermic

Examples of Endothermic Processes:
http://antoine.frostburg.edu/chem/senese/101/thermo/faq/exothermic-endothermic-examples.shtml

Bibliography

Churchill, E. Richard, Loeschnig, Louis V., Mandell, Muriel, "365 Simple Science Experiments with Everyday Materials," Sterling Publishing Company.

Bonus Activity

Nuclear Chain Reaction

Observe fission reactions similar to those in a nuclear reactor.

Materials

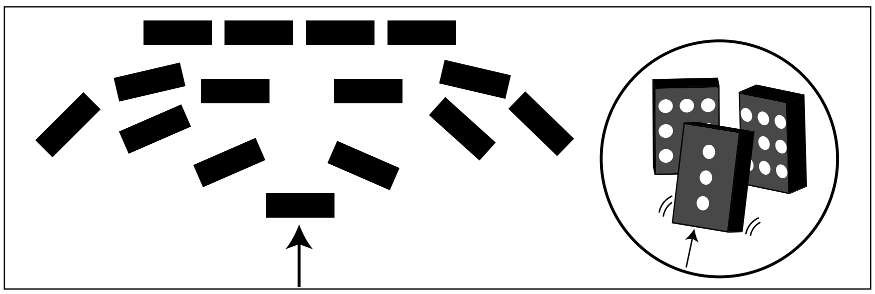
Dominoes

Ruler

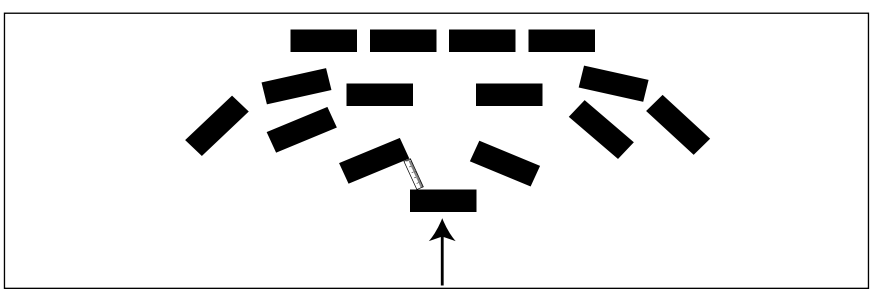
Steady flat table

Instructions

1. Arrange the dominoes in a similar formation to the figure below.



2. Knock over the domino labeled with an arrow and observe what happens.
3. Build a straight line of dominoes and knock it down.
4. Rebuild the formation from step 1.
5. Place the ruler between the domino marked with an arrow and either of the dominoes it will directly knock over. Knock over the domino marked with the arrow and note any differences from the first trial.



6. Rebuild the formation and place the ruler in another location. Knock over the domino marked with the arrow and observe that happens. Repeat as desired.

Discussion Questions

In the first formation, how many dominoes did each individual domino knock over?

How did the number of dominoes knocked over change at each step in the first formation?

How is the first formation different from a straight line of dominoes?

What happened when the ruler was placed between two dominoes?

Bonus Activity

FOR THE TEACHER

Nuclear Chain Reaction

Discussion

A nuclear chain reaction is a series of several nuclear reactions. To start the chain reaction a neutron must collide with a nucleus, or in this simulation a finger must strike a domino. Then the radioactive element involved in the reaction, such as Uranium-235, undergoes a process called fission. The Uranium-235 nucleus splits into two lighter nuclei such as strontium and xenon, and releases several neutrons and photons along the way. The neutrons strike more Uranium-235 atoms causing the fission process to start all over again. The repetitive nature of this process causes a nuclear chain reaction. The photons emitted in the process are light in the form of gamma rays, which are very dangerous to living things. The first domino formation simulates such a chain reaction. In this case each reaction triggers two more reactions. This contrasts with the straight line formation, in which only one reaction is triggered by each completed reaction.

Once fission occurs and begins a nuclear chain reaction, we sometimes need to control how many more fission reactions occur. If the number of released neutrons were not controlled, then the number of fission reactions would increase drastically (more and more dominoes would fall down, as seen in the first formation). One way to control the number of released neutrons is to use a control rod. In the experiment, the ruler acts as a control rod. Since the neutrons that are produced during the splitting of the nucleus are the reason that a fission reaction occurs, something is needed to prevent the neutrons from colliding with more Uranium-235 atoms. A control rod absorbs neutrons so more fission reactions will not take place. When the ruler is placed between two dominoes in the second formation, the ruler acts as the control rod by absorbing the released neutrons from the dominoes' fission reaction and therefore prohibits another nuclear reaction.

Materials

Dominoes

Ruler

Steady flat table

Suggested Resources

Nuclear Reaction:
http://en.wikipedia.org/wiki/Nuclear_reaction

Nuclear Chain Reaction:
http://en.wikipedia.org/wiki/Nuclear_chain_reaction

Uranium Fission:
http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/u235chn.html

Bibliography

Nuclear Chain Reaction:
http://www.energyquest.ca.gov/projects/nuclear.html

Bonus Activity

Half-Life

Experimentally determine the half-life of an M&M sample.

Materials

100 plain (not peanut) M&Ms

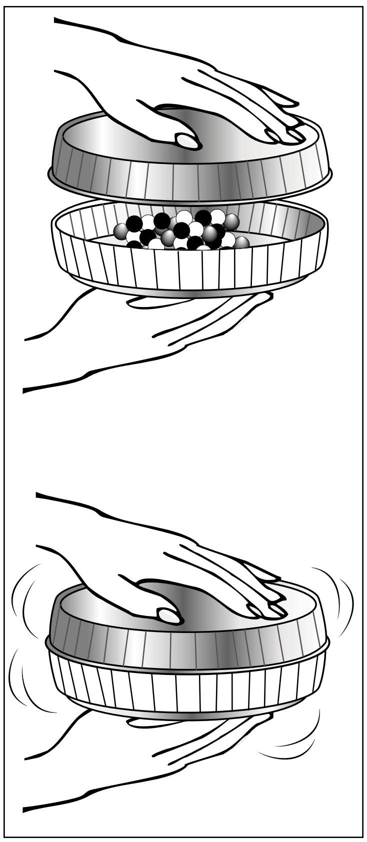
2 pie tins

Graph paper

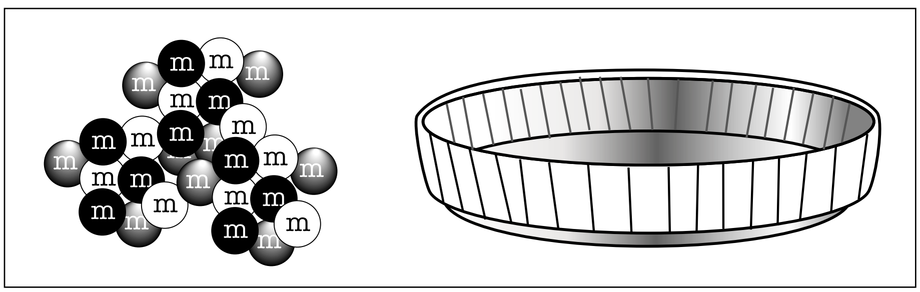
Pencil

Instructions

1. Place the candies "M" side down in one tin.
2. Cover the filled tin with the empty tin and shake the tins gently. Make sure that the tins are shaken enough to bounce the candies around the improvised container.



3. Remove the top tin and take out all the "changed" ("M" side up) candies in the bottom tin.



4. Record the number of "changed" candies and "unchanged" (still "M" side down) candies in a chart similar to the one below. You may need to add space for more trials at the bottom of the chart.
5. Repeat steps 2, 3, and 4 until all the candies have flipped. Each time you record the number of "changed" candies write down the total number outside the tin, not just the ones removed in the last trial.
6. Graph the information from the chart on the graph paper. Draw a smooth curve through the data.

Trial	Number of “changed” atoms	Number of “unchanged” atoms
0	0	100
1		
2		
3		
4		
5		

Discussion Questions

Can you see a pattern to the decay of the candies? Describe it.

How many tosses does it take before half the candies have decayed?

During each shake, what were the odds that any one M&M would change?

Bonus Activity

FOR THE TEACHER

Half-Life

Discussion

The half life of something describes how long it takes for half of it to decay, or change. In this activity, the students measure the decay or change rate of M&M candies. Depending on how they shake the tins the students may find different decay rates. It is important that the students shake the tins in a consistent way for their data to make sense.

In science, decay rates are usually found for radioactive isotopes of different elements. For example, beryllium-11 (beryllium with 4 protons and 7 neutrons) decays into boron-11 (boron with 5 protons and 6 neutrons). We describe the rate at which this happens by measuring the isotope's half-life. The half-life is a measurement of how long it takes for half of a sample to decay. For beryllium-11 decaying into boron-11 the half-life is about 13.8 seconds, so after 13.8 seconds half of the beryllium-11 you started with will have decayed into boron-11. If you wait another 13.8 seconds, half of the remaining beryllium-11 will have decayed, leaving only 25% of the original sample in its original form.

This process will happen the same way regardless of the size of the sample, so it is a great way to find out how long a sample of a radioactive isotope has been sitting around. The half-life of a dangerous radioactive isotope can also be used to determine how long to wait before it is safe to expose humans or other living things to the sample. It is necessary to wait much longer to open a sample of radioactive material with a long half-life because the material decays into safer isotopes more slowly.

The students can find the half-life of the M&M candies by checking how many trials it takes for half of the candies to flip over. If they are consistent they should find that when they repeat the experiment with a different number of M&Ms the half life will be about the same.

Materials

100 plain (not peanut) M&Ms

2 pie tins

Graph paper

Pencil

A description of the use of the half-life of carbon-14 from *Active Physics Predictions***:**

Geologists and archaeologists take advantage of the known half-lives of common nuclei to date materials that contain these nuclei. The nucleus used to develop radioactive dating was one type of carbon called carbon-14 because it has 6 protons and 8 neutrons, 14 particles total, in its nucleus.

The half-life of carbon-14 is 5730 years. Every half-life, the radioactivity of the carbon-14 atom decreases by half. Living things like plants or animals absorb carbon-14, which is produced in the atmosphere by cosmic radiation, and build it into their tissues along with other kinds of carbon. When they die, the carbon-14 in their tissues decays. By measuring the remaining radioactivity due to carbon-14 in a long-dead sample, archaeologists can determine how many half-lives the material has been dead.

Tips

For a little variety you may wish to have some students work with sugar cubes that have been marked on one side with marker or food coloring. The students should start with the marked side down and only remove the cubes that have the colored side facing up at the end of each trial. Since the cubes have six sides instead of the two sides of the M&Ms, a smaller percentage of the cubes "decay" after each trial and the cubes show a longer half-life. This difference demonstrates that different isotopes have different half-lives based on their properties.

Suggested Resources

Half-Life:
http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html

Bibliography

Eisenkraft, A., *Active Physics, Predictions*, American Association of Physics Teachers, 1995.

Radioactive decay graph from http://home.earthlink.net/~bhoglund/radiation_Facts.html

Below is a sample graph of radioactive decay. The students' graphs should show a similar shape, though the axes should be "Unchanged M&Ms instead of "Amount" and "trials" instead of "Time (in Years)."