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Critical Thinking/ Problem Solving

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To the Teacher

Critical Thinking/Problem Solving worksheets in this booklet exercise the students' abilities to apply thinking skills to situations related to concepts presented in the student edition. Students will apply their knowledge to a new situation, analyze the new information, and synthesize in order to respond in a creative way. A series of responses that students might give are provided for you at the end of this booklet.

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Critical Thinking Problem Solving

Table of Contents

To the Teacher ii

Skills Correlation iv

Activities

1 Testing the Waters 1

2 Breaking All the Records 2

3 Power from Fluids 3

4 Discovering Hidden Planets 4

5 New Insulation for Space Shuttles 5

6 The Appeal of Perpetual Motion Machines 6

7 Stonehenge—An Engineering Marvel 7

8 Energy-Saving Refrigerators 8

9 Radon Risk 9

10 What's the difference? 10

11 Ancient Mysteries and Carbon-14 Dating 11

12 Pollution Goes Undergound 12

13 The Birth of an Element 13

14 Gasoline—Finding a New Formula 14

15 Building Materials of the Future 15

16 Acid Precipitation Report Card 16

17 Environmentally Friendly Cars 17

18 Pole Reversal 18

19 Patient-Friendly Cancer Treatment 19

20 Regulating Nuclear Power Plants 20

21 Supersonic Impact 21

22 Treating Cancer with Light 22

23 Swimming with Sharks 23

Answer Key 24

Critical Thinking / Problem Solving Skills Correlation

	Activity																						
Skill	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Clarifying issues														✔									
Comparing and contrasting						✔	✔								✔							✔	
Developing a perspective																	✔			✔			
Distinguishing relevant from irrelevant facts																✔							
Drawing conclusions				✔						✔									✔		✔		
Evaluating information					✔				✔														
Examining and evaluating assumptions		✔				✔		✔			✔	✔						✔					
Extrapolating data/ information													✔						✔				✔
Generating and assessing solutions	✔		✔					✔				✔					✔						✔
Making a hypothesis	✔														✔							✔	
Making predictions or interpretations		✔												✔									
Making judgments																							
Observing and inferring							✔		✔	✔	✔					✔							
Recognizing cause and effect			✔	✔	✔								✔					✔			✔		
Summarizing/synthesizing				✔			✔		✔														

Problem Solving

Testing the Waters

Activity 1

No one knew why fish were dying in Oshkosh, Wisconsin. Every year, one or two major fish kills occurred on the Fox River that flows through the town. Fish kills are not unusual. They can be caused by natural events such as the stress of spawning or lack of dissolved oxygen in the water. But, the number of fish being killed was so large that something unnatural seemed to be the cause.

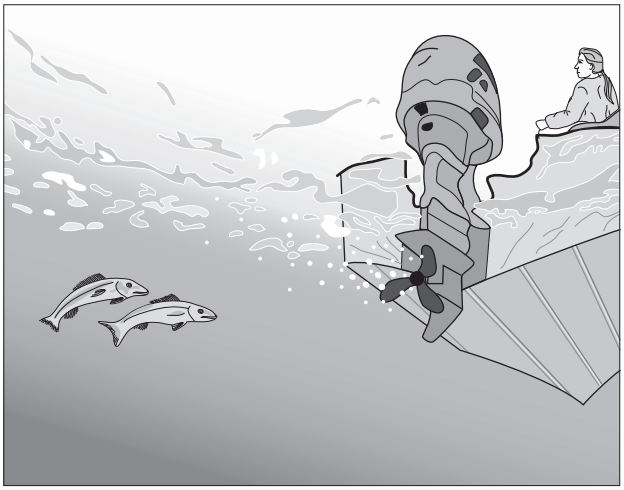
Searching for Clues

Scientists began to investigate. They tested the water and the fish for known causes of fish kills—pesticides, herbicides, toxic waste, and toxic metals. These substances were not causing the problem, so scientists measured the level of chlorine in the water. Chlorine was being used to treat sewage at a water-treatment plant located near the river.

Researchers hung cages of live fish directly in the water-treatment plant's discharge. The fish lived, which indicated that chlorine from the water-treatment plant was not the cause of the problem.

The search continued. Scientists had noticed an outboard motor plant across from the water-treatment plant a few hundred meters downstream. They found that the plant tested its new outboard motors in the river, running several motors at once. Outboard motors vent their exhaust into the water to muffle the noise.

Scientists hypothesized that the carbon monoxide coming from the motors' exhaust pipes might be the cause of the problem. Too much carbon monoxide in the water can restrict the flow of oxygen through the blood.



Outboard motors inject carbon monoxide into the water.

Testing a Hypothesis

Scientists found no evidence that carbon monoxide had ever caused large fish kills in the area. Still, they wanted to test their hypothesis. They performed a series of tests in the lab and at the river. They discovered that high levels of carbon monoxide were, in fact, killing the fish. The plant was testing more powerful motors than it had tested in the past. These motors were injecting more carbon monoxide into the water than the less powerful motors did in the past. The new fish kills were the result of these higher levels.

After scientists notified the company of their results, the company installed an exhaust ventilation system. This system helped prevent carbon monoxide from entering the water. No fish kills have been reported since the installation of the ventilation system.

Applying Problem Solving Skills

1. If scientists had discovered that the outboard motor plant was not polluting the water, what step would you have recommended that they take next?
2. According to some researchers, one result of the increase in carbon dioxide in the air from the burning of fossil fuels is that the ocean absorbs more of it. Based on the findings in this article, what might be a result of increased carbon dioxide levels in the ocean? Form a hypothesis and suggest one way in which you would test your hypothesis.

Problem Solving

Breaking All the Records

Activity 2

Every two years, the Olympic games give athletes around the world a chance to compete. The performance of Olympic athletes improved dramatically in the twentieth century. The distance of the men's long jump increased by 66 percent. The distance of the shot put increased by 100 percent. The length of the ski jump increased by 700 percent.

Four-Minute Mile

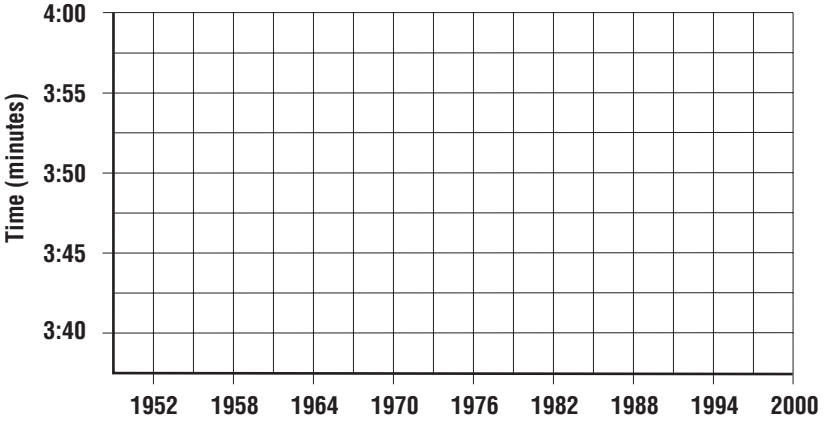
Advances in training techniques, sports science, and sports medicine have led to these improvements. One of the improvements that generated the most attention was the mile run. Before 1950, people thought that no one could run the mile in less than 4-min. Now, however, most world-class athletes routinely break the 4 min mile record. In fact, in 1999, Hicham el Guerrouj broke the 3-min, 45-s mark.

Dr. Trevor Kitson of Massey University in New Zealand compared records for the mile run with the dates of those records. He observed that the graph of this data was a straight line. From the graph, he predicted that the mile might be run in 3 min, 30 s by the year 2033. By following the line downward to the *x*-axis, it looked as though the mile would be run in 0 min, 0 s by the year 2528.

Predicting Performance

Of course, running a mile in 0 min, 0 s is impossible. Still, Kitson's graph provided an interesting look at sports improvements over time. Which improvements will happen next? When will they happen? What limits might someday be reached?

Date	Runner	Mile run time
1954	Sir Roger Bannister	3:59.4
1967	Jim Ryan	3:51.1
1985	Steve Cram	3:46.32
1999	Hicham el Guerroj	3:43.13



Applying Problem Solving Skills

1. Use the blank graph above to construct a graph similar to the one constructed by Dr. Kitson. Use the information in the table. Are the points in a straight line?
2. What probably will happen to the shape of the graph of mile-run records versus years as time goes on? Draw a sketch of the possible graph on another sheet of paper.

Problem Solving

Power from Fluids

Activity 3

What makes a vehicle come to a stop when the driver steps on the brakes? In a car or a truck, the driver is applying pressure to a fluid. Using fluids to operate or move an object is called hydraulics.

Pascal's Principle

Liquids and gases are classified as fluids. A fluid has the ability to flow. It is known that a fluid exerts pressure in all directions. Pressure is defined as the amount of force applied over a given area.

Blaise Pascal (1623–1662) combined these two concepts into an idea now known as Pascal's principle. It states that pressure applied to a confined fluid is transmitted unchanged throughout the fluid. The advantage gained by Pascal's principle is that an input force over a small area is translated into a large force over a large area (with equal pressure at both ends).

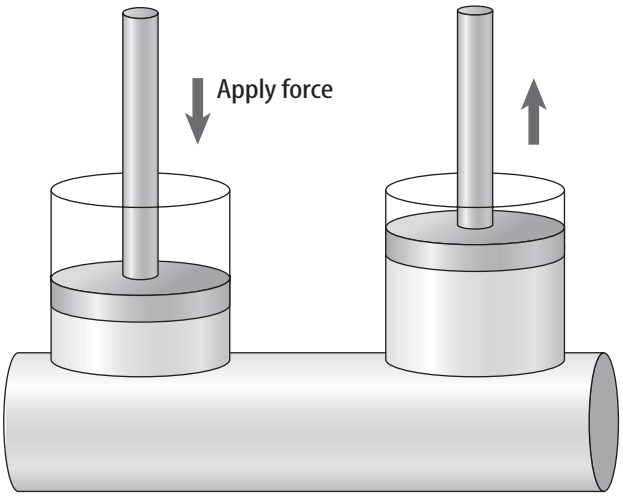
The hydraulic brake system of a car is an application of Pascal's principle. Hydraulic brake systems use a pressurized liquid to do the work. When the brake pedal is pressed, the master cylinder presses on the brake fluid in the brake lines. This same pressure is transferred to the brakes. At each wheel, the brake system uses this pressure to exert a force on brake shoes or discs. These cause the car to stop by rubbing against the wheels.

Increasing Force

With hydraulics, it's easy to increase the amount of force. It's done by trading force for distance. The input force on a small area moves over a long distance, while the large force on a large area moves through a proportionally smaller distance. Although a larger force may be generated, the work done is the same.

Liquid versus Gas

Why is a liquid used in brake lines instead of a gas, such as air? A liquid cannot be compressed. When it is put under pressure, its density does not change. A gas, however, is compressible. If a gas were used in a brake system, pushing the pedal would just compress the gas. It would not make the brakes move. That's why it's important to remove or "bleed" air from the brake lines when brakes are serviced on a car.



Applying Problem Solving Skills

1. Pascal's principle states that when pressure is exerted on an object, it puts an equal amount of pressure on another object in that system. What would be one way to increase the amount of pressure being exerted from one object to another?
2. The brakes on your family car do not work as well as they used to. What might be the problem?

Critical Thinking

Discovering Hidden Planets

Activity 4

In the first half of the 1800s, astronomers noticed that there was something wrong with the orbit of the planet Uranus. It wasn't following quite the right orbit for a planet that is affected just by the gravity of the Sun and the gravity of other planets. The orbit had an unexpected acceleration that resulted in a little wobble. This wobble in Uranus's orbit led scientists to hypothesize that another planet must be pulling on Uranus. It wasn't long before Uranus's neighbor, Neptune, was discovered.

Looking for the "Wobble"

Like tireless detectives, astronomers continue to improve on their methods of finding and following clues in space. Scientists have identified 50 planets outside our solar system and more discoveries are likely on the way. Astronomers made these findings with tools that allow them to detect and measure the effects of gravity on objects in the universe.

One technique scientists use is the Doppler effect. As an object is pulled by a planet's gravitational field and moves relative to Earth, its light frequency changes from blue (when the object is closer to Earth) to red (when it is farther from Earth). Scientists placed bottled iodine vapor on the focus of a telescope, removing certain colors from the light spectrum, and found six planets. This technique allows scientists to detect slight shifts in the light frequency of stars as planets move around them. Measuring the shift in the color spectrum tells scientists about the orbit and mass of the planets.

Sometimes, because of the angle of planets, the length of time of their orbits, or the massive amounts of dust in young planetary systems, measuring light shifts is impossible. In those cases, scientists also look at the spiral patterns planets leave in the dust disks where they form. The patterns tell scientists about the size and orbit of individual planets. This method helped scientists locate a planet ten times the mass of Earth orbiting the star Beta Pictoris.

Using Radio Telescopes

Radio telescopes also allow scientists to explore space objects that do not show up with light-sensing techniques. Radio waves can detect objects in young planetary systems with lots of dust. This technique helped researchers find a young star cluster—less than 1 million years old—in the beginning of its formation.

Because of improved technology, the ability to identify planets has increased dramatically over the last five years. Scientists have even found a multi-planet system around the star Upsilon Andromedae. NASA plans to launch a space telescope mission to look for new planets.

Applying Critical Thinking Skills

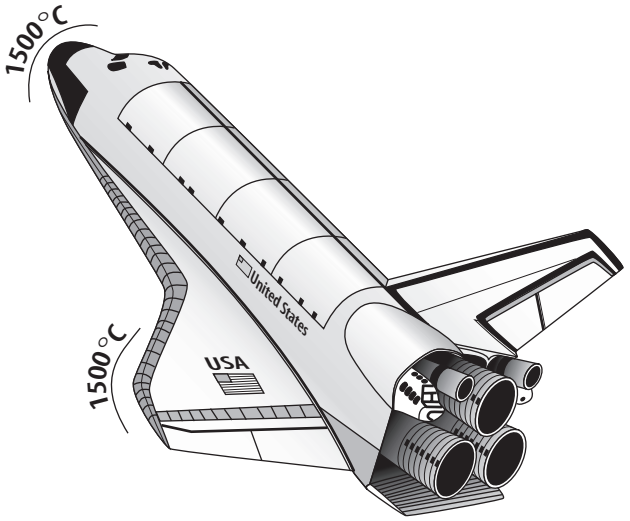
1. What would happen to the motion of a spacecraft if it traveled near asteroids or comets?
2. When would the orbit of Uranus be most affected by Neptune?
3. A person who weighs 45.4 kg on Earth would weigh only 7.6 kg on the Moon. This difference is related to the difference in mass of the Earth and the Moon. Write a general statement that expresses the relationship between mass and gravitational force or weight.

Problem Solving

New Insulation for Space Shuttles

Activity 5

Imagine a vehicle designed to withstand temperatures ranging from –156.7°C to 1,648.9°C and hundreds of voyages out of Earth's atmosphere into space and back again. Space shuttles, designed for repeated space missions, are continuously being improved to make them better insulated against such extreme temperatures.



Space shuttles are designed to withstand intense heat.

Extreme Heat

When a space vehicle reenters Earth's atmosphere after orbiting Earth, it is subjected to high temperatures caused by air friction. The amount of heat depends on the shape of the vehicle and its position during re-entry. On a space shuttle, the nose and some parts of the wings encounter the highest temperatures during reentry.

Before shuttles became a part of the space program, little consideration was given to reusing the materials that shielded space capsules from heat. Heat shielding involved using materials that would vaporize upon reentry.

Today's space shuttles are made of materials that can withstand hundreds of trips into space. A thermal protection system with reusable materials protects the crew and contents of the shuttle from the heat of reentry, the cold of space, and the ice that forms on fuel tanks when the vehicle is awaiting launch.

Space-Age Insulators

A variety of materials are used as insulators. Most of them contain silica fibers. These materials are nonconductors. They work by preventing heat from passing to the shuttle's surface. In addition to being good insulators, materials must be strong, lightweight, flexible, and reusable.

NASA has made improvements on older versions of tiles that were used to cover the outside of spacecraft. Some of them now have a layer of a substance called aerogel made of silica, alumina, carbon, or other materials. The aerogel acts like a vacuum. It does not allow air or any other gas to transmit heat through the material.

Installing the Tiles

Each tile is installed over a slightly flexible pad. It is held in place with a silicone rubber adhesive. Depending on the amount of protection needed, the tiles vary in thickness from about 1/2 cm to almost 4 cm. Different types of tiles are used in different areas. Black tiles cover places that reach temperatures no higher than 1,260°C; white tiles cover areas that reach temperatures no higher than 648.9°C.

Some parts once protected with tiles now are covered with a new material called reinforced carbon-carbon. This material covers surfaces, such as the area from the nose cap to the nose landing gear doors, that are exposed to temperatures greater than 1,260°C. Insulating blankets, which are easier and cheaper to maintain than tiles, replaced tiles on the mid-body section of the shuttle *Columbia.*

Applying Problem Solving Skills

1. Why do you think the tiles that cover the outside of the spacecraft must be flexible?
2. Why would the nose encounter more intense heat than other parts of the shuttle during reentry?

Problem Solving

The Appeal of Perpetual Motion Machines

Activity 6

Machines are supposed to make work easier. Is it possible to build a machine that will run endlessly on its own after it is started, with no outside energy source? Some creative thinkers in the seventeenth century tried to build such a machine. At that time, building a perpetual motion machine was a popular topic among tinkerers and would-be inventors. Thousands of designs were created. Some were actually built.

A Good Idea, but . . .

Take, for example, one design for a perpetually spinning wheel. It put to use many known simple machines—wheels, gears, levers, inclined planes, and a giant moving screw called an *auger*. A large wheel had compartments to hold heavy wooden balls. It resembled a Ferris wheel with a wooden ball in each "seat."

Instead of getting on at the ground level, a wooden ball would be dropped into the top compartment from above. Then the weight of the ball would make the wheel turn. When the ball got to the bottom of the wheel, it would roll out of its seat, down a chute, and into an auger, and it would be powered by gears and levers attached to the turning wheel. The ball would then ride to the top of the auger like it was an elevator. When it was at the top, the ball would drop onto the wheel again.

Facts of Friction

As balls kept dropping and rolling, the wheel would keep spinning over and over forever, right? Wrong. What the inventors didn't think about was friction. When the wheel spun, balls rolled, or gears turned, surfaces came into contact and friction occurred. Enough energy was lost to friction that the wheel could never get started. Despite all their complexity, this and other perpetual motion machines failed to deliver.

Breaking the Laws

The first two laws of thermodynamics, formulated in the nineteenth century, explain why the machines cannot work. The first law, the law of conservation of energy, states that energy cannot be created or destroyed but always converts it into another form. The machines must lose some energy when they operate; through friction, for example. The second law states that the loss of a machine's energy could be redirected back to the machine only by an outside power source.

Interest in perpetual motion machines seemed to wane when the internal combustion engine was invented. Tinkerers turned their attention toward using engines to make jobs easier.

Applying Problem Solving Skills

1. Sometimes, when calculating the work input and work output of machines, an ideal machine is used as a model. An ideal machine is not real because it does not create friction and no energy is converted to heat. It is used because work input equals work output. How does an ideal machine compare to a perpetual motion machine?
2. What assumption is made about the amount of energy input and output in the perpetual motion devices? Why was it unrealistic to expect them to work?

Problem Solving

Stonehenge— An Engineering Marvel

Activity 7

In southern England on Salisbury Plain stands a group of huge stones. Called megaliths, the stones are part of a structure created by people who lived in prehistoric Europe. The structure, called Stonehenge, is considered to be one of the most remarkable achievements of prehistoric engineering. How could people have possibly moved such heavy stones over such a long distance and then set them in place?

Where did they come from?

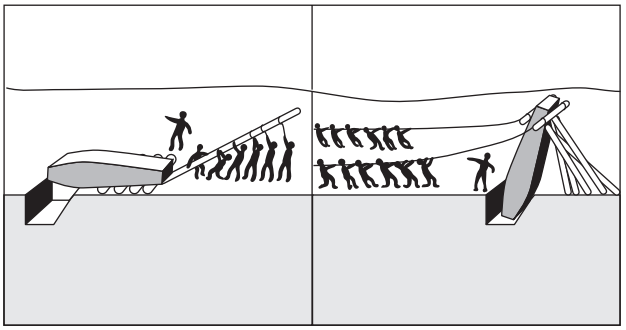
Stonehenge is estimated to have been built in phases between 3100 B.C. and 1500 B.C. It includes stone and timber structures, and carved earthen ditches and banks. One type of stone used in the monument, bluestone, is found hundreds of kilometers away in the Preseli Hills in southwest Wales. The heaviest pieces of stone, called the sarsens, likely came from a site 30 km north of Stonehenge. The stones form a horseshoe surrounded by a circle and originally were topped with smaller stones called lintels.

How were they moved?

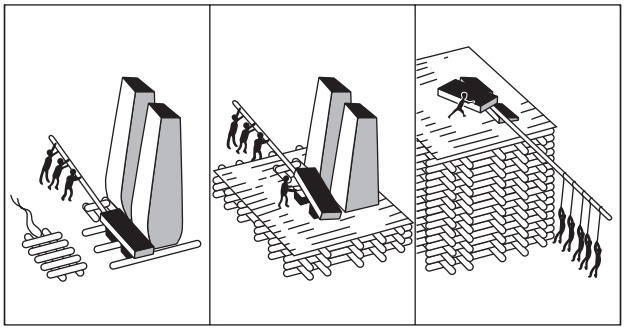
The question of how the stones were moved has intrigued scientists for years. One theory is that they were moved by boat, then dragged on sledges and rollers. A sledge is a low platform with runners. It resembles a sled. To pull the heaviest stones up hills, about 500 people would have been needed to pull the ropes on the sledges. An extra 100 people would have been needed to lay the rollers in front of the sledge. They also would have had to keep the sledge from wandering sideways. Scientists estimate that it might have taken 1,000 people several years to move 80 sarsen stones a distance of 30 km. Another theory is that the heavy rocks were already in the area around Stonehenge, carried there by glaciers.

Using Simple Machines

The diagrams below show methods and machines that probably were used to raise the sarsens and the lintels into place. The method that was used to raise the lintels has been used by modern engineers in countries where no gas-powered cranes were available.



Raising the sarsens



Raising the lintels

Applying Problem Solving Skills

1. Suppose a new Stonehenge were to be constructed in the near future. What modern machinery could be used to raise the sarsens and the lintels? How many workers would be needed for this new Stonehenge project? Explain.
2. Do you think the sarsens and the lintels could have been transported over hundreds of kilometers of land to construct Stonehenge? Why or why not?
3. Write a step-by-step plan of how someone who lived between 3100 B.C. and 1500 B.C. might have organized such a large project.

Problem Solving

Energy-Saving Refrigerators

Activity 8

Until the 1980s, refrigerators used a great deal of energy and were cooled with substances called chlorofluorocarbons (CFCs). However, scientists discovered that CFCs can destroy the ozone layer in the atmosphere, which blocks the Sun's ultraviolet rays.

For this reason, in 1987 most of the industrial nations of the world signed a treaty, agreeing to reduce CFCs 50 percent by 1998 and to eliminate them by 2000. Today's refrigerators use CFC-free methods of cooling, making them more energy efficient.

Energy Hogs

Refrigerators still use more electricity than any other kitchen appliance. However, modern refrigerators use less than half the energy of a refrigerator built in the 1970s. In fact, they are so efficient that the Department of Energy states that if every home upgraded to a new refrigerator, the United States would save 3.8 billion L of oil per month. That reduction in fuel use would eliminate the need for more than 20 power plants.

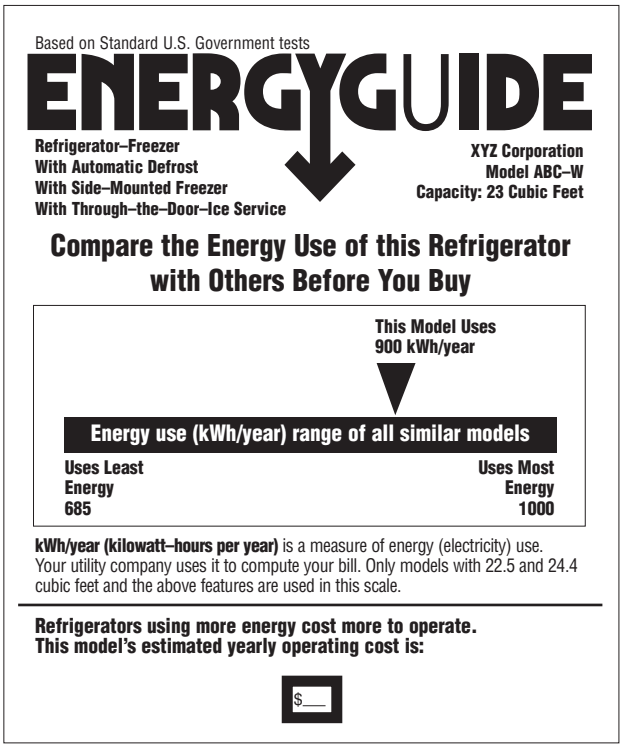
Today's refrigerators stay cool with a mechanism that draws out heat through the evaporation of a liquid. Liquids absorb heat as they cool. Refrigerator liquids, called refrigerants, have a low boiling point. The boiling point is so low that the boiling liquid would feel extremely cold to human touch. The liquid, therefore, evaporates at a low temperature. It draws heat out with it, keeping the inside of the refrigerator cold.

Cool It

A refrigerator should be placed in a position to allow proper ventilation behind and above it so heat can escape efficiently. It should not be placed next to other heat-producing appliances, and the door seals should be airtight. The temperature should remain between 2.8°C and 4.4°C in the main compartment and -17.8°C to -15°C in the freezer. Extra features, such as automatic icemakers and water and ice dispensers in the doors, reduce efficiency.

Consumer Information

The federal government now requires that EnergyGuide labels (like the one below) appear on all new appliances, listing how much electricity an appliance uses in one year. The higher the number of kilowatt-hours (kWh) it lists, the more energy it uses and the more expensive it is to operate.



Applying Problem Solving Skills

1. Think of another appliance that people might have in their homes that could be more energy efficient. Describe two methods you might use to test your assumption.
2. Use the information in the EnergyGuide above to calculate how much it would cost to operate this refrigerator for one year. Base your calculation on a 2000 U.S. government report that says the average cost of a kilowatt-hour of electricity is 8.034 cents. Round your answer up to the nearest dollar.

Problem Solving

Radon Risk

Activity 9

Radon-222 is an element found almost everywhere. It is produced from the decay of two naturally occurring elements, radium-226 and uranium-238, found in rock and soil. As a gas, radon is mobile. It poses little risk if it makes its way into open air. But if it seeps into a house, it can collect in hazardous concentrations.

Dangerous By-Products

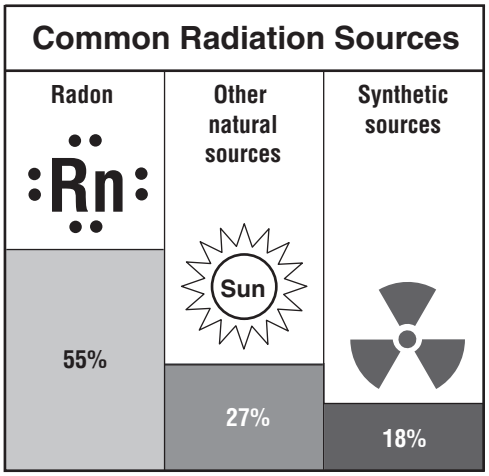
Radon decays into another element, polonium-218, and releases an alpha particle. Polonium-218 further decays into lead-214, to bismuth-214, and to polonium-214. These by-product elements, called radon daughters, can be inhaled directly, or they can attach to dust particles that lodge in the lungs. After they are in the lungs, radon daughters can emit alpha particles that can cause lung cancer. In fact, radon is second only to smoking as a cause of lung cancer.

The location of a house can, to some extent, reveal whether radon might be a problem. For example, certain types of rocks—light-colored volcanic rocks, granites, dark shales, sedimentary rocks containing phosphate, and metamorphic rocks formed from these rocks—have high uranium contents. Houses that rely directly on groundwater also are at higher risk for radon buildup. The only way to find out whether radon gas is in your house is to test for it.

Test kits are available in stores. If the radon level in your house is high, contact your local health department or the EPA for further information on testing for radon.

Reducing the Risk

Methods that might help decrease radon include the following: (1) provide natural ventilation to the basement; (2) supply woodstoves, furnaces, and fireplaces with an outside air supply; and (3) close entry points. Recall also that radon is a gas. It can travel more quickly through porous, dry soils than it can through damp, clayey soils.



Applying Problem Solving Skills

1. Why might houses that rely on groundwater be at risk for radon buildup?
2. Why is ventilating the basement a good way to reduce radon buildup?
3. Based on radon movement, what type of setting could be the safest for building a house?

Critical Thinking

What's the difference?

Activity 10

If you begin paying attention to all the physical and chemical changes going on around you, you will have countless opportunities to become an expert at telling the difference between them.

Dawn to Dusk

In the morning, the cold water you place on the stove begins to boil for hot cereal. You notice the condensation of steam vapor on the bathroom mirror. After breakfast you put on your warm, leather jacket and thick-soled boots, because last night's rain turned from water to ice on the sidewalk.

You take a bus to meet a friend. Inside the bus engine, gasoline is being burned in the presence of oxygen with a release of energy that moves the bus. The burning fuel also produces some exhaust in the form of carbon monoxide and other pollutants. You get off the bus near a big statue in your town's main square. The statue has turned green with a patina of hydrated copper carbonate.

You and your friend meet and walk to the library. Your breath comes out as steam in the chilly air. All that aerobic exercise has caused the buildup of lactic acid in your muscles, making you feel tired. So you get your favorite carbonated beverage to drink and watch as bubbles come up out of the solution. You board the bus for home, rubbing your hands together rapidly to keep them warm.

Seeing Is Believing

Looking back on your day, you smile as you realize how many chemical and physical changes you noticed—and how well you understood them.

Applying Critical Thinking Skills

1. Write which are physical changes and which are chemical changes. Give a reason for each answer.

   cold water heating up to its boiling point: _____

   rain turning to ice: _____

   thick-soled boots preventing slipping on the ice: _____

   _____

   gasoline and oxygen combining to release energy and waste products, including carbon monoxide:

   _____

   copper metal combining with gases in the air to form a patina of hydrated copper carbonate:

   _____

   breath coming out as steam: _____

   sugars and oxygen in the muscles producing lactic acid: _____

   carbon dioxide gas escaping from a solution in the form of bubbles: _____

   rubbing hands rapidly together to warm up: _____

2. Methods for cleaning clothing have not always been as efficient as they are today. Fabric was sometimes soaked in buttermilk and left in the Sun. The lactic acid in the buttermilk combined with the sunlight caused fabric to bleach white. Do you think that was a physical or a chemical change? Suppose you want to bleach a stain out of your favorite white sweatshirt today. Would this require a physical or chemical change? Why?

Critical Thinking

Ancient Mysteries and Carbon-14 Dating

Activity 11

When did the last of the mammoths live? How old are the Dead Sea Scrolls? Physicists are able to determine the ages of ancient artifacts by measuring the residues of atomic behavior.

In 1946, Willard F. Libby of the University of Chicago developed a method that determines the age of carbon-containing materials. The carbon atoms in the materials can be used to determine the materials' age, back to about 50,000 years. Libby's method, called radiocarbon dating, earned him the Nobel Prize in Chemistry in 1960.

How does it work?

Radiocarbon dating, or carbon-14 dating, uses the fact that all living matter contains carbon. Three isotopes of carbon are found in living matter. Carbon-12 and carbon-13 are stable isotopes and have been around for a long time. The other isotope, carbon-14, emits beta (electron) radiation as it changes to carbon-12 or carbon-13. The rate at which carbon-14 changes is called the decay rate. If the amount of carbon-14 in a piece of material can be found, and the decay rate for carbon-14 can be measured, the age of the material can be determined. The decay rate for carbon-14 has been established. Half of the existing carbon-14 atoms will decay in 5,730 years and half of the rest of the carbon-14 atoms will decay in an additional 5,730 years.

Dating the Dead Sea Scrolls

Researchers used radiocarbon dating to determine the age of the Dead Sea Scrolls. A herdsman looking for a stray goat in caves east of Jerusalem found the first of the scrolls in 1947. The scrolls almost instantly sparked scholarly controversy. Nearly 50 years later, however, the date of the scrolls was settled by radiocarbon testing.

In 1994, researchers from the University of Arizona dated 18 of the texts. The paper from one of the texts dates to between 150 B.C. and 5 B.C. with a 95 percent probability. The dates the Arizona team found confirmed dates found by a lab in Zurich, Switzerland, in 1990. The Arizona team took small samples from the ragged edges of the manuscripts and analyzed them using a tandem accelerator mass spectrometer. Using small samples of material, the accelerator measures the amount of carbon-14 in a substance.

Examples of How Carbon Dating Has Been Used

	**Tutankhamen** An examination of mummified remains revealed that this Egyptian child-king reigned more than 3,300 years ago.	1323 B.C.
	**Stonehenge** Carbon dating of wood in the area revealed that this circle of huge stones was built by a group of prehistoric people who lived in England 5,000 years ago.	3100 B.C.

Applying Critical Thinking Skills

1. What do scientists assume to be true when carbon-14 is used to date artifacts? Can you think of reasons why those assumptions might not be true?
2. Why can't carbon-14 dating be used to determine the age of dinosaur bones?

Critical Thinking

Pollution Goes Underground

Activity 12

According to the Environmental Protection Agency (EPA), half of all the people in the United States rely on groundwater for the water in their homes. Groundwater also is pumped to the surface for use by industry and in irrigating farmland.

The Hydrologic Cycle

Groundwater is part of the hydrologic cycle, which involves the continuous movement of water from Earth to the atmosphere and back again, through evaporation and precipitation. It collects naturally in the ground when rain or snow soaks into the soil. It moves through the soil between rocks, until it reaches rocks that are impermeable to water. The area just above this is filled with rock fragments. Water collects in the small spaces between these fragments, called pores.

Large areas where water flows freely through permeable rock are called aquifers. The top level of such an area of water is called the water table.

Underground Pollution

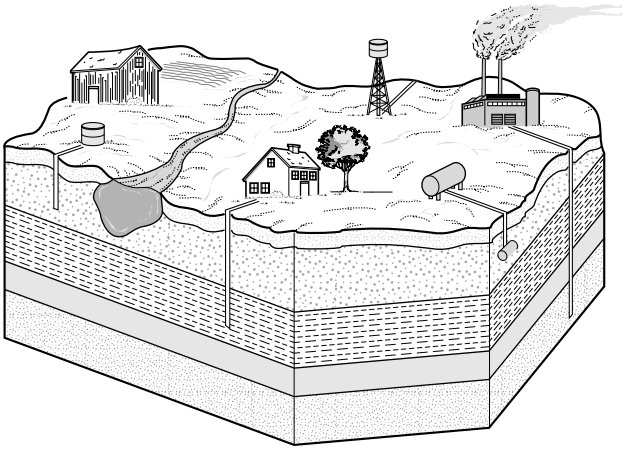
Until about 30 years ago, many people believed groundwater was immune to pollution because of the many layers of soil surrounding it. They also thought that sand, gravel, and clay effectively filtered out pollutants. In spite of all this natural filtration, the EPA reports that every state has some contaminated groundwater.

Contamination can start at the surface, in the ground above, or below the water table. The closer a pollutant is introduced to the groundwater, the more powerful its effect is. Pollutants introduced farther away have less effect because of the natural processes of filtration, dilution, oxidation, and biological decay.

One category of groundwater pollutants is volatile organic compounds, often called VOCs. These are organic chemical compounds that evaporate easily. They contain hydrogen, carbon, and sometimes other elements. These chemicals are found in fuel, paint, paint thinner, dry-cleaning chemicals, and other products. They can leak into groundwater as liquids from landfills, leaky storage tanks, spills, and storm water runoff from paved areas. When they become airborne, these chemicals can combine with rain, fall back to Earth, and soak into groundwater as part of the natural hydrologic cycle.

Watching Waste

Many groundwater pollutants come from the improper disposal of household waste. Motor oil, pesticides, cleaning products, weed killers, paint cans, batteries, and other toxic waste items should be set aside for hazardous waste pickup. Keeping them out of drains, landfills, and yards helps protect groundwater.



Sources of groundwater pollution

Applying Critical Thinking Skills

1. Why do you think it took people so long to realize that groundwater can be polluted?
2. If you were on a committee that was asked to find a location for a new landfill in your county, what advice would you give to the committee?

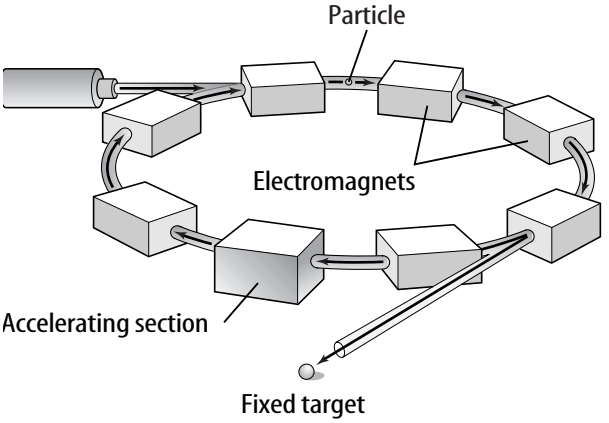
Problem Solving

The Birth of an Element

Activity 13

What happens when you take two small pieces of clay and smash them together? The single piece that results is as big as the two smaller pieces. That's similar to what scientists did to create a new element.

In 1994, after ten years of work, a group of researchers collided nickel with lead. The two elements fused and a new, much heavier synthetic element, number 110, was created. Although element 110 only lasted 0.001 s, its discovery helped to provide a better understanding of superheavy elements and how they can be created.



Particle accelerator

Adding to the Periodic Table

Between 1994 and 1999, Russian, German, and American scientists created many other new elements. They discovered elements 111, 112, 114, 116, and 118.

These elements were created using a device called a particle accelerator. It accelerates atomic particles to a high speed. When particles traveling close to the speed of light collide, they form a new element.

Because these elements break down within such a short period of time, scientists have not been able to study their properties. Element 114 lasted between 20 s and 30 s. That's much longer than the life span of elements 109 through 112, so it was the first considered to be somewhat stable.

Gone in the Blink of an Eye

Element 116 was in existence for only .0012 s, and element 118 was around for only .0002 s. Element 118 was created when scientists bombarded lead with a million trillion ions of krypton for more than ten days. Three atoms of element 118 came out of this experiment. The atoms quickly broke down into elements 116, 114, and other elements.

Because of this experiment, scientists think they can make element 119 by colliding bismuth and krypton. They believe element 119 would break down into elements 117, 115, and 113, which are yet to be discovered.

Applying Problem Solving Skills

1. Use the periodic chart to explain how colliding lead and nickel atoms could create an element assigned the atomic number of 110.
2. Name two solid, metal elements that scientists might use to create an element with an atomic number of 129.

Critical Thinking

Gasoline—Finding a New Formula

Activity 14

The carbon monoxide and other chemicals that spew from the tailpipes of the many millions of cars and trucks in the United States create the smog that blankets our country's largest cities. Laws have been passed requiring manufacturers to make vehicles that operate more efficiently. In 1995, however, a federal program was launched requiring oil companies to make changes in gasoline.

The cities with the most smog were the targets of the program. The new gasoline, called reformulated gasoline or RFG, had to burn more cleanly and release fewer smog-forming and toxic pollutants.

Finding the Formula

The federal government required oil companies to create their own formulas to meet the stricter standards. One requirement was that the gasoline contain two percent oxygen.

To oxygenate the gasoline, most oil companies chose to add either ethanol or a chemical called methyl tertiary-butyl ether (MTBE) to their formulas. Both reduce the amount of carbon monoxide that is released when gasoline is burned.

But despite benefits, drawbacks to using each of these chemicals exist. MTBE is highly soluble and travels easily in water. Spills, improper disposal, and leaky tanks can pollute ground-water and surface water. Ethanol is an alcohol produced by the fermentation of sugar. When it is added to gasoline, it reduces the amount of carbon monoxide that is released and creates more oxygen than other additives create. However, it causes gasoline to evaporate more quickly. As gasoline evaporates, it releases more pollutants into the air.

Despite the quick evaporation, however, the Environmental Protection Agency (EPA) claims that using ethanol as an additive is much better for the environment than using MTBE. The EPA recommends that the use of MTBE in gasoline be reduced or eliminated.

Noticeable Improvement

Although questions remain, the RFG program has been successful in reducing pollution in the targeted areas. According to the EPA, at least 75 million people breathe cleaner air today than they did before RFG. At least 17 states and the District of Columbia use reformulated gasoline, and at least one-third of the gasoline sold in the United States is reformulated.

Applying Critical Thinking Skills

1. What factors do you think the EPA had to consider before recommending the use of ethanol over the use of MTBE in reformulated gasoline?
2. What opinions might auto manufacturers have about the RFG program? Ethanol producers? Oil companies?

Problem Solving

Building Materials of the Future

Activity 15

What do soft-drink bottles, plastic bags, and compact discs have in common? They're all polymers. The word *polymer* comes from the greek word *polumeres*, which means "having many parts." A polymer is a chemical compound made up of large molecules formed from many smaller molecules. These molecules are linked together in long chains.

A Closer Look

The arrangement of the chains determines the properties of the polymer. Rubber is a polymer that is made up of long, kinked chains. When rubber is pulled, it snaps back, demonstrating its elastic quality. Polymers with chains of molecules held tightly together, such as Formica or Plexiglas, are stronger but less flexible.

Rubber, cellulose, and wool are natural polymers. Nylon, plastic foam, nonstick coating, and hundreds of other types of plastics are examples of synthetic polymers.

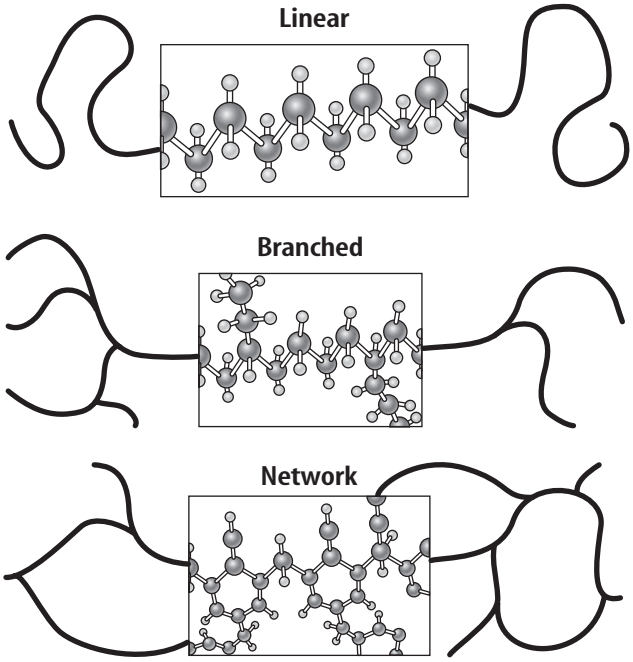
Aluminum Alternative

Polymers are twice as light as aluminum and can be molded into many more shapes. This makes them an interesting alternative to aluminum. Some race car bodies are made from a complex form of polymer, known as a polymeric composite. Polymeric composites are plastics that have been reinforced with glass or carbon fibers. Composites, however, are very expensive.

Plastics Plus Fiber

Engineers are experimenting with the use of fiber-reinforced plastics in structures such as bridges. Smith Road Bridge in Butler County, Ohio, is the nation's first bridge made completely from plastic reinforced with carbon fibers. A four-member team from the Wright-Patterson Air Force Base near Dayton created the space-age material that was used to build the bridge. Called a "smart bridge," it can hold up under extreme temperature changes and can support a load of more than 36,000 kg. The Smith Road Bridge is five times stronger than one made just like it out of concrete and steel.

In addition to being strong, smart bridges last three times as long as other bridges. Concrete and steel bridges last only about 50 years and often need repair. Smart bridges need little or no repair, making them cheaper to maintain. Eventually, smart-bridge technology could replace or help repair almost 230,000 bridges—nearly half the nation's concrete and steel bridges.



Polymer structures

Applying Problem Solving Skills

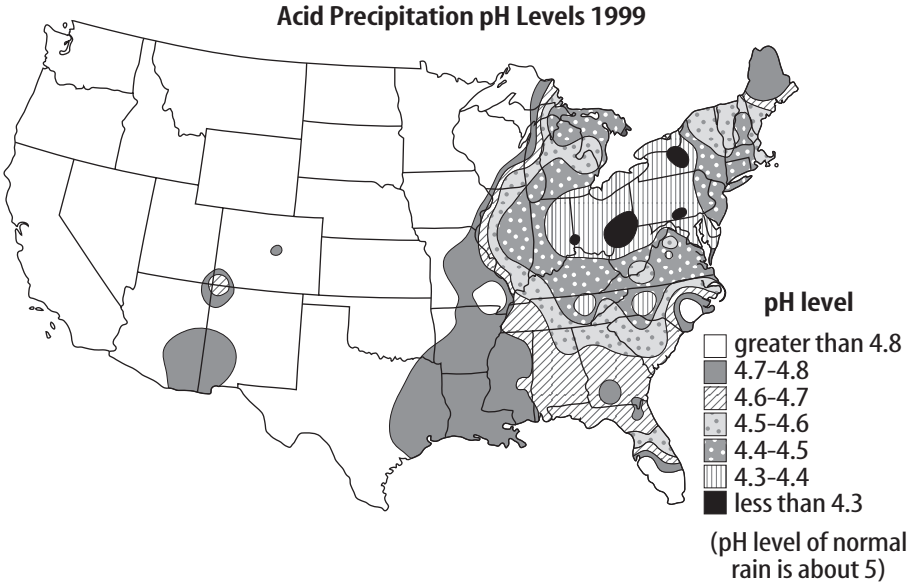
1. Look at the three illustrations of polymers. Judging from the appearance of each type of chain, which type of polymer would be strongest?
2. Besides bridges and automobiles, suggest two other ways that reinforced plastics might be used to replace materials that are now being used in other products and structures. What advantage might the use of plastics provide?

Problem Solving

Acid Precipitation Report Card

Activity 16

We might think of acid rain as a modern-day environmental problem, but it's not. In 1872, the effect of acid precipitation was discovered in Britain—the world's first industrialized nation. A Scottish scientist saw a link between the sulfur dioxide that was being released when coal was burned and the damage being done to local plant life. He studied the chemistry of rain, fog, and snow. He found that high levels of sulfur gas were mixing with moisture in the air to create highly acidic precipitation. He called it acid rain.



Identifying the Problem

It wasn't until the 1950s, however, that acid precipitation became a public concern. In December 1952, 4,000 Londoners died as a direct result of a kind of air pollution known as smog. After that, British politicians passed the world's first air pollution law, the British Clean Air Act. Industrialized nations, however, continued to build smokestacks at their factories, so acid pollution got worse.

Worldwide research throughout the 1960s and 1970s showed a strong link between acid precipitation and contamination of soil, forests, and lakes. The highly acidic conditions were killing plants, trees, and fish. Canada complained that acid rain caused by car emissions in the United States was killing fish in Canada. By 1980, a joint report from the United States and Canada showed that air pollution was, in fact, crossing the border between these two countries.

By the early 1990s, Austria and Sweden had reduced their sulfur dioxide emissions by an average of 81 percent. Thirteen other European countries cut their emissions in half; nine more and Canada each cut their emissions by more than one-third. By 1992, the United States showed a decrease of only 13 percent.

Weighing the Costs

Even though acid pollution continues to be a problem, the public's attention has moved to other problems, such as global warming and depletion of the ozone layer. The 1990 Clean Air Act Amendments in the United States still require strict controls, but the cost of controlling emissions is expensive. Controlling sulfur dioxide emissions costs $1 billion to $5 billion per year and controlling nitrogen oxide costs $75 million to $90 million each year. However, many people think the damage to forests, lakes, buildings, plants, animals, and humans is even more costly.

Applying Problem Solving Skills

1. How do you think the Scottish scientist in 1872 linked the condition of the plants to acid precipitation? Describe two things he would have to do to make this connection.
2. Based on the map, which part of the United States has acid precipitation with the highest pH levels? Why do you think this is the case?

Critical Thinking

Environmentally Friendly Cars

Activity 17

How would you like to own a car that is noiseless, does not pollute, never needs a tune-up, and rarely needs major repairs? An electric car might be the answer.

Plug It In

Auto manufacturers have been experimenting with the idea of replacing gasoline engines with electric motors for many years. One car manufacturer in the United States recently started selling the first mass-produced electric car. Recent improvements allow the car to go between 89 and 153 km or 120 and 209 km before recharging, depending on the type of battery pack.

Widespread use of electric cars would eliminate the pollutants emitted from gasoline engines. Electric cars do not use energy when they are not moving. With an electric car, drivers could save money on gasoline, tune-ups, and major repairs.

Electric cars do have disadvantages, however. They are more expensive to buy than similar gasoline-engine cars. They can travel only short distances before they need to be recharged, and batteries must be replaced two or three times during the life of the car.

The standard lead-acid batteries used in electric cars are heavy, expensive, and take up a lot of space. They are also hazardous to the environment when they are discarded. Electric cars accelerate slowly and reach a top speed of only about 129 km per hour. Although electric car engines burn more cleanly, they still cause some pollution.

A Dual Approach

In response to the problems of electric cars, Japanese automakers began selling hybrid models that use electricity and gasoline. These cars recharge themselves by storing energy produced during deceleration and then convert it back into electric power. They accelerate more quickly and their aerodynamic shape minimizes wind resistance, allowing for better gas mileage. A computer determines when it is most efficient for the car to use electricity or gasoline.

Other automakers have plans to release cars that use electric-diesel engines and fuel-cell-powered engines. Fuel cells are now used in spacecraft. The cells take hydrogen from the fuel and mix it with oxygen. The reaction, in turn, generates electricity. Fuel cells are more than twice as efficient as gasoline engines. Their only emission is water vapor.

Applying Critical Thinking Skills

1. If you were buying a new car, would you buy an electric car? Why or why not?
2. In what ways could governments (federal, state, and local) support the use of electric and hybrid cars?

Problem Solving

Pole Reversal

Activity 18

You're lost in the wilderness. Luckily, you have an iron needle, a cork, a small permanent magnet, and a cup. You rub the needle over the magnet several times in the same direction to magnetize it. You stick the needle through the top of the cork and float it in a cup filled with water. After the cork stops bobbing around, it becomes still. Then the needle is aligned in a north-south direction. Knowing where north is, you can head for home. You've created a crude compass, not unlike those that were first used thousands of years ago by Chinese navigators.

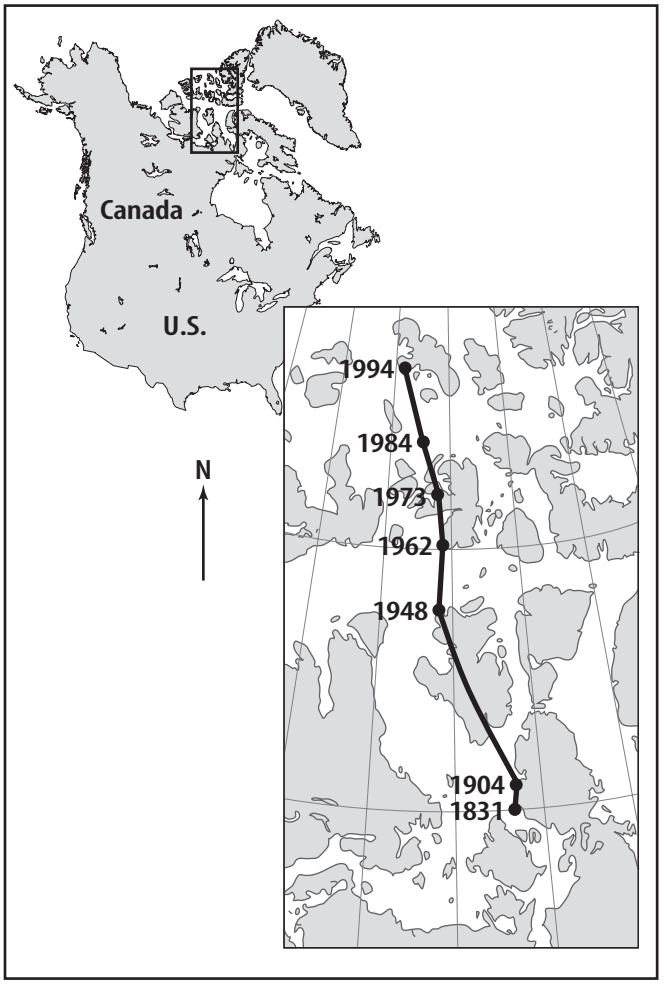
Earth as a Magnet

Early explorers used compasses, but they were still in the dark about why compasses worked. It wasn't until a few centuries later that investigators discovered that in northern Canada, a huge area of magnetic iron ore was attracting compass needles. These rocks were named lodestone, or leading stone.

When these rocks were formed millions of years ago, atoms of iron within the molten rock lined up with Earth's own magnetic field. After the rocks hardened, the pattern of magnetic domains remained unchanged. Because of the phenomenon, geologists can tell that the magnetic north and south poles (different from the geographic poles) have periodically flip-flopped over the course of millions of years.

A Distorted Magnetic Field

Deep within Earth is a core of metal made of iron and nickel. If you were in outer space and could sprinkle iron filings around Earth, would you get the characteristic pattern of a magnetic field? Yes—and no. Earth's magnetic field does magnetize particles in the atmosphere. But the solar wind caused by the Sun blows on the magnetic field and distorts it. Instead of a symmetrical pattern coming from Earth's north and south poles, the magnetic field facing the Sun is round and the far side has a long, cometlike tail.



The location of the north magnetic pole is really an average position. The pole shifts daily and over the years has moved gradually north.

Applying Problem Solving Skills

1. Many biologists are puzzled by the ability of birds and other animals to migrate great distances around the globe with unbelievable precision. Recent studies show that Monarch butterflies may use magnetic fields for orientation. Some studies reveal that migrating animals have some sort of magnetic-sensing device in their brains. What element might these sensing devices contain? Explain.
2. Suppose a dogsled race was taking place near the arctic circle. Could the drivers simply read an ordinary compass to tell their direction? Why or why not?

Critical Thinking

Patient-Friendly Cancer Treatment

Activity 19

Radiation is a word that makes many people think of a bad accident at a nuclear power plant. But radiation in the form of radioisotopes is being used every day to treat cancer.

A radioisotope is a single atom of an unstable element. It is a radioactive form of an element that is made by hitting a stable element with neutrons. This usually happens in the core of a nuclear reactor or with the help of an accelerator. The use of radioisotopes in diagnosing and treating disease is called nuclear medicine. In the United States, almost one out of every three people going into a hospital is given a test or treatment that uses radioisotopes.

Pinpointing the Cancer Cells

Doctors are using nuclear medicine to develop promising treatments for cancer patients. Using radioisotopes, doctors can treat only the bad cancer cells. This is not only better for the patient, but also for destroying the cancer.

With traditional cancer treatments, patients are given drugs (known as chemotherapy) or their bodies are exposed to radiation. These treatments work by killing the cells. The problem is that they kill cancer cells and healthy cells. With nuclear medicine, doctors can target clumps of cancerous cells or tumors.

One promising form of nuclear therapy involves joining an antibody with a radioisotope. An antibody is a protein molecule that binds with a specific type of cell; in this case, cancer cells. When they are put together, the antibody and radioisotope form a cancer-fighting weapon that targets cancer cells. The antibody binds itself to the cancer cell and the radioisotope eventually breaks down. When it does, it releases radioactive energy, hopefully destroying the cancer.

Doctors are referring to these treatments as being patient-friendly because they're easier on the patient compared to whole-body radiation and chemotherapy. Whole-body radiation and many other treatments don't do much to stop a cancer patient's pain. However, studies on 150 patients who received radioisotopes showed that the treatment reduced up to 80 percent of their pain.

A Medical Shortage

There are problems, however, with nuclear therapies. Many of the radioisotopes that are used to treat cancers need to be created in a lab with special equipment. Ninety percent of medical isotopes used in the United States come from Canada and other countries. The U.S. Congress provides millions of dollars each year to the Department of Energy to fund production. The demand, however, continues to exceed the supply.

Applying Critical Thinking Skills

1. Some antibodies that are linked to radioisotopes can take 48 h to find their target cell. What problem might this cause for a cancer patient?
2. How might other diseases be treated using radioisotopes? Be specific.

Critical Thinking

Regulating Nuclear Power Plants

Activity 20

What is a clean, affordable way to supply communities with electricity? Some people believe that nuclear power plants are the answer. Countries such as Japan, France, and Great Britain use nuclear power to supply a significant amount of their electricity. As of 2000, however, only 24 percent of power in the United States was generated by nuclear plants.

Safety Concerns

Why doesn't the United States rely more heavily on nuclear power plants for its energy? The answer is safety. In 1979, when a nuclear accident occurred at the Three Mile Island nuclear power plant in Pennsylvania, people began to fear what could happen if that accident had been more serious. The greatest risk is exposure to radiation. The degree of risk depends on the amount of radiation that leaks, whether precipitation such as snow or rain occurs simultaneously (which could carry the radiation directly into the ground), wind speeds, and location of the accident.

Finding a Dump Site

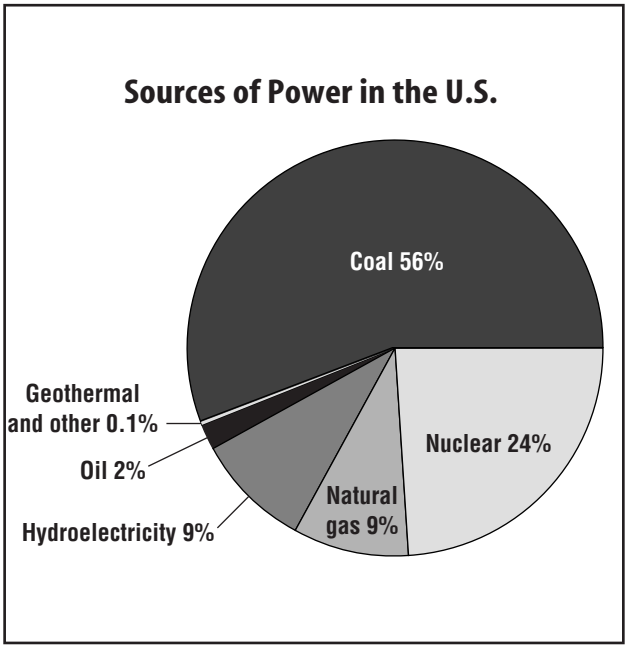
Disposal of nuclear waste also is a problem, because it remains dangerously radioactive for several hundred years. Therefore, it has to be stored in a place where leakage cannot occur. Most of it is buried deep underground in tunnels of solid rock. Although the threat of contamination is low, many people prefer not to live in or near an area where nuclear waste is stored.

Another reason few nuclear power plants are built is money. It costs an extraordinary amount of money to get licenses and to construct nuclear power plants. Because plants can operate only for a few decades, money also has to be set aside to dismantle the plant when it is closed down, or decommissioned. Currently, plants that produce energy-using fossil fuels are cheaper to build and operate.

A Nuclear First

In March 2000, the United States government renewed the license of a nuclear power plant for the first time. The Calvert Cliffs plant obtained approval to operate until 2036. The plant is located in Calvert County, Maryland, 64 km southeast of Washington, D.C.

The Nuclear Regulatory Commission (NRC) took two years to make its decision. It evaluated the environmental effects, consulted with federal, state, and local agencies, and reviewed public input. By the year 2020 it is likely that nuclear plants will provide less than half the power they provide in the United States today.



Applying Critical Thinking Skills

1. Should the United States continue to develop nuclear energy as a way to generate electricity? Why or why not?
2. Suppose your electric company wanted to switch from a coal-burning to a nuclear-powered facility. Would you support the change? Why or why not?

Critical Thinking

Supersonic Impact

Activity 21

For years, many people thought nothing could travel through the air at the speed of sound, approximately 1,207 km per hour. Many early, high-speed military planes experienced shock waves, and crashed after reaching the speed of sound.

Breaking the Sound Barrier

Because of the difficulty of traveling faster than sound, the speed of sound became known as the sound barrier. But on October 14, 1947, U. S. Air Force Captain Charles E. Yeager flew a Bell X-1 rocket plane faster than the speed of sound. He also experienced shock waves, which were heard on the ground as a sonic boom.

When an airplane travels through the air, it creates pressure disturbances that travel away from the plane. If the plane travels more slowly than the speed of sound, the pressure disturbances move away from the plane faster than the plane itself is moving. When this happens, you hear the sound of the plane before it flies by.

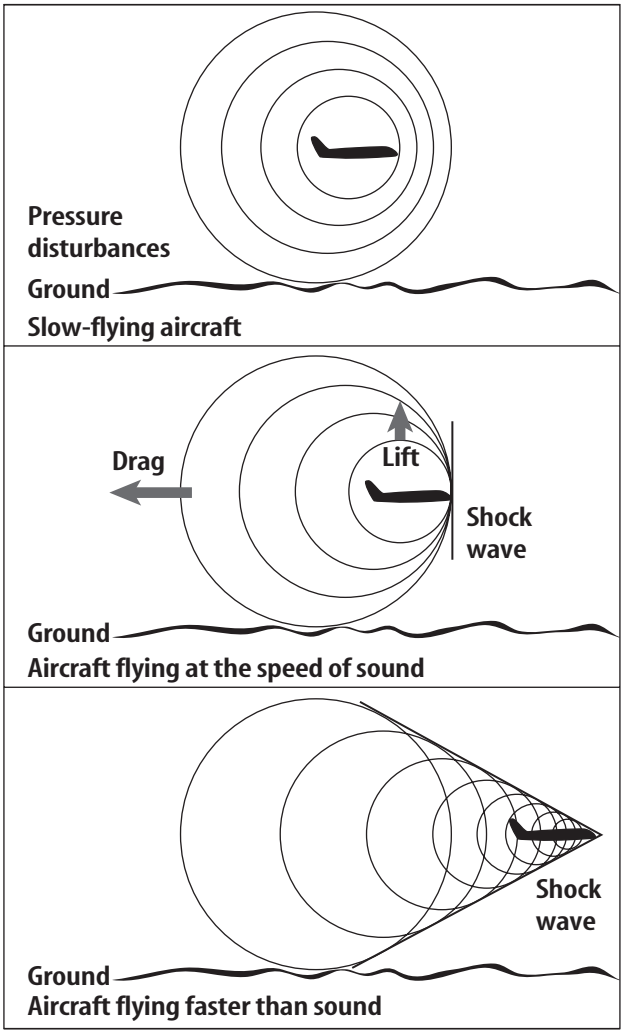
When an airplane travels at the speed of sound, pressure disturbances pile up in front of the plane. This piling up of compressed air is called a shock wave. The shock wave increases the drag on the plane and destroys its lift or upward force, making the plane difficult to control.

When an airplane travels faster than the speed of sound, it gradually moves faster than the pressure waves. As the shock wave at the front of the plane spreads out and reaches the ground 2 s to 1 min after flyover, it creates a sonic boom that can be heard and felt.

Beyond Airplanes

A space shuttle creates a double sonic boom when it reenters Earth's atmosphere. Shock waves move out and back from its nose and tail. The space between the nose and tail is so long, the shock waves reach the ground at different times, creating a double sonic boom.

In Los Alamos, New Mexico, researchers use microphones to listen for sonic booms caused by meteors entering Earth's atmosphere. By recording the time the sound waves from a meteor start and by checking the frequency at different posts, researchers can tell where the meteor will hit.



Stages of a sonic boom

Applying Critical Thinking Skills

1. Aircraft that travel at supersonic speeds cannot be heard on the ground. Why?
2. What is one advantage to tracking meteors sonically?

Problem Solving

Treating Cancer with Light

Activity 22

One of the most commonly used treatments for cancer is chemotherapy. In chemotherapy, drugs are used to kill cancer cells. One drawback to chemotherapy, however, is that the patient usually gets sick. Nausea and other side effects occur because the drugs attack healthy cells as well as cancer cells.

Targeting the Cancer Cells

Medical researchers have found a way to treat some types of cancers without these side effects. The process, called photodynamic therapy (PDT), uses lasers and special drugs that change in the presence of light.

The treatment begins when patients are injected with a photosensitive drug. This type of drug is sensitive to a particular kind of light. At first, all the body's cells, cancerous and normal, absorb the drug. After a period of time, most of the normal cells release the drug, but the cancer cells retain it.

Then, a laser is aimed at the cancerous tissue. The photosensitive drug in the cancer cells absorbs the light and produces a type of oxygen that destroys the cells.

Only light of a specific wavelength and energy can transform the harmless photosensitive drug into a cancer killer. The laser that is used is a low-power red light that is directed through a very thin glass fiber. The laser can be focused precisely on a single area of tissue. It does not produce heat, so it does not burn surrounding tissue.

However, the laser can penetrate only about 3 cm of tissue. For this reason, it only can be used to treat cancer near the surface of the skin or on the lining of internal organs.

Reduced Side Effects

One side effect of PDT is that patients are more sensitive to light for about 60 days after the treatment. They must wear sunglasses and protective clothing before going outdoors.

PDT currently is being used to treat some types of lung and esophageal cancers. It can be repeated several times and also can be used with other treatments such as chemotherapy and radiation therapy.

Research continues on other types of lasers and photosensitive chemicals. Doctors hope to find a process that will let them treat cancers farther below the surface of the skin and inside organs.

Applying Problem Solving Skills

1. Some cancers form thick, round tumors while others are long and flat. Predict which kind of tumor would most likely respond to photodynamic therapy.
2. The original idea for PDT came from a plant. Compare a plant's use of light energy to that in PDT.

Problem Solving

Swimming with Sharks

Activity 23

To an amateur swimmer, 0.1 s might not seem like much time, but Olympic swimmers know that it can mean the difference between a gold medal and no medal. Many of the swimmers who won medals at the 2000 Olympics in Australia say they were able to shave off tenths of seconds by wearing a new type of swimsuit.

Imitating Nature

The new suits were full-body suits. They had long sleeves and pant legs that extended to the ankles. The real secret behind the new suits was their texture. They were made of a fabric designed to mimic sharkskin.

A fish curator at the British Museum of Natural Science is credited with the idea. He noticed that sharks can glide easily through water even though their shape is not particularly well-suited to speed.

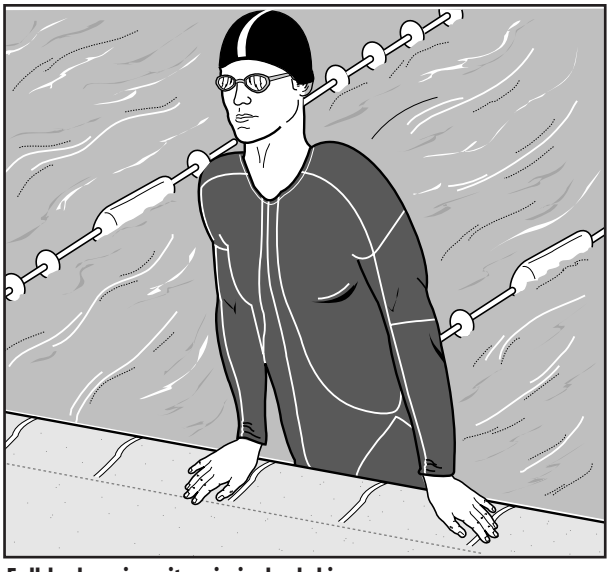
Under the Microscope

Sharkskin, although it looks smooth, is quite rough to the touch. When magnified, it looks like thousands of tiny paddle-shaped teeth. The teeth are the key to its efficiency in water.

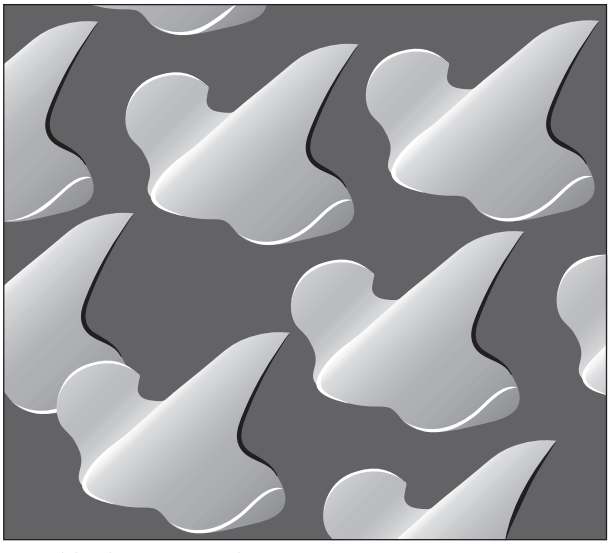
According to the suit's manufacturer, water cannot adhere to its surface. This reduces some of the drag. The more drag that occurs, the more energy the swimmer has to exert. Over the years, swimmers have donned tighter and smoother swimsuits, and swimcaps, and even shaved their bodies to cut down on drag.

Sharkskin suits also help control the turbulence churned up by other swimmers. When water is crashing into them from all sides, swimmers must expend added energy to stay on course. The ridges of the sharkskin suits help deflect some of that force.

The $600 sharkskin suits take at least 20 min to put on and are skin-tight. However, most Olympic swimmers who wore the suit said it was a small price to pay for improving their overall times.



Full-body swimsuits mimic sharkskin



Magnification of sharkskin

Applying Problem Solving Skills

1. Sharkskin suits were valuable to Olympic swimmers because they reduced drag in the water. What other applications might items made of sharkskin have?
2. Think of a sport that you enjoy participating in or watching. Describe a new piece of equipment or an article of clothing that might improve an athlete's performance in that sport.

Answer Key

Activity 1 _____ page 1

Testing the Waters

1. **Generating and Assessing Solutions:** Answers will vary. Students should examine probable causes for fish kills and make a suggestion for further reasearch into one of these areas.
2. **Making a Hypothesis:** Students' hypotheses will likely state that carbon dioxide has some effect on marine life. Students should propose one way of testing their hypotheses. After completing this activity, you might want to tell students that studies have shown that increased levels of carbon dioxide in the world's oceans will increase its acidity. Among other effects, increased acidity can be corrosive to calcium carbonate, which is a part of shells and coral.

Activity 2 _____ page 2

Breaking All the Records

1. **Examining and Evaluating Assumptions:** If the graph is carefully constructed, these points will not fall on a straight line. The downward slope decreases very gradually.
2. **Making Predictions:** The slope of the curve will probably decrease and become almost parallel to the *x*-axis.

Activity 3 _____ page 3

Power from Fluids

1. **Recognizing Cause and Effect:** Students should deduce that if the second object had a larger area or mass than the first, the force on the second object would be greater.
2. **Generating and Assessing Solutions:** Answers will vary but could include the following: The master cylinder is low in brake fluid; there is air in the brake lines.

Activity 4 _____ page 4

Discovering Hidden Planets

1. **Recognizing Cause and Effect:** The path of the spacecraft may be changed due to the pull of the gravity of the asteroids or comets on the spacecraft.
2. **Drawing Conclusions:** The orbit would be most affected when Neptune is near Uranus.
3. **Summarizing/Synthesizing:** The greater the mass of an object, the more gravitational force it exerts on another object. Because Earth is larger than the Moon, a person weighs more on Earth than on the Moon.

Activity 5 _____ page 5

New Insulation for Space Shuttles

1. **Evaluating Information:** Because extreme changes in temperature, as well as the stress of launching, cause the tiles to contract or expand, they could bend, break, or become detached.
2. **Recognizing Cause and Effect:** As the first part of the shuttle breaks through the atmosphere, it is exposed to the most friction.

Activity 6 _____ page 6

The Appeal of Perpetual Motion Machines

1. **Comparing and Contrasting:** We assume that an ideal machine is a frictionless machine and that no energy is converted to heat. In such a machine, work input equals work output. In a perpetual motion machine, the expectation is that work input will be enough to sustain work output over time and that there will be no energy lost.
2. **Examining and Evaluating Assumptions:** The assumption was that once the initial work was put into the machine, it would continue working indefinitely. However, the law of conservation of energy suggests that you can never get more out of a machine than you put in to it. A shift is needed from an ideal (nonexistent) machine to actual devices with moving parts. The devices in these machines had many moving parts that would have lost much energy to friction. Thus, work input would have been greater than work output rather than the other way around.

Activity 7 _____ page 7

Stonehenge—An Engineering Marvel

1. **Comparing and Contrasting:** A bulldozer could raise the sarsens. A crane could raise the lintels. Using these machines, a single worker could accomplish this task.
2. **Observing and Inferring:** Yes; simple machines have been used for thousands of years, and their proper application could have accomplished this. No; it would be too difficult to recruit enough workers. Accept all reasonable answers.
3. **Summarizing/Synthesizing:** Answers will vary. Students might say that a leader recruited volunteers to work on the project or that community members were required to work a certain amount of time on it. Plans might have been made to determine placement and size of the stones. Then stones would have been located and carried. Next, moving equipment would have been built and taken to the stones before transportation could begin.

Activity 8 _____ page 8

Energy-Saving Refrigerrators

1. **Examining and Evaluating Assumptions:** Students should choose an appliance that they think could be made more energy efficient. They should list at least two methods they would use to help them determine whether their assumption was correct. They might suggest comparing that appliance to similar appliances that are older or newer; tracking electricity bills; or measuring the output of two similar appliances, such as the amount of electricity it takes to do a single load of laundry or any other reasonable test.
2. **Generating and Assessing Solutions:** 8.034 cents $\times$ 900 kWh/year = $73.00

Activity 9 _____ page 9

Radon Risk

1. **Observing and Inferring:** Houses that rely directly on groundwater are at greater risk because the radon does not have time to dissipate before the water enters the house.
2. **Evaluating Information:** Ventilating the basement is a good way to reduce radon buildup because it prevents the radon from collecting in hazardous concentrations. Ventilation allows the radon to mix with outside air, and radon in the open air poses little risk.
3. **Summarizing/Synthesizing:** The safest location for a house would be in an area with clayey soil. The area should not be dependent on groundwater.

Activity 10_____ page 10

What's the difference?

1. **Observing and Inferring:** *physical:* there are no new compounds in boiling water; *physical:* there are no new chemicals in freezing rain; *physical:* friction prevents slipping on ice; *chemical:* reaction produces new end-products, such as carbon monoxide; *chemical:* hydrated copper carbonate is formed; *physical:* water in breath becomes visible vapor; *chemical:* lactic acid forms; *physical:* carbon dioxide that was under pressure escapes solution; *physical:* hands stay warm with energy from friction.
2. **Drawing Conclusions:** The bleaching action of lactic acid and sunlight is a chemical reaction that changes the molecules that cause color in the fabric. Today, you might use a chlorine bleach.

Activity 11_____ page 11

Ancient Mysteries and Carbon-14 Dating

1. **Examining and Evaluating Assumptions:** Assumptions: (A) The original amount of carbon-14 in the artifact is known. (B) The material can take in carbon-14 while it is alive but not when it is dead. (C) The rate of decay is constant. (D) The amount of carbon-14 can be measured accurately from the artifact. Reasons will vary and might include that the original amount is not really known, the organism might take in carbon-14 after death, the decay rate could vary with location, and carbon-14 can be more accurately measured in some artifacts than in others.
2. **Making Inferences:** Radiocarbon dating can be used only for materials that are not older than 50,000 years. Dinosaurs lived more than 65 million years ago. Bones from the era need to be dated by using the age of the rock they are found in.

Activity 12 page 12

Pollution Goes Underground

1. **Examining and Evaluating Assumptions:** Answers will vary, but students might refer to the fact that people thought natural filtration would prevent serious pollution. Also, because groundwater sites are so far underground, people were unable to see the effects of pollution as they do in surface waters, such as rivers and streams.
2. **Generating and Assessing Solutions:** Students might say that they would advise the committee that the landfill should not be located close to a shallow groundwater area. Other recommendations might include that the landfill should rest on rock that is not too porous, and that it should be lined with a material that is impermeable to water.

Activity 13 page 13

The Birth of an Element

1. **Recognizing Cause and Effect:** Lead has an atomic number of 82 and nickel has an atomic number of 28. The sum of the two numbers is 110.
2. **Extrapolating Data/Information:** Students should choose any two solid, metal elements whose atomic weights add up to 129. Examples: silver 47 and lead 82; palladium 46 and bismuth 83

Activity 14 page 14

Gasoline—Finding a New Formula

1. **Clarifying Issues:** Answers will vary. Students should recognize that the benefits and drawbacks of using each additive must be considered.
2. **Making Predictions or Interpretations:** Students should consider the impact of the RFG program on each of these groups. Auto manufacturers were probably relieved that the financial burden of developing new technology was being shared by another industry. Ethanol producers would welcome the program, especially if the EPA recommended that their product be used in the gasoline over another product, increasing their profits. Oil companies would be the least enthusiastic because of the money and research involved in developing RFG options.

Activity 15 page 15

Building Materials of the Future

1. **Making a Hypothesis:** Based on the appearance of each chain in the three illustrations, students should conclude that the network polymer structure would likely be strongest.
2. **Comparing and Contrasting:** Answers will vary. Suggestions might include buildings or other structures or medical implants. Advantages might include that plastics do not rust, rot, or break down as quickly as metal, wood, or concrete.

Activity 16 page 16

Acid Precipitation Report Card

1. **Distinguishing Relevant from Irrelevant Facts:** Answers will vary. Students should recognize that the scientist probably had to eliminate other probable causes for the damage to plant life. After he pinpointed precipitation as a possible cause, he had to find out what it contained. He also had to identify the source of the contamination.
2. **Observing and Inferring:** The Northeast; students should mention the number of vehicles and industries as the probable cause.

Activity 17 page 17

Environmentally Friendly Cars

1. **Developing a Perspective:** Answers will vary. Yes; less pollution, easier to maintain; No; too expensive, too small, limited range between recharging, lack of recharging areas other than the home, travel distances too short
2. **Generating and Assessing Solutions:** Possible answers include providing tax breaks to people who buy electric and hybrid cars and to companies who build them, supporting research, providing education on the benefits of electric cars, and passing laws that require the use of electric cars in cities.

Activity 18 page 18

Pole Reversal

1. **Examining and Evaluating Assumptions:** These sensing devices would probably contain iron, a magnetic element found in living things. The iron could contain magnetic domains that line up with Earth's magnetic field and help the animals navigate in some way.
2. **Recognizing Cause and Effect:** If the drivers used an ordinary compass, the reading would not indicate true north. In the far north, the separation between true north and magnetic north becomes very great, possibly too great to use a compass as a navigational aid.

Activity 19 page 19

Patient-Friendly Cancer Treatment

1. **Drawing Conclusions:** Much like traditional cancer treatments, the cancer-fighting weapon has a better chance of hurting healthy tissues and organs if it stays inside the body too long before finding its cancerous target.
2. **Extrapolating Data/Information:** Targeted radiation inside the body rather than outside could relieve the pain of arthritis, stop bleeding in a hemophiliac, or help keep arteries clear in a patient with heart disease.

Activity 20 page 20

Regulating Nuclear Power Plants

1. **Developing a Perspective:** Yes; while we should continue to develop other forms of alternative energy, we should also explore the safe use of nuclear energy. No; the risks of radiation from nuclear power plants are too great to allow nuclear energy to be used.
2. **Developing a Perspective:** Yes; the nuclear plant would reduce the emission of greenhouse gases and supply electricity safely. No; the nuclear plant conversion would be expensive and pose the threat of radiation leakage.

Activity 21 page 21

Supersonic Impact

1. **Recognizing Cause and Effect:** The aircraft are traveling ahead of the sound they make.
2. **Drawing Conclusions:** If a meteor that could cause damage is approaching Earth, people can be warned before impact.

Activity 22 page 22

Treating Cancer with Light

1. **Making a Hypothesis:** To activate the drug, the laser's light must come into contact with it. The cancer cells in the middle of a thick tumor might be blocked from the light of the laser and never be affected.
2. **Comparing and Contrasting:** Plants use specific wavelengths of light to change chemical configurations just as lasers do in PDT. In plants, pigments absorb light. In PDT, it is the drug that absorbs light.

Activity 23 page 23

Swimming with Sharks

1. **Extrapolating Data/Information:** Answers will vary. Examples might include boat hulls, fishing nets, or swim fins.
2. **Generating and Assessing Solutions:** Students should select one sport and suggest an article of clothing or a piece of equipment that could be designed to help to improve an athlete's performance in that sport.