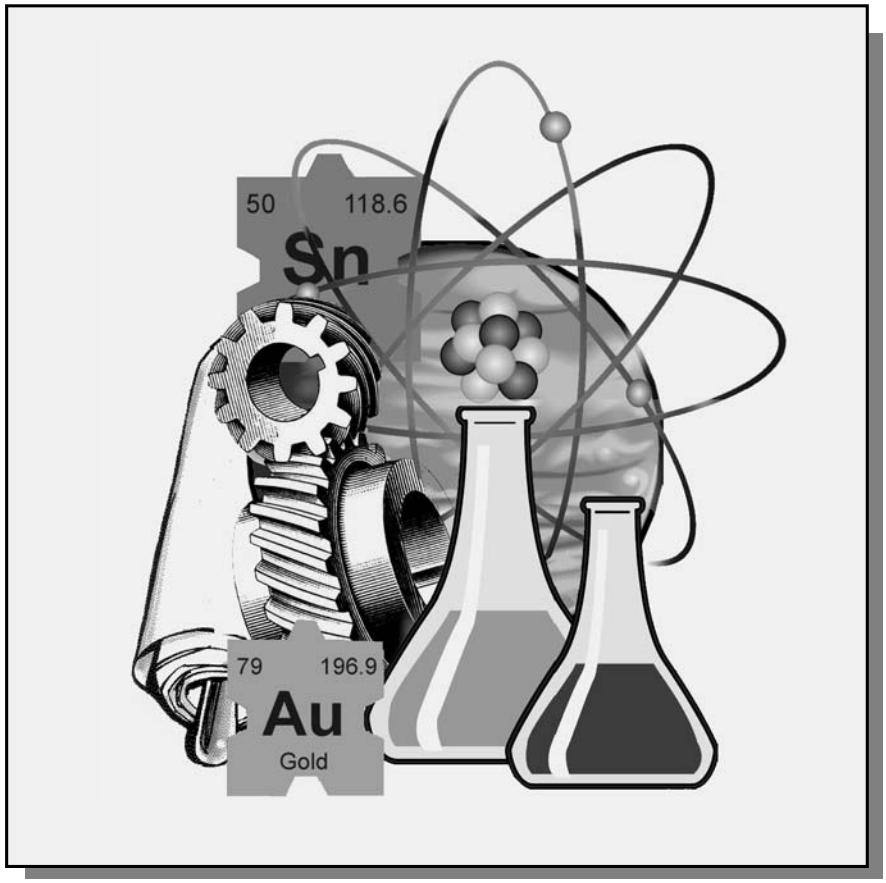
Integrated Physics & Chemistry

This chapter requires a companion activity book in which students respond to questions on text content. Answers are found in the *Teacher's Resource Kit*.



Chapter 12

IPC 76172 Revision: 01-21-05-1

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

PROFESSIONAL CREDITS

Integrated Physics & Chemistry

Chapter 12, Text

Publisher and Managing Editor
Ronald E. Johnson, Ph.D.

Writer
John Hudson Tiner

Editor
David Browder

Consulting Editors
Dortha Collins
Grant Hicks
David Riley

Production Manager
H. Michael Young

Page Composition
Randy Burch
Amy Luna
H. Michael Young

Graphic Artists

Randy Burch	Patrick Floyd	Michael Tummillo
LeAnne Butler	Lydia Johnson	Connie Watson
Roy Collins	Amy Luna	H. Michael Young
	Raeanne Stranc	

Quality Assurance
Cheryl Carithers Sarah Johnson
Nancy Johnson Lisa Weber
Nora Young

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

IPC, CHAPTER 12
TABLE OF CONTENTS

PAGE

SECTION 1

1. SPEED, DISTANCE AND TIME 1-4
2. ENERGY. 5-9
3. FORCE AND SIMPLE MACHINES 11-14
4. LAWS OF MOTION. 15-18
5. HEAT 19-22

SECTION 2

6. PRESSURE AND DENSITY 23-26
7. WAVE MOTION 27-30
8. LIGHT 31-34
9. ELECTRICITY 35-38

PAGE

10. SERIES AND PARALLEL CIRCUITS. 39-42

SECTION 3

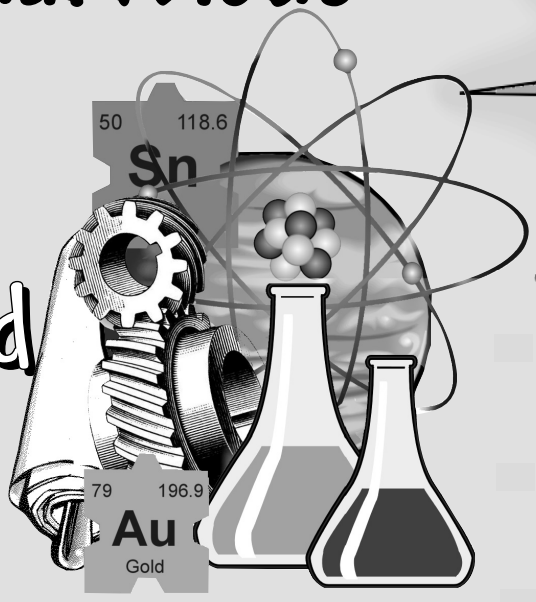
11. PARALLEL CIRCUITS. 43-46
12. CURRENT AND POWER. 47-50
13. KEEPING ELECTRICITY SAFE 51-54
14. DISCOVERY BY DESIGN. 55-58
15. A CAREER IN PHYSICS MAY BE FOR YOU 59-62



©Copyright 2005, Paradigm Accelerated Curriculum

DUPLICATION BY WRITTEN PERMISSION ONLY.

"The study of science is the chronicle of man's quest to discover the essence of life and how the marvelous laws of creation are applied to human needs."



—Ronald Johnson, Ph.D.

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry



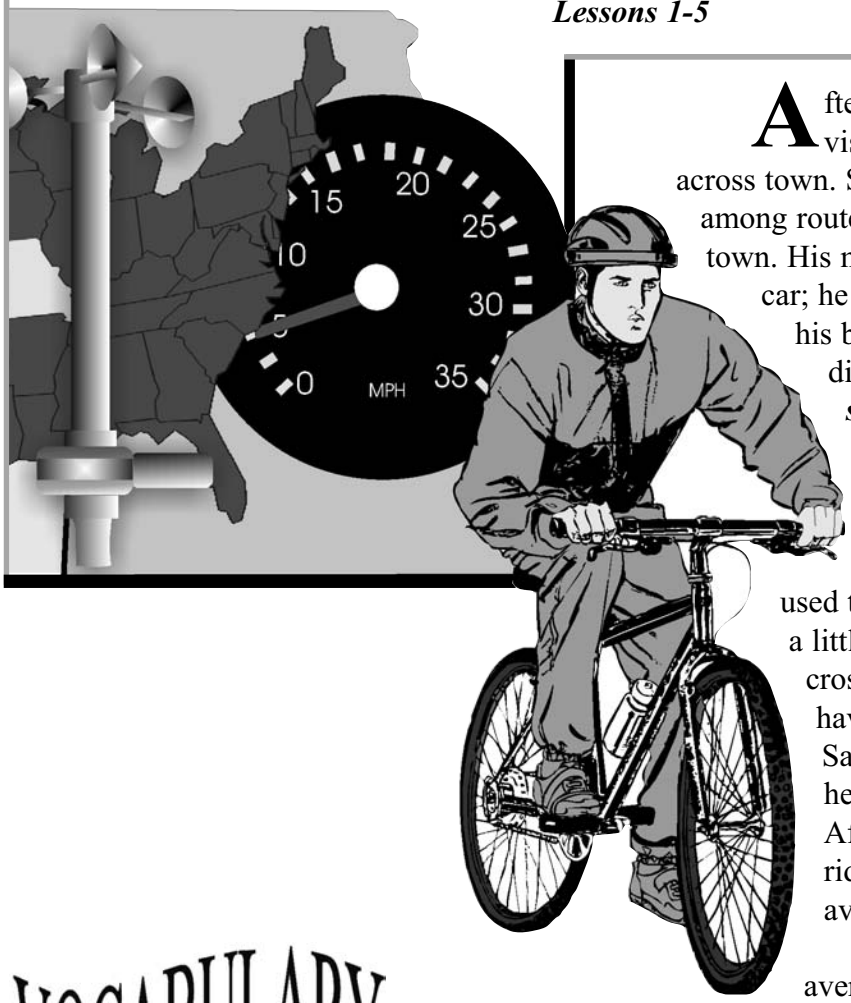
Lesson 1
Motion

Chapter 12

SPEED, DISTANCE AND TIME

Section 1

Lessons 1-5



After school, Samuel planned to visit his friend, Adam who, lived across town. Samuel had several choices among routes and ways of getting across town. His mother could take him in the car; he could walk, or he could ride his bicycle. Each route took him a different way and at a different ***speed***. Samuel chose to ride his bicycle along a paved recreational trail along the river. Only walkers, bicycles and people with in-line skates used the trail. Although the trail was a little longer, it had no traffic crossings, and Samuel would not have to watch for automobiles. Samuel checked his watch when he left; the time was 4:37 p.m. After completing the seven mile ride, his watch read 5:05. His average speed pleased Samuel.

Average speed is speed averaged over a period of time. Average speed is found by dividing the total distance by the total time: *speed = distance/time*. Samuel rode a distance of seven miles, for a total of 28 minutes. Speed = distance/time = 7 mi / 28 min = 0.25 mi/min. However, most people state speed in miles per hour, not miles per minute. Because 60 minutes equals an hour, divide 28 by 60 to change measurements by minutes into an hour: 28/60 = 0.467 hr. Now the speed can be calculated in miles per hour: speed = distance/time = 7 mi / 0.467 hr = 15 mi/hr (rounded).

VOCABULARY

Speed: distance divided by time
Velocity: speed and direction
Resultant velocity: a single velocity that is the result of two or more velocities acting on the same body

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Speed is found by dividing the distance by the time. The distance can be measured in many different units such as feet, meters, miles or kilometers. Physicists use the *meter*, the standard unit of measure for length in the metric system, to measure distance. In the 1700s, the meter was defined as $^{1}/_{10,000,000}$ (one ten millionth) of the distance from the equator to the North Pole. Later, it was defined by two marks inscribed on a special metal alloy bar kept in a vault in Paris, France. In 1983, a meter was defined as the distance traveled by light in a vacuum in $^{1}/_{299,792,458}$ of a second.

Other units of length are derived from the meter, such as the millimeter ($^{1}/_{1,000}$ of a meter, or 0.001 m), the centimeter ($^{1}/_{100}$ of a meter or 0.01 m) or kilometer (1,000 meters or 1.0 km). The yard and inch are defined in terms of the standard meter. A yard is about 3.37 inches shorter than a meter.



Speed = (distance/time) or
256 miles / 4 hours = 64 miles per hour

Physicists measure time with the *second* as the standard unit. At first, the second was measured by the rotation of the Earth. The second was defined as $^{1}/_{86,400}$ of an average day. However, because the Earth does not spin at a constant rate due to tides and other gravitational effects, scientists in 1967 defined the second by much more regular events that take place inside a cesium atom.

Other units of time are derived from the second, such as the millisecond ($^{1}/_{1,000}$ of a second), minute (60 seconds), hour (60 minutes or 3,600 seconds), day (24 hours or 86,400 seconds) and so on.

Speed is stated in distance per unit of time: feet per second (ft/sec), miles per hour (mi/hr), meters per second (m/sec) or some other unit that involves distance divided by time.

As examples, during the first modern Olympic Games in 1896 in Athens, Greece, American Thomas Burke ran the 100-meter dash in 12 seconds. His average speed, based on the formula for speed, was speed = distance/time = 100 m / 12 sec = 8.33 m/sec. One hundred years later at the Atlanta Olympic Games in 1996, Canadian Donovan Baily finished the 100 meter dash in 9.84 seconds. His average speed was calculated as speed = distance/time = 100 m / 9.84 sec = 10.16 m/sec.

Whether the metric system or some other system is used, speed is found by dividing distance by time. For instance, suppose a driver makes the 256-mile trip from St. Louis to Kansas City, Missouri in 4 hours. For highway driving in the United States, average speed is usually stated in miles per hour. The distance, 256 miles, is divided by the time, 4 hours, to give average speed, or Speed = distance/time = 256 miles / 4 hours = 64 miles per hour.

Suppose another driver travels the 256-mile route in 3 hours, 42 minutes. Because the driver completed the trip in less time—3 hours 42 minutes compared to 4 hours—the second driver was going faster. To calculate the second driver's average speed, first change the 42 minutes into a fraction of an hour. Because there are 60 minutes in an hour, divide 42 minutes by 60 minutes: 42 minutes / (60 minutes/hour) = 0.70 hours. The second driver's total driving time was 3 hours + 0.70 hours = 3.70 hours. Now calculate the average speed: speed = total distance/total time = 256 miles / 3.70 hours = 69.18 miles per hour. The second driver is traveling a little over 5 miles per hour faster than the

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

first driver.

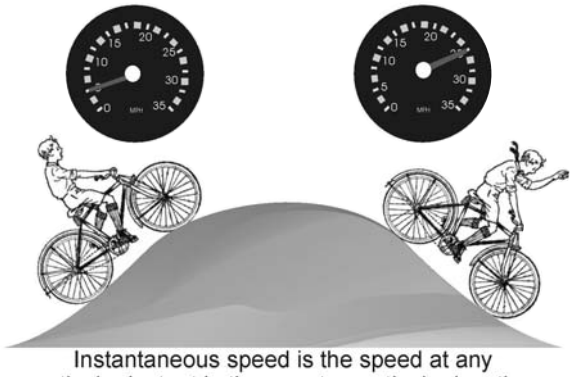
Speed calculated by total distance divided by total time is the average speed. A single number represented the speed over the entire route.

Unless the automobile travels on a straight and level highway without other traffic, maintaining an exact speed that does not vary is difficult. Even with a skilled driver or with a car that has cruise control, the speed changes as the car passes another vehicle, goes up or down hills or rounds curves. On a four lane divided interstate highway, a driver can maintain constant speed more easily than on a narrow, curvy, mountainous road. Even so, the average speed can vary considerably from the actual speed at any given moment.

For instance, in the 100-meter dash, just as the runners break from the starting blocks, their speed is near 0 meters per second. Within a few strides, the runners are up to their full speed, which they maintain to the finish line. The best runners continue to gain speed throughout the entire run and cross the finish line at their fastest speed. The average speed of 10.16 m/sec for Donovan Baily was certainly faster than his speed at the beginning of the race. A runner's average speed is likely to be less than his final speed as he crosses the finish line.

Instantaneous speed is the speed at any one particular instant in time or at a particular location. Usually, instantaneous speed is shown by a speedometer that reads the rate at which a wheel turns. When Samuel rode his bicycle to visit his friend Adam, Samuel covered the seven miles at an average speed of 15 miles per hour. If his bicycle had a speedometer, he could see at any given moment his actual or instantaneous speed. The bicycle speedometer is connected to the wheel or to the gears that turn the wheel. For a wheel of a certain size turning at a certain rate, the speedometer gives the instantaneous speed. It may read 5 miles per hour as Samuel pedals up a hill, or it may read 25 miles per hour as he zooms down the hill.

The bicycle possibly may have an

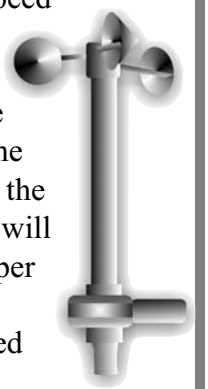


Instantaneous speed is the speed at any particular instant in time or at a particular location.

average speed of 15 mi/hr, but seldom travel at exactly that speed. If the route goes up a long steep hill and then goes down that hill, the bicycle will travel slower than 15 mi/hr going up and faster than 15 mi/hr going down. Only for part of the trip as the bicycle goes over the crest does it go exactly 15 miles per hour.

Automobile speed laws are concerned with instantaneous speed. Speed limits are based on the instantaneous speed, not average speed. A driver who is traveling 90 miles per hour is exceeding the speed limit, although the driver may later slow so that his average is under the speed limit.

Velocity measures the speed of an object and its direction. Physicists give the term velocity a special meaning. The velocity of an object includes the direction it is moving. Suppose the weatherman says that the wind will be out of the north at 30 miles per hour. This description gives the wind's speed as a velocity: speed



©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

(30 mi/hr) and direction (from the north).

Velocity is used when two different velocities are acting upon a body. For instance, suppose a flag is flying on a ferry that is crossing a lake. The ferry is going directly west at 12 miles per hour. This is a velocity because both speed (12 mi/hr) and direction (west) are given. At the same time, the wind is blowing from the north at 5 miles per hour. This is also velocity because both the speed (5 mi/hr) and direction (north to south) are given. The direction the flag flies is a combination of the two velocities. Rather than fluttering in a straight east-west line, it responds to both motions as it angles to the southeast. By knowing the two velocities that are acting on the flag, physicists can calculate the combined effect. The ***resultant velocity*** is a single velocity that replaces two or more other velocities.

Knowing the exact direction a flag is flying is not a particularly important problem. But suppose a jet aircraft carrying passengers is flying through the jet stream. Knowing the resulting velocity of the aircraft over the ground becomes an important point. The pilot must calculate velocity so he will arrive at the airport on time. If the airplane arrives too early, another plane may not have cleared the gate. The first plane will have to circle around the airport to wait for approval to land. If the plane lands too late, some passengers will miss their connecting flights. The speed of the airplane is not as important as its velocity in relation to the ground and the direction of its motion.

Life Principle



"A dream without action remains a daydream."

— Anonymous

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

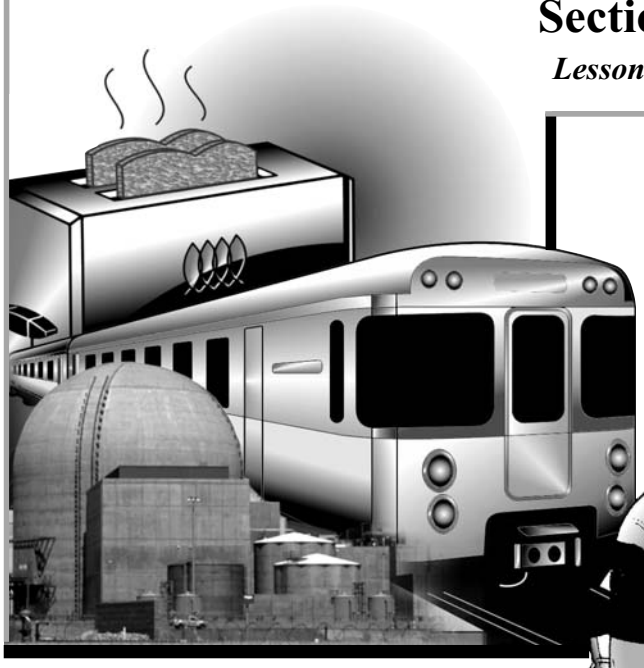
Lesson 2
Energy

Chapter 12

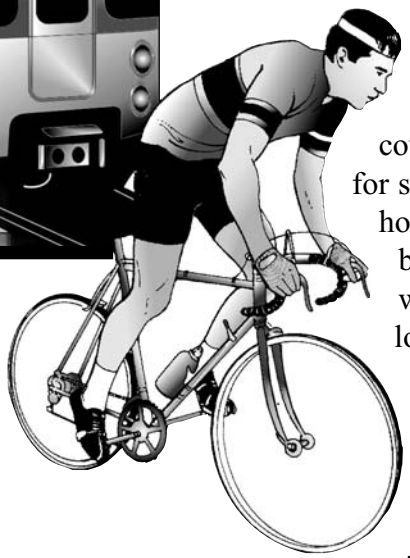
ENERGY

Section 1

Lessons 1-5



To peddle his bicycle to his friend Adam's house, Samuel had to expend ***energy***. The energy in this case came from his muscles. As his muscles contracted and relaxed, they gave motion to Samuel's legs. His legs turned the pedal that transferred the energy to the chain and to the bicycle wheel.



Depending on his strength and endurance, Samuel could have ridden the bicycle for several hours. Eventually, however, he would have become tired. His muscles would have protested the long, unbroken activity.

Part of the reason muscles grow tired is the build-up of waste products in muscle cells. Another reason is a decrease in the vital nutrients to power the cells. In the case of muscles, whether human or animal, energy is generated by the breakdown of food. The body converts carbohydrates into glucose, a simple sugar. The sugar is taken throughout the body by the blood and is used as a source of energy. The sugar reacts with oxygen to give carbon dioxide, water and energy. The type of energy produced from food is ***chemical energy***.

The chemical reaction changes the chemical energy into mechanical energy. *Mechanical energy* is the ***kinetic energy*** plus the ***potential energy*** of a body. In the example of Samuel with his bicycle, chemical energy is changed into mechanical action of the muscles. The muscles move his legs that pump the pedal and then turn the wheels.

VOCABULARY

Energy: the ability to do work, to put matter in motion or make physical changes
Chemical energy: energy produced by a chemical reaction
Kinetic energy: energy of a body due to its motion and mass
Potential energy: reserved energy due to position or conduction, such as a coiled spring or the gravitational potential energy of water behind a dam

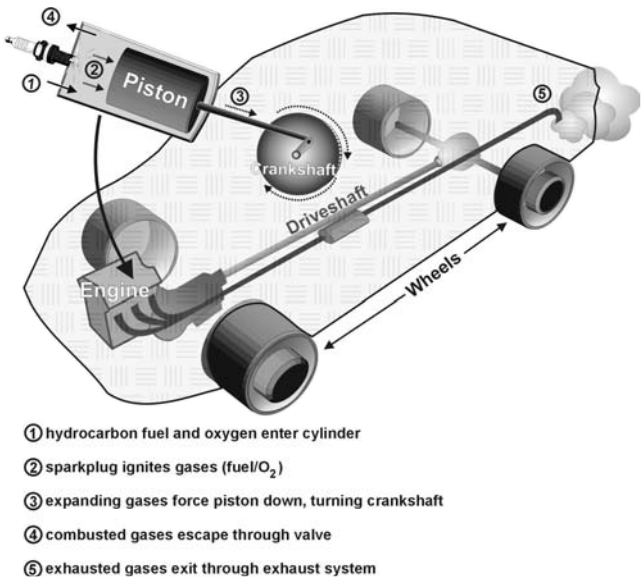
©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Not all energy arrives at the drive wheel. Usually, heat is generated when energy changes from one form to another. *Heat energy* is the result of the internal kinetic energy of atoms and molecules. If Samuel exerts himself particularly hard, the chemical reactions generate more heat than the body needs. The excess heat is then eliminated by exposure to the air through sweat glands and from the breath (nose and mouth).



Heat is eliminated from the body through sweat and breathing.

Suppose that instead of riding his bicycle, Samuel's mother had transported Samuel in a car to Adam's house. Again, energy is needed, and, again, it begins as chemical energy. The automobile has a fuel tank that holds between 15 and 20 gallons of gasoline when full. Gasoline is a mixture of liquid hydrocarbons. Most motor fuels contain heptane (C_7H_{16}) with seven carbon atoms and 16 hydrogen atoms, and octane (C_8H_{18}) with 8 carbon atoms and 18 hydrogen atoms. The hydrocarbon fuel is mixed with oxygen from the air and introduced into the cylinder of the automobile engine. An electric spark from a spark plug ignites the fuel and oxygen mixture. The chemical reaction converts hydrocarbon and oxygen into water and carbon dioxide. Because of the heat, both are gases and expand rapidly. The expanding gases push the engine piston which is connected to the crankshaft and eventually to the wheels of the car.



Like the human body, the automobile converts chemical energy into mechanical energy. As in the human body, not all of the energy goes into moving the car. Some becomes heat, and the engine becomes hot. The exhaust pipe of an automobile can quickly become too hot to touch. Other moving parts are heated by friction. The flex of the tires as they rotate and the scrubbing they experience when the car turns a corner causes tires to gain heat energy. Almost all energy changes produce heat.

Instead of riding with his mother, Samuel could have taken a city metro train that operated on electricity. Most subways and above ground commuter trains are powered by electricity. A third rail on the

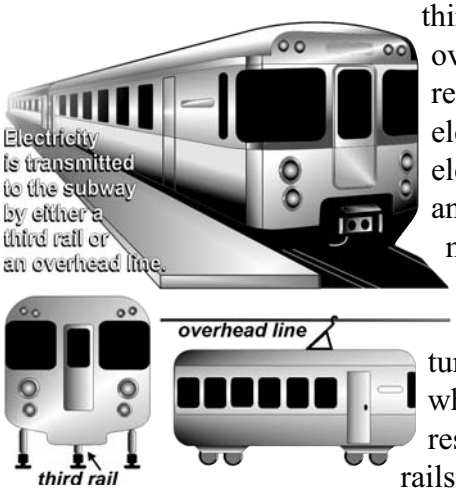
VOCABULARY

Fossil fuel: a hydrocarbon fuel such as coal, oil or natural gas; fossil fuels form from ancient living matter

Electrical energy: a form of energy that can generate by friction, induction or chemical changes and can produce heat, light magnetism or chemical changes.

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

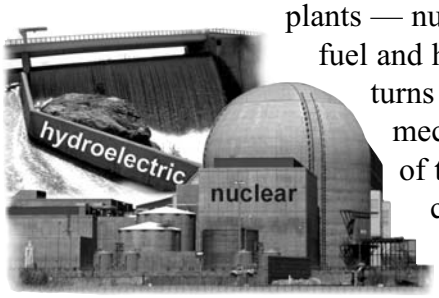
track or an overhead line carries the electricity. A conducting probe extends from the train engine and makes contact with the third rail or the overhead line to receive the electricity. The electricity runs an electric motor, located in the train engine, that turns the drive wheels which rest on metal rails.



The electricity begins its trip to the train from a distant power generating station. The station may be nuclear powered. As the enriched uranium fuel undergoes fission the atoms come apart and release vast amounts of heat. Water under pressure is pumped through the reactor core, where it is heated to about 600°F. For safety reasons, the hot water is passed by a closed secondary loop to a second source of water. The water in the secondary loop changes to steam and spins a turbine to give mechanical motion. Not all of the heat from the nuclear reaction goes into kinetic motion of the turbine. After passing through the turbine, the steam continues to carry heat. Prominent features of most nuclear reactors are large cooling towers. Energy from the steam enters the air, and the steam condenses back into water.

Burning coal, petroleum or natural gas may also generate electricity. Burning of fuel is a chemical reaction that combines the hydrocarbon ***fossil fuel*** with oxygen to give carbon dioxide, water and heat. The heat changes water to steam that turns a turbine.

A hydroelectric plant may also generate electricity. A dam across a river increases the water level. The water behind the dam has more gravitational potential energy than water released to flow into the river below the dam. The falling water turns a turbine that generates electrical energy.



Each of the three types of power plants — nuclear, fossil fuel and hydroelectric— turns turbines. The mechanical motion of the turbines is changed into ***electrical energy***. In a modern hydroelectric power plant, each turbine spins a series of coils around a circle of magnets generating electricity in the coils. Each of these changes of energy from one form to another generates heat. Heat is the random motion of atoms and molecules in a substance. Scientists have discovered that only part of the heat of a body can be changed back into some other type of energy. Once energy becomes heat, some of it is forever lost for useful purposes. Of all forms of energy, heat is the hardest one to recover.

Energy is lost in going from a coal burning electrical power plant to its final use in the home. The loss is measured by the efficiency. *Efficiency* compares the energy that goes into the task compared to the total energy that is expended. Efficiency can never be 100 percent. The total energy required to operate a machine is always more than the work that the machine performs.

efficiency = energy output/energy input

In Samuel's bicycle, a well-oiled gear loses about one percent of the energy. Of the energy that Samuel puts onto the pedal, one percent is lost at the pedal gear, another one percent is lost at the wheel gear. About 98 percent of the energy produced by Samuel is transferred from the pedal to the bicycle wheel.

In an automobile, the energy changes are far more involved — from chemical

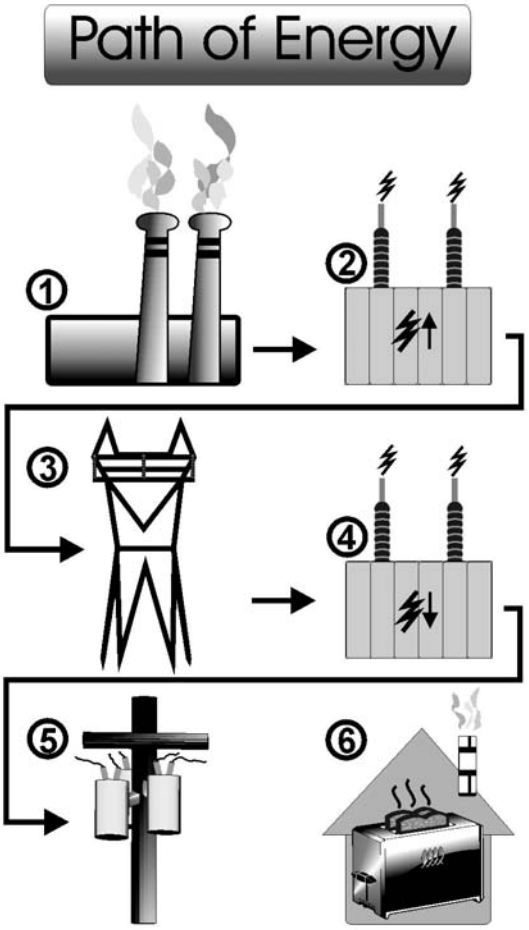
©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

energy of the fuel to heat to mechanical energy of the piston. The energy is transferred from the crankshaft to the transmission for shifting gears, to the drive shaft, differential and finally to the wheels. An automobile has an efficiency of only about 25 percent. Of the total energy in the fuel, 75 percent is lost as heat during energy conversion and from friction experienced by gears and tires.

The most modern, fuel-efficient electric generating plants have only about 50 percent efficiency. Only about half of the energy of the fuel is converted into electricity. Some older power plants have an efficiency of only about 30 percent.

Still more energy is lost as it is distributed from the power plant to homes and industry. Electricity heats the wire through which energy flows. Scientists discovered that the heating effect could be reduced by the right combination of current and voltage. A lower current generates less heat. However, the voltage must be increased to ensure that the same amount of power passes through the wires. A transformer is used to step up voltage as the electricity leaves the plant. At the destination, a step down transformer lowers the voltage to a safer level. Most electrical service lines to U.S. homes and small businesses enter the transformer at 440 volts and enter the home at 220 volts, then enter wall outlets at 110 volts.

At its destination, electrical energy undergoes transformation into other energy types. Notice the ways electricity is changed into other forms of energy once it enters the home. An electric motor converts electricity into mechanical motion. The electric motor may pump water, turn a fan or raise a garage door. Electricity that passes through a wire with a high resistance generates heat to toast bread, to energize an electric stove or to warm a small room. Electricity may change into invisible electromagnetic radiation for use in a microwave. It may cause the filament of a light bulb to glow to give visible light. Electricity may charge batteries that will be used in a cellular telephone or portable computer. Charging batteries uses electricity to produce a chemical change. Later, the chemical change will be reversed to generate electricity.



① coal-burning power station

② transformer–electricity is stepped up to a higher voltage

③ cross-country transmission line (high voltage)

④ transformer–electricity is lowered

⑤ transformer–electricity is lowered to about 120 volts

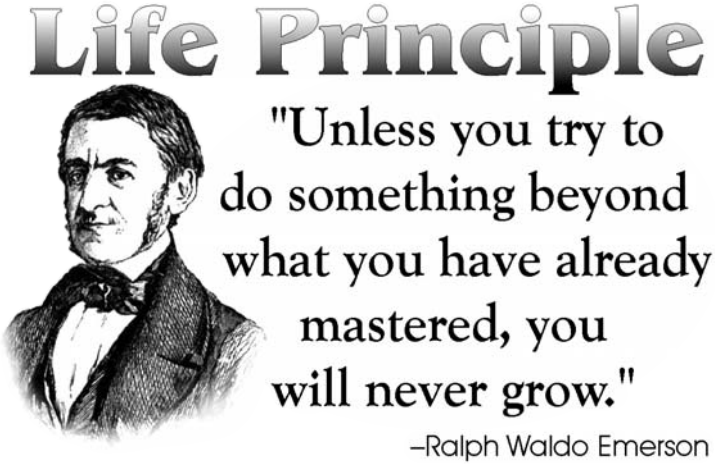
⑥ electricity is used in the home

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Notice the total path of the energy. Assume that energy begins in a coal burning power station and ends at an electric bread toaster. Chemical energy (coal) → heat energy (steam) → kinetic energy (turbine) → electricity at low voltage (at the power station) → electricity at high voltage (cross country transmission line) → back to low voltage (distribution to the home) → heat energy (toaster).

All of these changes in the form of energy cause heat and a loss of energy. Measuring the energy that is lost from start to finish is not easy. However, most scientists believe that only about seven percent of the original energy from the fuel burned at the power plant makes its way to its intended use in homes and factories. One of the great efforts of scientists at the start of the 21st century is to discover more efficient uses of energy.

One promising technology is fuel cells. A *fuel cell* generates electricity directly from hydrocarbon fuels. The fuel enters a porous terminal that is one side of a conducting electrolyte. Air with oxygen enters a porous terminal that is on the other side of the electrolyte. The reaction produces carbon dioxide, water and an electric current that flows from the oxygen terminal (cathode) to the fuel terminal (anode). Most major car manufacturers are experimenting with fuel cells which have an efficiency of about 75 percent.



©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.



©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

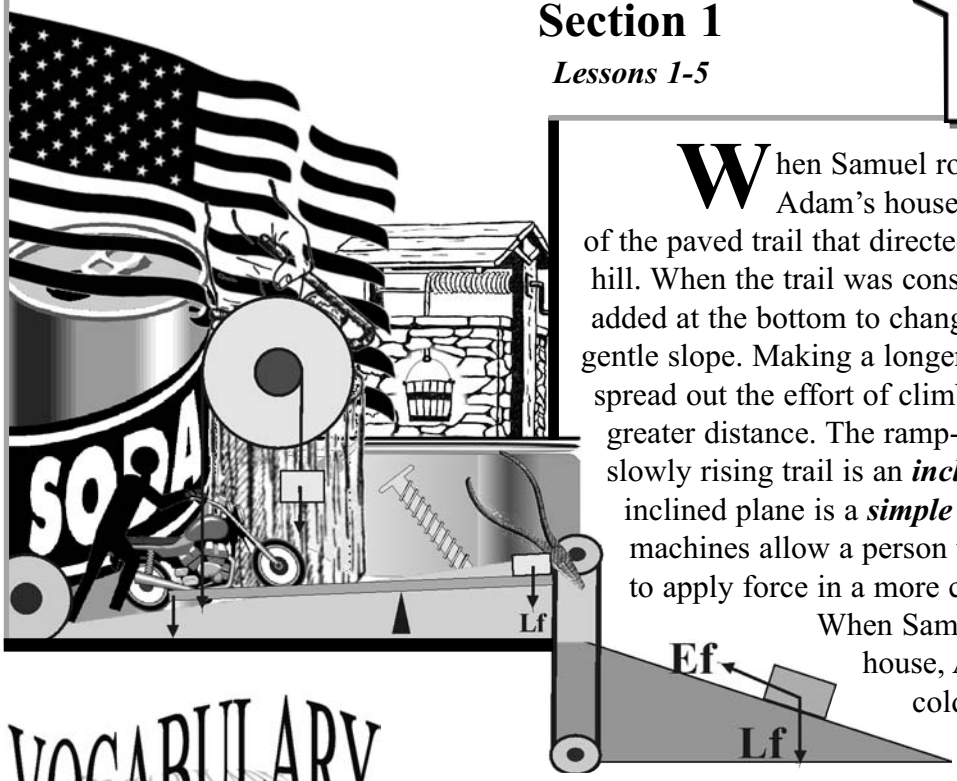
Lesson 3
Energy

Chapter 12

FORCE AND SIMPLE MACHINES

Section 1

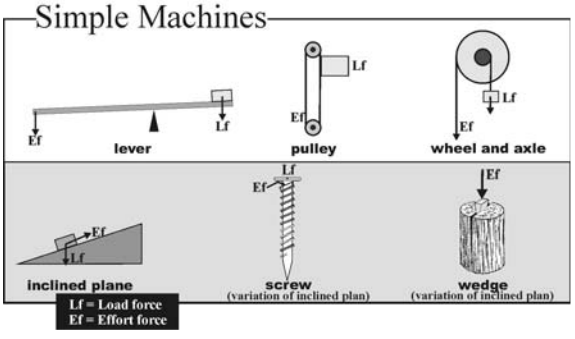
Lessons 1-5



When Samuel rode his bicycle to Adam's house, he came to a section of the paved trail that directed him to the top of a hill. When the trail was constructed, fill dirt was added at the bottom to change the steep slope into a gentle slope. Making a longer approach to the hill spread out the effort of climbing to the top over a greater distance. The ramp-like construction of a slowly rising trail is an ***inclined plane***. An inclined plane is a ***simple machine***. Simple machines allow a person to apply less force or to apply force in a more convenient direction.

When Samuel reached his friend's house, Adam offered Samuel a cold drink that came in a pop-top can. Although Samuel did not think about it, when he popped the top of the can, he used a lever. The pop-top had a place for Samuel's finger or thumb. The place in which the pop-top was attached to the can (the brad) was the pivot point or fulcrum. The pop-top pressed against the top of the can to bend back the opening. The ***lever*** on the top of a pop-top can is an example of a simple machine.

Pulling down on a rope to raise a flag to the top of a flagpole is easier than climbing the pole and then pulling up the flag. The flag is raised by a simple ***pulley*** system whereby the rope goes over a wheel at the top of the pole. Pulling down on the rope raises the flag. The pulley is another example of a simple machine.



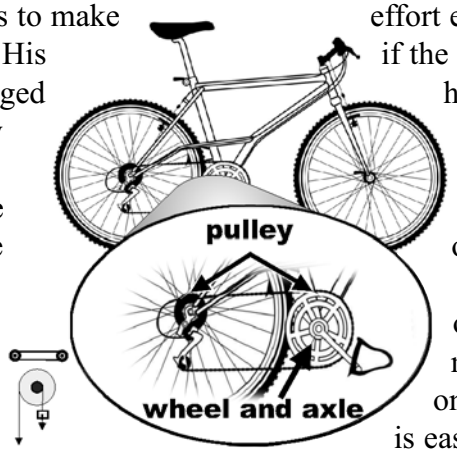
VOCABULARY

Inclined plane: a simple machine in the form of a ramp for raising or lowering a load
Simple machine: a device that changes the amount or direction (or both) of a force required to move a load
Lever: a simple machine with a pivot point (fulcrum) and a place for the load and effort
Pulley: a simple machine that changes the direction of a force for lifting a load
Work: a force acting through a distance, $E = F * d$, with E the work (or energy), F the force, and d the distance

©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

Lifting objects becomes easier if the direction the force is applied can be changed. A barn usually has a pole that projects from the hayloft. The purpose of the pole is to support a pulley. Bales of hay are lifted into the loft by a rope and pulley system. The force that a person must pull down on the rope is equal to the weight of the bale of hay. However, the task is easier because the farmer pulling on the rope can let his weight work for him in lifting the bale.

As Samuel rode the bicycle, he pressed down the pedals to make the bicycle go forward. His vertical thrust was changed to a horizontal thrust by the wheel. By pressing down, Samuel made the bicycle go forward. The bicycle changed the direction of the force. The process involved a lever and pulley system.



Another purpose of a simple machine is to reduce the amount of force that is needed to do a task. The *mechanical advantage* is the force produced by the simple machine compared to the needed force without the simple machine. Or, in symbols, *M.A. = load force/effort force*. In the case of the single pulley lifting the flag, the mechanical advantage is 1.0 because the effort and load are the same. The force that the person uses to pull down on the rope (effort force) equals the weight of the flag (load force). If the mechanical advantage is greater than one, then less force is needed to move the object.

Mechanical advantage of any simple machine may be less than one if the effort is greater than the load, equal to one if the effort equals the load, and greater than one if the effort is less than the load. For a heavyweight object that is difficult to move, a person would want the effort to be less than the load, so a mechanical advantage greater than one is desirable.

A loading ramp is an example of a simple machine that has a mechanical advantage greater than one. Rolling a motorcycle up a ramp is easier than lifting the cycle into the back of a pickup truck. Suppose the motorcycle weighs 425 pounds, and a ramp reduces the force to 70 pounds. The mechanical advantage is *M.A. = load force/effort* force = 425 / 70 = 6 (rounded).

Most people are aware that "you don't get something for nothing." Work is necessary and honorable. ***Work*** is defined as the force times the distance through which the force is applied. Although the force is reduced, it must be applied over a greater distance. The work required is not reduced. In the case of the motorcycle, the force must be applied along the entire length of the ramp. Another way to calculate the mechanical advantage is: *M.A. = effort distance/load distance*.

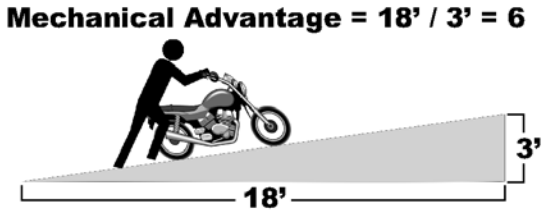
A motorcycle to be loaded on a truck bed located 3 feet above the ground level is loaded easily with the use of a ramp 18 feet

VOCABULARY

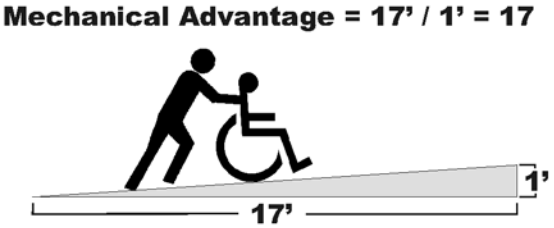
Wheel and axle: a simple machine with a wheel that turns an attached axle, the mechanical advantage is the circumference of the wheel divided by the circumference of the axle, because circumference and diameter are proportional, the mechanical advantage is also equal to the diameter of the wheel divided by the diameter of the axle

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

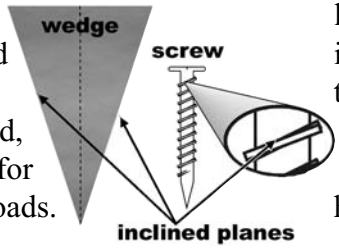
long. The effort must run along a distance of 18 feet, but the distance the load rises is only 3 feet; therefore M.A. = effort distance/load distance = 18 ft / 3 ft = 6ft.



People in wheelchairs may access most buildings by convenient ramps. The purpose of a ramp is not only to eliminate the barrier of steps but also to reduce force to gain extra height. A typical wheelchair ramp has a mechanical advantage of 17. The wheelchair rolls a distance of 17 feet for each foot gained in elevation. A wheelchair that gains an elevation of 3 feet must roll a distance of 3 * 17 = 51 feet. The mechanical advantage of 17 also means that the force for pushing the wheel chair and occupant is $1/17^{th}$ as much force as for lifting the chair and occupant three feet. The force is lessened, but it must be applied over a greater distance.

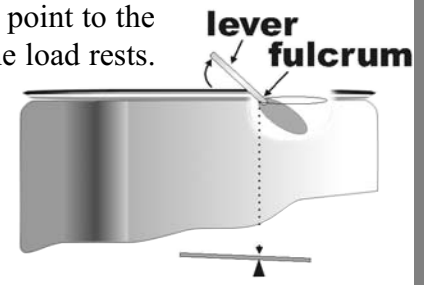


Examples of inclined planes include a loading ramp, wheelchair ramp or a highway that has the grades reduced. The grade of a hill is usually stated as a percent, such as 8 percent. Out of every 100 feet of travel, the road rises 8 feet. By filling in the valleys and cutting down the hills, the grade can be reduced, making the road easier for trucks carrying heavy loads.



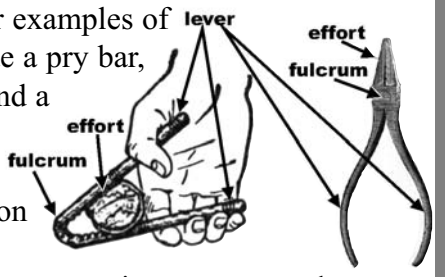
A *wedge* for splitting wood and a screw are also inclined planes. A wedge is two inclined planes put back to back. A *screw* is an inclined plane wrapped around a cylinder.

The *lever* is another common simple machine. A lever consists of a bar with three properties. It has a pivot point, called the fulcrum. A lever has a place for the load and the effort. Mechanical advantage is given by dividing the length of the effort arm by the length of the load arm. The *effort arm* is the distance from the pivot point to the place the effort is applied. The *load arm* is the distance from the pivot point to the place where the load rests. For a lever, the mechanical advantage is *M.A. = effort arm/load arm*.



The pop-top can is opened with a lever. From the end of the ring to the fulcrum is 20 mm. From the fulcrum to the part that presses against the can is 4 mm. Mechanical advantage = effort arm/load arm = 20 mm / 4 mm = 5. Opening the can is made 5 times easier by using the pop-top.

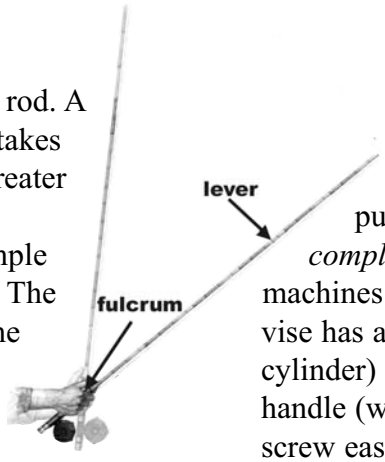
Other examples of levers include a pry bar, wire pliers and a nutcracker.



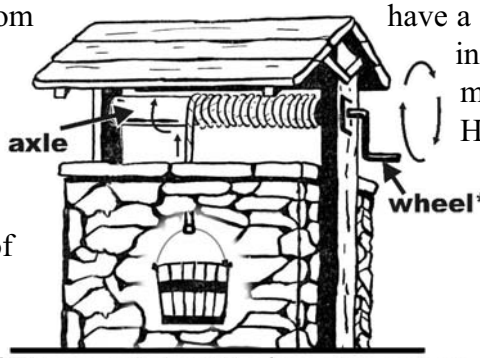
In some cases, a person is willing to exert more force to gain greater speed. In those cases, the mechanical advantage is less than one. For instance, a fisherman who is fly-casting gains greater speed at the tip of the rod by snapping the rod with a quick motion. The rod acts as a lever. The fulcrum, or pivot point, is at one end; the fisherman's hand makes the effort nearer the fulcrum

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

rather than near the tip of the rod. A small movement of his hand takes the tip of the rod through a greater distance.



The fourth type of simple machine is a ***wheel and axle***. The axle is usually smaller than the wheel, so turning the large wheel is easier than turning the small axle directly. One of the first uses of a wheel and axle was to raise a bucket of water from a well. A rope passed around an axle and down to the bucket. Turning the wheel wrapped the rope around the axle and made raising the bucket of water easier.



*The crank handle functions as a wheel because it turns the axle.

Before cars were equipped with power steering, one of the choices an automobile buyer had was the size of the steering wheel. The steering wheel was mechanically linked to the front wheels. If a person were not particularly strong, he or she would buy a car with a larger steering wheel because it made turning the front wheels easier.

The mechanical advantage of a wheel and axle is given by the ratio of the circumference (distance around) of the wheel compared to the circumference of the axle. Circumference is proportional to the diameter, so the mechanical advantage can be computed by measuring the diameter: *M.A. = diameter of wheel/diameter of axle*.

A screwdriver is an example of a wheel and axle. A standard screwdriver has a handle with a diameter of 36 mm and a shaft with a diameter of 6 mm. The mechanical advantage is M.A.= wheel diameter/axis diameter = 36 mm / 6 mm = 6. Because the wheel is larger than the axle, the M.A. is greater than one.

The four types of simple machines are wheel and axle, pulley, lever and inclined plane. A *complex machine* has two or more simple machines that work together. For instance, a vise has a screw (inclined plane around a cylinder) for tightening the jaws together. A handle (wheel and axle) makes turning the screw easier. Scissors are two levers that share the same fulcrum. The scissors also have a cutting edge (wedge or two inclined planes). A bicycle is a more complex machine. However, each individual part makes use of the principles of simple machines.

Life Principle



"We are not here to merely make a living. We are here to enrich the world, and we impoverish ourselves if we forget this errand."

—Woodrow Wilson

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry



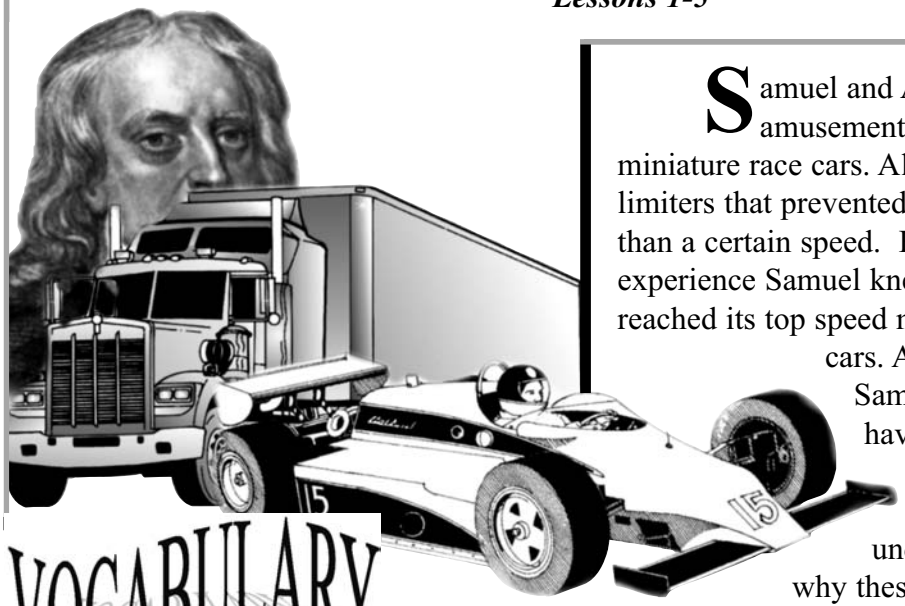
Lesson 4
Motion

Chapter 12

LAWS OF MOTION

Section 1

Lessons 1-5



Samuel and Adam went to an amusement park where they rode miniature race cars. All of the cars had speed limiters that prevented drivers from going faster than a certain speed. However, from his experience Samuel knew that his favorite car reached its top speed more quickly than other cars. Adam wondered what made Samuel's car quicker. It could have been lighter. Samuel's car could have had a more powerful motor. To understand the physics of why these two quantities make a difference, recall English scientist Isaac Newton's Three Laws of Motion.

An object in motion will continue in a straight-line motion at the same speed unless it is acted upon by some outside force. One common outside force is ***friction***. If the engine dies, the miniature race car (or any other moving object) will eventually slow because of friction. If the friction could be removed, then the object would continue to roll without loosing any speed. This observation is the *First Law of Motion*: an object at rest will remain at rest and an object in motion will continue in straight-line motion at constant speed unless acted upon by an outside force.

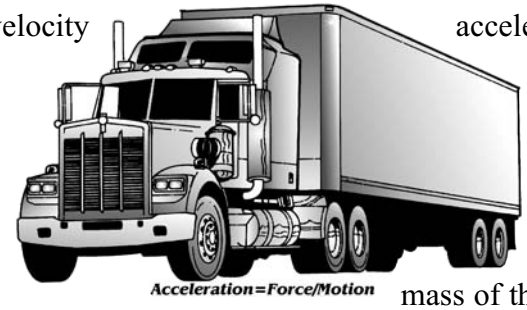
The main force acting on the miniature race car is the thrust (or force) of the engine that acts in the forward direction. The other important force acting on the miniature race car is friction that acts in a direction opposite the force of the engine. If the two forces are equal, then the car has zero ***net force*** acting on it. The race car travels at a constant speed. If the car is going 25 miles per hour and has a net force of zero, then it will neither gain nor lose speed nor change direction.

VOCABULARY

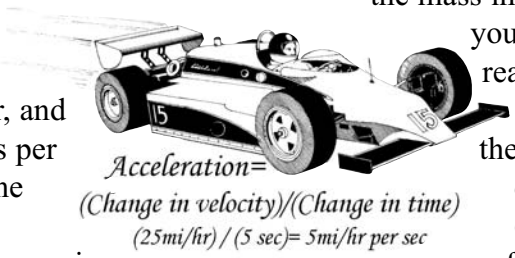
Friction: the force that resists motion of one object sliding across another object
Net force: a single force that represents all of the forces that are acting on an object, also known as the resultant force
Law of Gravity: every object attracts every other object in the universe with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance separating them; another name for the Law of Universal Gravitation
Elongated: lengthened, extended

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

If speed is constant, no change in velocity will occur and acceleration will be zero. *Acceleration* is the rate at which velocity changes. A car traveling at constant speed in a straight line has an acceleration of zero. When the velocity does change, physicists say the vehicle undergoes acceleration. Acceleration is calculated by dividing the change in speed by the change in time: *(acceleration) = change in speed/change in time.*



When the race car first starts motion, the engine produces more force than the friction acting against the car. The net force is greater than zero because all of the forces are not in balance. The car accelerates. Suppose it starts at rest, 0 miles per hour, and zooms up to 25 miles per hour in 5 seconds. The acceleration is: a = change in velocity/change in time = 25 mi/hr / 5 sec = 5 mi/hr per sec. On average, the car gains five miles per hour in speed every second. If the acceleration continued without change for another four seconds, the car would gain an additional 20 miles per hour (4 * 5 mi/hr = 20 mi/hr). The final speed would be 45 mi/hr (25 mi/hr + 20 mi/hr = 45 mi/hr).



As another example, suppose a marathon runner is running at 14 feet per second until he nears the finish line. Then in the last 10 seconds of the race, he increases his pace to 17 feet per second. To calculate the change in speed, subtract the initial speed from the final speed. In this example, the final speed is 17 feet per second. The initial speed is 14 feet per second. The change in speed is 17 ft/sec - 14 ft/sec = 3 ft/sec. Next calculate the acceleration: a = change in velocity/change in time = 3 ft/sec / 10 sec = 0.3 ft/sec^2. The answer is read as 0.3 ft per sec per sec or 0.3 ft per sec squared.

The *Second Law of Motion* shows how force, mass and acceleration are related. The second law states that acceleration is directly proportional to the force acting upon it and inversely proportional to the mass of the object: *a(acceleration) = F(force)/m(mass)*.

Notice that in the formula *a = F/m,* the mass is in the denominator. Increasing the mass reduces the acceleration, while reducing the mass increases the acceleration. Suppose you wanted the miniature race car to reach its top speed quicker. One way of doing that would be to reduce the mass. The lighter the car, the quicker it can go provided the engine continues to deliver the same force to the wheels.

Automobile manufacturers improve the fuel economy by making cars lighter. Building the frame and skin of a car with aluminum and other alloys, reduces the weight from 3,200 pounds to 2,000 pounds. Lighter cars equipped with the same engine have better acceleration.

Adam and his family took their vacation in a sport utility vehicle (SUV). During the school year, Adam's mother drove the vehicle. She could merge into traffic quickly because the engine provided good acceleration. During the vacation, however, the vehicle did not have the quickness that his mother had experienced in town. A moment's thought revealed the reason. The vehicle included the family's luggage and camping gear. Rather than containing only one or two people, the SUV carried the whole family and

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

baggage. Overall, the vehicle carried 1,000 additional pounds. The extra mass caused the car to experience reduced acceleration.

Suppose a person knows that a vehicle will be carrying a heavy load or pulling a travel trailer. If the weight increases, another adjustment can be made to experience rapid acceleration. The second law formula, $a = F/m$, shows that force is the other quantity that affects acceleration. A vehicle accelerates more quickly by increasing the force that the engine provides. If a person buys a vehicle and knows it will be used for pulling heavy loads, the vehicle is purchased with a larger engine. The larger engine provides greater force. The increased motor horsepower in the original SUV body weight enables greater acceleration.

When shopping at the supermarket, Samuel's young sister, Sydney, pushes the cart. When it is empty, the young girl has no problem starting, stopping and turning the cart. However, products are placed in the cart, the increased mass requires a greater force to start, stop and turn the cart. The shopping cart becomes more difficult for the young girl to handle. The Second Law of Motion shows that if the force remains the same but the mass increases, then the change in velocity is not as great.

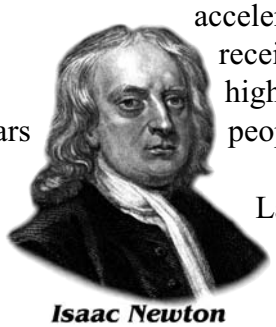
The *Third Law of Motion* states that two objects that act upon one another exert equal forces, but in opposite directions.

In everyday experience, the Three Laws of Motion are not readily apparent because objects usually have more than one force acting simultaneously. One of the forces is friction. Remove friction, and suddenly the three laws become plain to see. For example, during an ice storm, cars have difficulty operating on slick highways, difficulty moving, difficulty steering, and difficulty stopping. Cars easily follow the First Law of Motion because they stay at rest if they are stopped. If they are moving on ice they continue in a straight-line motion at constant speed according to the first law, even if the wheels are turned, and the brakes are applied.

When Samuel and Adam first learned to use their in-line skates, the boys noticed quickly the Three Laws of Motion. Both boys had to learn how to stop, turn and accelerate. If they were out in the middle of a paved lot and pushed away from each other, both saw the Third Law of Motion at work. Samuel rolled away from Adam, and Adam rolled away from Samuel. Each one exerted an equal force on the other.

If each received the same force, they did not necessarily both roll away at the same speed. If their weights were different, then the same force gave the lighter boy a greater final velocity.

Samuel's young sister, Sydney, went ice-skating with her mother. Because of the greatly reduced friction, all Three Laws of Motion were easily experienced on the ice rink. Sydney and her mother were in the middle of the ice rink. As they pushed away from each other, mother and daughter felt the same force. Sydney's force acting on her mother was equal to the mother's force acting on Sydney. Sydney went in one direction. Her mother went in the other. Although the forces were equal, the masses were different. Sydney weighed only about one-third of the weight of her mother. Because Sydney had only one third the mass, she experienced acceleration three times as great as the acceleration of her mother. Sydney received the greater acceleration and higher final speed when the two people pushed against each other.



Isaac Newton

In addition to stating the Three Laws of Motion, Isaac Newton identified the ***Law of Gravity***. He showed that gravity acts on

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

any two objects in the universe, whether the object is an apple, a planet or a comet. The attraction depended upon the mass of the objects. Small objects such as two apples did not have as much force of attraction between them as two large objects such as the Moon and Earth. According to the Law of Universal Gravitation, the force of attraction between two objects is directly proportional to the product of their masses.

The other quantity that affects gravitational attraction is distance. The force of attraction between two objects is inversely proportional to the square of the distance separating them. The farther away two objects are from one another, the weaker grows the force of attraction.

Some comets have greatly ***elongated*** orbits that take the comets deep into space. Comets orbit the Sun further out than Pluto, the most distant planet. Because of the great distance, the attraction between these distant comets and the Sun becomes weak. Gravitational attraction of nearby stars can change the orbits of comets that travel far from the Sun.

Life Principle

"By removing friction from our relationships, we can usually see our positive options plainly."

— N. Johnson

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

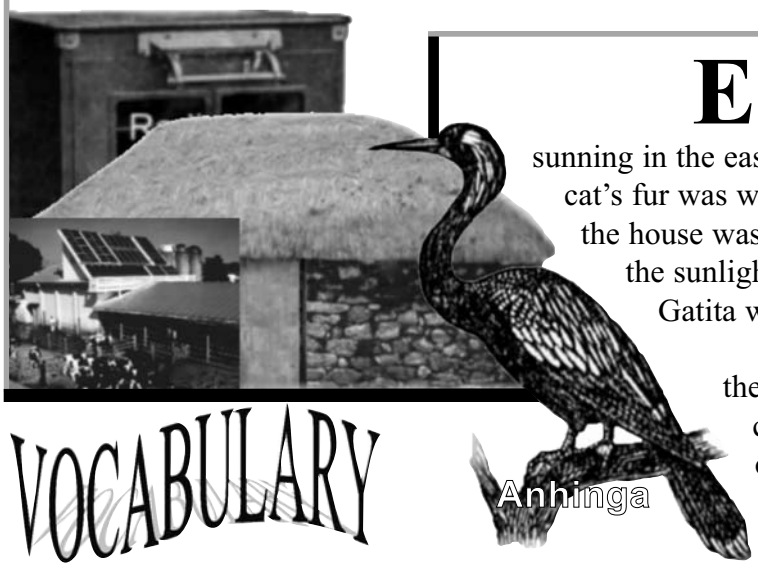
Lesson 5
Energy

Chapter 12

HEAT

Section 1

Lessons 1-5



Anhinga

Early in the morning when Sydney awoke, she found her cat, Gatita, sunning in the east window of the breakfast room. The cat's fur was warm to the touch although the air in the house was still cool. The cat, however, was in the sunlight that streamed through the window. Gatita was being warmed by ***radiant heat***.

Many animals take advantage of the radiant energy of sunlight to maintain comfortable body temperatures. On a cool morning, turtles will sit on a log in a pond getting warm before plunging into the cold water. Amphibians and reptiles, such as frogs, turtles and snakes, are ***cold-blooded***. Their body temperatures fluctuate—they are not constant. They vary depending on the temperature of the environment. Because their body functions are slower at a cool temperature, reptiles are slow and incapable of quick movements until they warm themselves in the Sun.

The anhinga is a bird that lives in the wetlands of Florida and other southern states. Birds are ***warm-blooded***. They maintain a constant body temperature, even in cold weather. Unlike most other water birds, anhingas have neither air sacs to help them float nor oil glands to make their feathers waterproof. When they settle in the water, their feathers become wet. Anhingas sink instead of floating.

An anhinga can silently sink below the surface without frightening its prey. Its black feathers make it nearly invisible underwater. The anhinga spears a fish with its long dagger-like beak. Then it brings the fish to the surface, tosses it into the air and swallows the fish head first.

After a few minutes in the water, the anhinga's feathers become waterlogged. They no longer offer protection against the chilly water, which means the bird cannot survive in cold

VOCABULARY

Radiant heat: radiant energy that travels as electromagnetic waves
Cold-blooded: a living organism whose body temperature varies with the temperature of its surroundings; they tend to avoid direct sunlight on hot days and seek sunlight during cold weather; fish, amphibians and reptiles are cold-blooded
Warm-blooded: a living organism whose body temperature remains relatively constant regardless of the environmental temperature; mammals and birds are warm-blooded
Archaeologists: scientists who study and analyze artifacts and remains of ancient cultures
Conduction: the transfer of heat by direct contact

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

water for long. The anhinga climbs out of the pond, shakes out its feathers, spreads its wings and warms itself in the sunlight. The anhinga's black feathers dry by absorbing solar heat. On cool days, or if the Sun "goes behind a cloud," the bird folds its wings. When the Sun "comes out," the bird again spreads its wings.

Once its wings are dry, the anhinga may re-enter the water. Or, if sundown is near, the bird skillfully uses rising air currents to ascend high in the air, where it soars to its roost. The anhinga's life depends on radiant energy from the Sun. The sunlight dries the anhinga's wings and transports the bird on convection currents produced by rising air that is heated near the ground by the Sun.

The Inca Indians of Peru also took advantage of radiant sunlight. The Incas once had a vast empire in South America in the high Andes Mountains. They achieved great power between A.D. 1200 and A.D. 1500. The Incas built large stone structures without mortar and constructed suspension bridges and roads that crossed the steep mountain valleys of the Andes Mountains. Some of their cities, such as Machu Picchu, still stand.

Archeologists who study the Inca culture have discovered many ways in which the Incas took advantage of radiant energy. Those Incas who lived in the high mountains experienced weather that was warm late in the day but became cold overnight as well as the following morning. Incas moderated temperatures in their homes by positioning their doors to face east. Open doors caught the first rays of sunlight, which warmed the interior. Later in the day when the temperature was hotter, the Sun shown on the west side where the buildings had no openings. Additionally, the west walls were made extra thick. The radiant energy of sunlight warmed the outer rocks. After dark, when the temperature fell, heat in the stone walls made its way through the walls and into the inner surface. There it provided warmth during the coldest part of the night.



The Incas also processed their food with sunlight. They developed a potato capable of growing at an elevation of 15,000 feet and withstanding a heavy frost that killed other plants. The Incas used the cold nights and warm days to change the harvested potatoes into flour. The potatoes were dug out of the soil and spread out on the ground to dry. Changes in temperature from night to day alternately froze and dried the potatoes. The low humidity and low air pressure removed the moisture. The freeze-dried potatoes were then pounded into potato flour which could be stored for later use in food preparation.

Radiant energy is one way that heat is transferred from one place to another. Heat from the Sun arrives at Earth in the form of radiant energy. Radiant energy is a form of electromagnetic waves that includes regular and infrared light.

Radiant energy can travel through the vacuum of space. Once it reaches Earth, radiant energy is absorbed by matter and becomes heat energy.

Heat is a type of energy which involves the rapid motion of atoms and molecules. Heat energy is kinetic energy—the energy of motion—at the atomic and molecular level.

When the anhinga rose into the air by soaring on air currents, the bird was riding convection currents. *Convection* is heat transfer in a gas or liquid by the circulation of currents from one place to another. Because of the rotation of Earth and uneven heating at the poles

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

and equator, the Earth has numerous convection currents. Trade winds and jet streams carry heat through the atmosphere of the Earth. Although part of their motion is caused by Earth's rotation, convection currents play a role, too. The warm Gulf Stream of the Atlantic Ocean and the cold Humboldt Current in the Pacific off the coast of Peru are two of the many convection currents that equalize the temperature of oceans.

Inca homes were heated at night by ***conduction*** of heat from the outside rock layer into the inner walls of the buildings. Conduction is the transfer of heat through a medium without noticeable motion of the medium itself. During conduction, the atoms and molecules vibrated and transferred their energy of motion to their neighbors—the inner walls of Inca huts.

The three methods of heating—conduction, convection and radiation—are used to heat modern homes. Many homes are built with large windows facing south. During winter, the Sun's rays enter through the windows because the Sun is lower in the south in winter than in summer. At night, heavy drapes cover the windows to prevent the heat from escaping. During summer when heat is not needed, the Sun's rays are more directly overhead and do not enter the windows.



Although some homes are located in mild climates where radiation heating from the Sun is sufficient, most need supplemental heating. A home or building may be heated with steam. A boiler in the basement heats water, which is pumped to radiators located throughout the building. Air around the radiator becomes warm by conduction. The rise of warm air and fall of cool air establishes convection currents in the room that keep the air circulating.

If the outside temperature is not too cold, an electric *heat pump* can extract heat from the outside air and pump it inside. Most heat pumps work as air-conditioners in the summer to cool the house. They can be reversed in winter to heat the home.

In colder climates, a heat pump is inadequate for heating a home. Some homes use forced air furnaces. The furnace burns oil or natural gas. A furnace fan blows the heated air through ductwork throughout the building. The fan produces convection currents.

Electric devices maintain climate in other homes. Heat is generated by electricity passing through a high resistance heating coil. The heat can be sent throughout the house by forced air in the same way as the hot air heated by a gas or oil furnace. Or, each room may have its own electric heater. Some homes have an electric heating element built into the floor. The entire floor is heated and radiates upward into the room. The air near the floor is heated by conduction. Then, as a current of rising warm air and falling cooler air is established, convection aids in heating the room.

Most homes have a water heater. Natural gas, propane or electricity may heat the water in the tank. A few custom-built homes use solar heating panels to warm water. The water runs through a series of small pipes inside a box that is covered with clear glass and faces the Sun. The water circulates through the pipes and is heated by the radiant energy of the Sun.

Gas or electric kitchen ovens heat food. Cake batter is mixed, placed in a pan

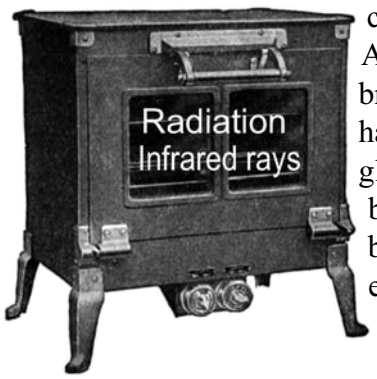
©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

and put in the oven. Conduction, convection and radiation bake the cake. All three methods of heating are applicable.

Most ovens have a heating coil or flames at the bottom of the oven. The air in the oven is heated. Air circulates all around the cake pan by convection. Conduction bakes the cake, too. Heat from convection currents can reach only the outer surface of the cake pan and the surface of the top of the cake. To cook the cake batter all the way through, conduction is required. The heat transfers from the molecules on the outer surface to the inner surface.

Radiation also plays a role in cooking in an oven. Although the oven never becomes so hot that it glows, it does become hot enough to emit infrared rays. These infrared rays are a type of radiant heat and contribute to the baking of the cake. Also, for some baking, a crispy, brown top is desired. Most ovens have an upper heating element that glows red hot for browning the top of baked goods. Infrared rays do the browning. Infrared rays are an example of radiant energy.

Oven



LIFE PRINCIPLE



"Wealth brings many friends, but a poor man's friends desert him."

— Proverb of King Solomon

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry



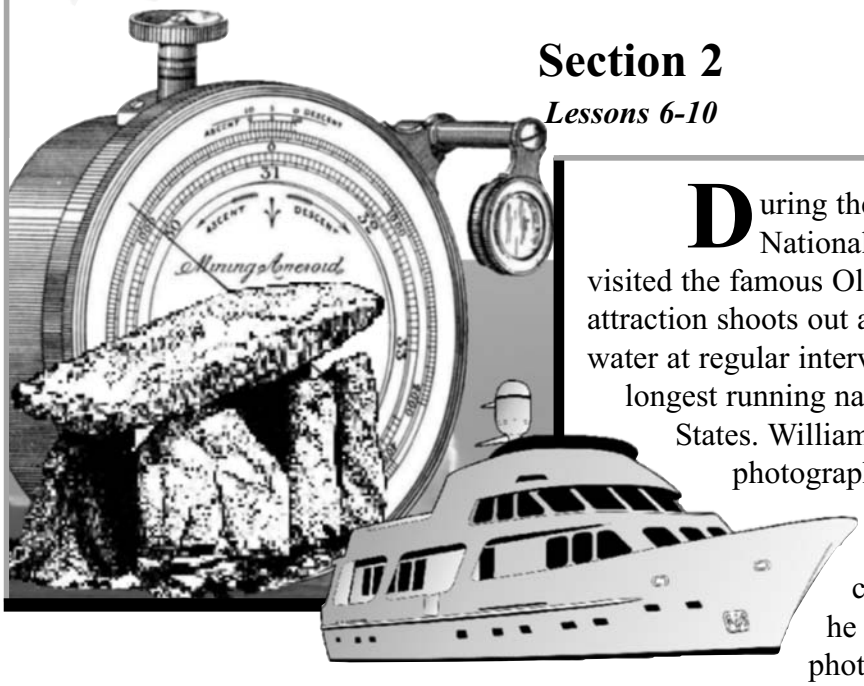
Lesson 6
Geology

Chapter 12

PRESSURE AND DENSITY

Section 2

Lessons 6-10



During their visit to Yellowstone National Park, Samuel and his family visited the famous Old Faithful ***Geyser***. This natural attraction shoots out a stream of steam and hot water at regular intervals. Old Faithful is one of the longest running natural shows in the United States. William Henry Jackson first photographed the geyser in 1871.

Because William Henry Jackson liked the wide, wild country of the American West, he became an outdoor photographer. He heard a rumor about wonderful sights in the Yellowstone valley in Wyoming. Ferdinand Hayden, an explorer for the United States government, planned a scientific expedition into the Rocky Mountains. He invited Jackson along as the official photographer, but limited the photographer to only one pack animal. Jackson succeeded in packing his cameras, film and darkroom tent upon a burro named Maud.

Tall mountains surround the northwest corner of Wyoming. The scientific expedition made a difficult climb up the steep side of a cliff. Maud, the burro, lost her footing on the treacherous trail and fell 30 feet. The animal landed upside-down in a scrubby tree. The burro struggled free, completely unhurt. She rejoined the end of the line as if nothing had happened. Miraculously, none of the equipment had been broken.

The Hayden expedition arrived at Yellowstone in the summer of 1871. William Henry Jackson took photographs of numerous sights including Old Faithful. When Hayden and Jackson returned to Washington, D.C., they urged Congress to set aside the valley as a park. Jackson's photographs helped establish the Yellowstone region as America's first national park.

VOCABULARY

Geyser: a natural formation that spews water and steam into the air, Old Faithful in Yellowstone National Park is the best known *geyser*, the word is from a Norse word meaning *to gush*

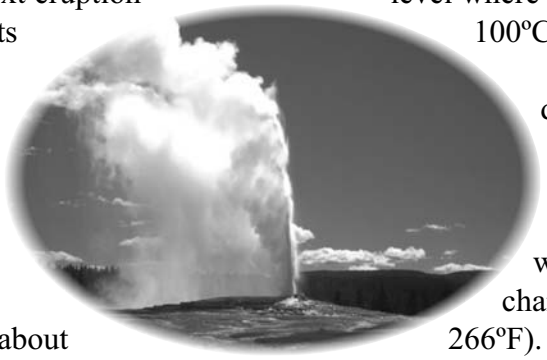
Pressure: force applied over a surface, measured in newtons per square meter or pounds per square inch

Isotherms: lines that connect weather readings of equal temperature

Isobars: lines that connect weather readings of equal air pressure

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Old Faithful is still the most photographed sight in Yellowstone. Normally, Old Faithful erupts about once every hour, although it can repeat as soon as 30 minutes or delay as long as 90 minutes. Park rangers note the amount of water, the height of the spray and the duration of the event. From that information, rangers can predict when the next eruption will take place. In its most powerful eruption, the column of hot water and steam rises to a height of almost 200 feet. At each eruption, Old Faithful sprays out about 10,000 gallons of boiling water.

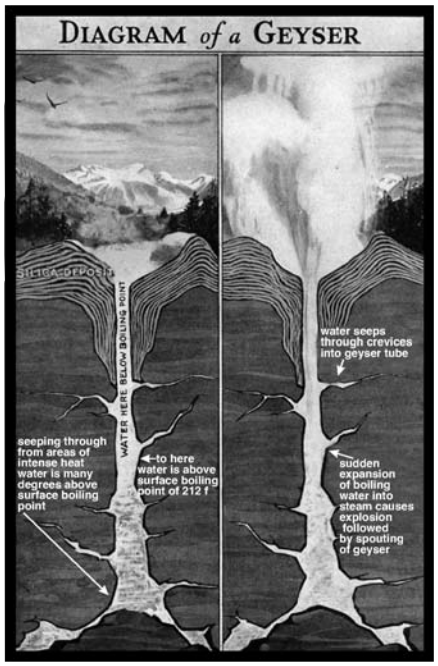


Although the times of its eruptions vary, Old Faithful is far more reliable than many other geysers. The majority erupt irregularly, with intervals that range from a matter of a few minutes to ten or more years. Geysers are not permanent features. Plume, a reliable small geyser in Yellowstone, erupted so violently once that it changed its shape and became a hot water spring rather than a geyser. As earthquakes and volcanoes change the flow of magma underground, geysers may change their frequency of eruptions. Even Old Faithful is not as regular as it once was.

The boiling water spews out because of ***pressure***, boiling temperature and the shapes of subterranean chambers in the rock. The boiling temperature of water varies depending on its pressure. At sea level, water boils at 100ºC (212ºF). Mountain air pressure is reduced, and the boiling point of water becomes less than 100°C. Going the other way, at a point below sea level, such as in Death Valley, California, or far below ground in a deep mine, air pressure is greater and water does not boil as readily. There, water boils at a higher temperature. Normal air pressure is at sea level where the boiling point of water is 100ºC or 212ºF.

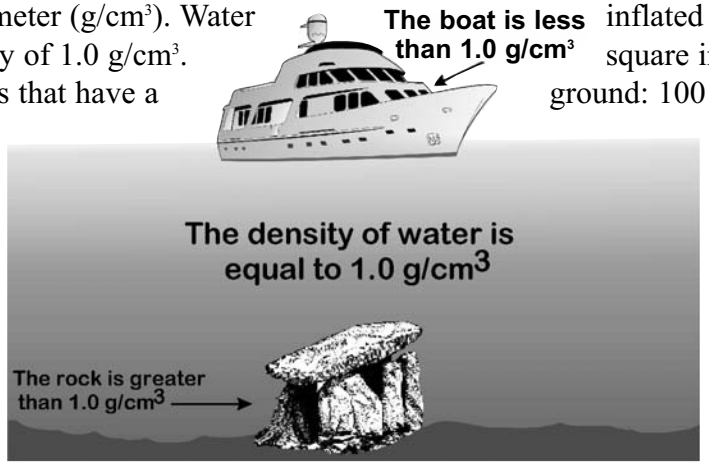
A geyser originates from a deep subterranean chamber filled with water. The rock walls of the chamber are hot volcanic rock. In the case of Old Faithful, the water at the bottom of the chamber is at about 130ºC (about 266ºF). The hot water deep in the geyser does not boil because of pressure from the water over it. Cooler rocks surround the water at the top of the chamber. The upper water has a temperature of 90ºC (194ºF), which is below the boiling point of water.

Eventually, however, the subterranean water becomes so hot it boils even at the increased pressure. At first, a few bubbles of steam rise to the top and shove out some of the water. This releases the pressure, and the hot water deep in the chamber expands as it turns to steam. The water blows out in a sudden swoosh. Similar to the action of a soft drink that is warm. When the drink can is opened, the sudden release of pressure causes the can's contents to spew out. In changing from liquid water to steam, water changes from a liquid to a gas. The three states of matter are solids, liquids and gases.



©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Density is one of the properties of matter. Density is defined as the mass per volume, usually expressed in grams per cubic centimeter (g/cm^3). Water has a density of 1.0 g/cm^3. Those solids that have a density less than 1.0 g/cm^3 will float in water. Those solids that have a density greater than 1.0 g/cm^3 will sink in water.



The human body has a density very nearly 1.0 g/cm^3. When a young girl takes swimming lessons at a pool, she puts on a small flotation vest. That slight aid is enough to keep the girl above water. One of the properties of a fluid such as water is *buoyancy*. Buoyancy is the upward force a fluid exerts on an object. Commercial divers wear elaborate flotation vests called buoyancy compensation vests. To rise, divers inflate their vests; to sink, air is released from the vests. The vests allow divers to adjust their buoyancy to rise, sink or stay at any particular depth.

Gases have a density about 1,000 times less than the density of a liquid or solid. Air, for instance, has a density of about 1/800 that of water or about 0.00125 g/cm^3. Because of the small numbers involved, rather than stating density in g/cm^3, scientists state the density of gases in grams per liter. A liter is a volume equal to 1,000 cm^3. The density of air is 1.25 grams per liter.

Pressure is defined as the force per unit area. Solids, liquids and gases can exert pressure. Automobile tires are inflated to a pressure of about 32 pounds per square inch. The entire weight of the car is supported by the parts of the tires that touch the ground. A 3,200 pound automobile with tires inflated to 32 lbs/in^2 must have 100 square inches of the tires on the ground: 100 in^2 * 32 lbs/in^2 = 3,200 lbs.

A bicycle and its rider weigh considerably less than an automobile. However, because the surface area of the bicycle tire that touches the road is much less and the bicycle has only two tires, the air pressure in the tires has to be higher. Bicycle tires often have an air pressure of 50 or 70 $pounds/in^2$.

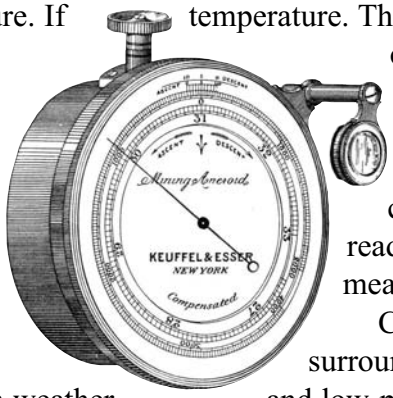
Imagine a woman who weighs 120 pounds standing in high heeled shoes. Now think of an African bull elephant that weighs 15,000 pounds (about 7.5 tons) standing beside the girl. You might question which one exerts more pressure against the floor. The answer depends on the surface area of the woman's shoes compared to the surface area of the elephant's feet. The woman's heels and shoes touch the floor over an area of only about 3 square inches. Her pressure is 120 lbs / 3 in^2 = 40 lbs/in^2. The elephant has feet about 22 inches across. The total area for all four feet is about 1,500 in^2. The elephant's pressure is 15,000 lbs / 1,500 in^2 = 10 lbs/in^2. The woman in high heeled shoes exerts more pressure per square inch than does the elephant.

Pressure is a factor in everyday life. Even the atmosphere exerts pressure. The pressure is equal to the weight of a one-inch square column of air that extends from the surface of Earth into space. The weight of that air is about 14.7 pounds; thus air pressure is 14.7 lbs/in^2.

Air and other gases respond to changes in temperature and pressure. Boyle's

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

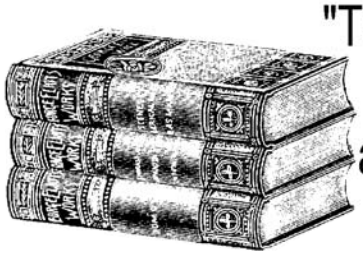
Law states that the volume of a gas is inversely proportional to the pressure. If the pressure doubles, the volume is reduced in half. If the pressure is released, the volume increases. Boyle's Law assumes that temperature remains constant. Changes in temperature can also change the volume. Air expands as it is heated and contracts as it is cooled.



One of the breakthroughs in weather forecasting occurred when scientists began measuring air pressure and air temperature from many different locations. With the telegraph, they could transmit weather information to a central location. For the first time, the weather across an entire nation could be shown on a weather map. Meteorologists connected those stations with line data about temperature. They called the lines ***isotherms***, a word meaning equal temperature. The meteorologists also connected stations that measured the same air pressure. They called these lines ***isobars***, a word which comes from equal barometer readings. A barometer is used to measure air pressure.

Curved lines of equal pressure surrounded the high-pressure areas and low-pressure areas. By watching how the isobars changed from one day to the next, and noting the direction of the wind, meteorologists could project the direction of high and low pressure areas. One of the main indicators of weather is atmospheric pressure. A high pressure indicates the onset of dry, sunny weather. A low pressure indicates cloudy skies and moisture—rain, snow or sleet.

LIFE PRINCIPLE



"The man who doesn't read good books has no advantage over the man who can't read them."

— Mark Twain

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

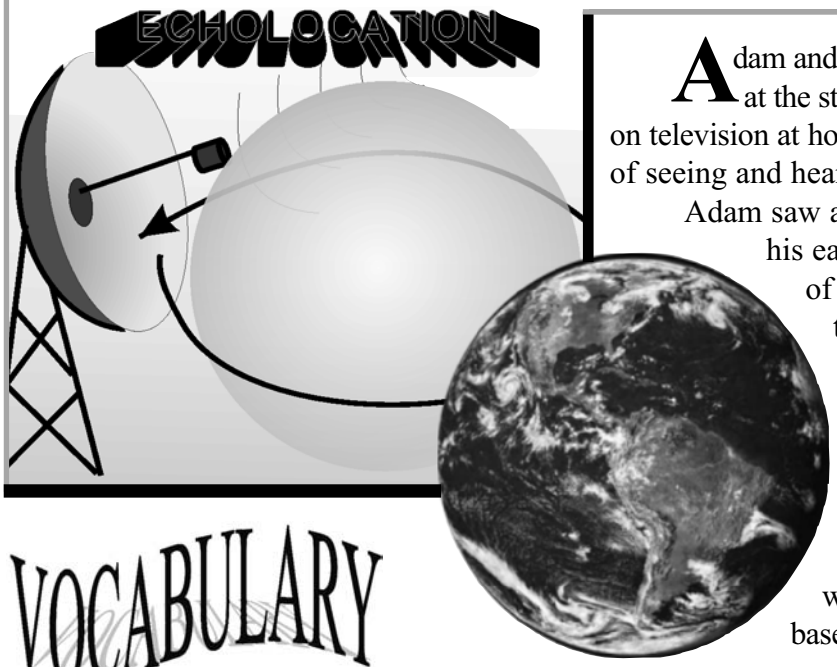
Lesson 7
Light & Sound

Chapter 12

WAVE MOTION

Section 2

Lessons 6-10



Adam and his father went to a baseball game at the stadium. Samuel watched the game on television at home. Obviously their experiences of seeing and hearing the game were different.

Adam saw and heard the game directly with his ears and eyes. He heard the crack of the bat on the ball. He watched the runner race for first base and arrive just as the ball was thrown to the first baseman who stretched to catch the ball. In the stands, Adam had a clear view of the first baseman catching the ball, but he could not see when the runner's foot hit the base. The runner appeared to be out.

On the field, appearances were different. The first base umpire called the runner safe because the umpire had heard the thud of the runner's foot on the base a split second before the pop of the ball sounded in the first baseman's glove.

At home, Samuel saw television replays from several different angles of the runner reaching first base. One replay showed the ball reaching the first baseman's glove well before the runner's foot came down on the base.

Sight and sound are two of the most important senses for human beings. Each one has advantages and disadvantages over the other. Because sound and light are both wave motions, they share some properties. However, they differ considerably in other properties.

First, they differ in the type of wave. Sound is a longitudinal wave. It vibrates back and forth in the same direction that it travels. If one could see a sound wave, it would be made of regions of increased air pressure followed by regions of decreased air pressure. Light travels in transverse

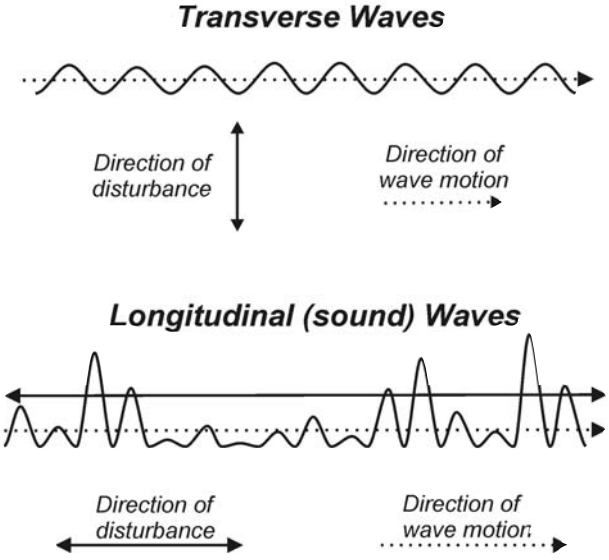
VOCABULARY

Geosynchronous orbit: an orbit around Earth over the equator and at such a height that the satellite takes 24 hours to circle the Earth; a satellite in a geosynchronous orbit appears to be motionless in the sky because Earth turns at the same rate as the satellite orbits Earth; most television and communication relay satellites are in geosynchronous orbits

Radar: a method of determining the velocity and position of an object by reflecting very high frequency radio waves from it, radar is from the words **Ra**dio **D**etecting **a**nd **R**anging

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

waves. The combination of electric and magnetic fields make light vibrate at right angles to the direction of travel. Light waves are like water waves. The disturbance of a water wave is vertical, but its direction is horizontal. The wave moves across the lake but the surface of the water bobs up and down.

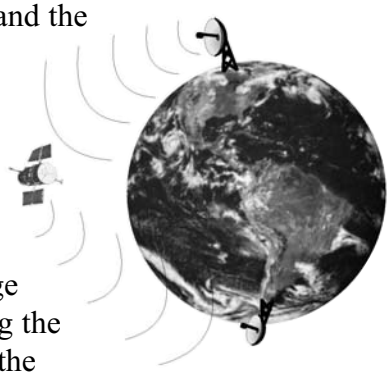


VOCABULARY

Echolocation: to determine the speed, location and other information about an object by the reflection of sound waves
Sonar: a method of underwater echolocation that uses very high frequency sound waves to detect an object and determine its velocity and position, sonar is from the words **So**und **Na**vigation and **R**anging
Sonogram: an ultrasound picture that reveals information about organs inside the human body, its primary use is to track the progress of a pregnancy because the ultrasound waves are believed to be harmless to an unborn child

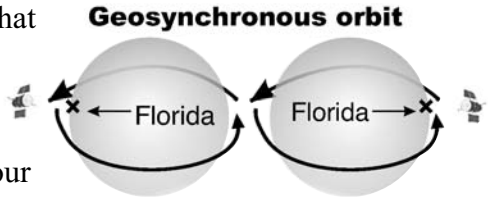
The second way sound and light waves differ is in speed. Light travels at 3.0 * 10^8 m/sec, or about 186,000 mi/sec. Sound travels at 334 m/sec, or about 1128 ft/sec. Light waves travel roughly 872,000 times faster than sound waves: (300,000,000 m/sec) / (344 m/sec) = 872,000 (rounded).

Television (TV) signals are a type of electromagnetic waves like light. TV signals travel at the same speed as light. Imagine a race between a television signal going to Samuel's house and the sound of the bat against the ball going to Adam's ear. If Samuel is in the same city as the game, he will see the image of the bat striking the ball long before the sound of the bat against the ball reaches Adam's ear. Light is so much faster that it could go half way around the world in the time required for sound to go halfway across the stadium.



The speed of sound waves and light waves differ depending on the medium. Sound travels about five times faster in water than in air and even faster in a solid such as steel. Light, on the other hand, travels slower in water than in air and even slower in a solid such as diamond.

The third way that light and sound differ is that light will travel in a vacuum. Electromagnetic television signals can be sent to orbiting satellites. These satellites are placed in ***geosynchronous orbits*** at 22,300 miles above Earth. Satellites at that height remain in orbit with Earth's 24-hour

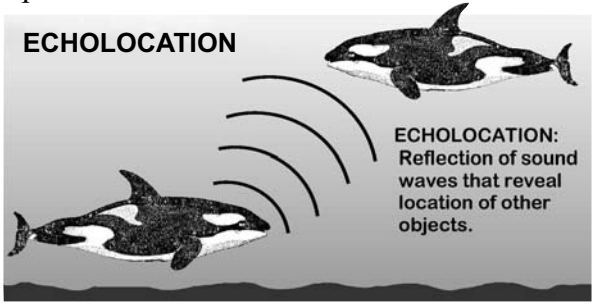


©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

rotation. The same spots on Earth stay below the satellites. From Earth, satellites appear to be hanging at the same locations in the sky. Satellites can send signals to other satellites around the Earth. Electromagnetic signals travel through the vacuum of space to reach the satellites.

Sound waves require a medium for transmission. Unlike light, sound waves will not travel in space. On the other hand, sound will travel through material that is opaque to light waves. For instance, sound waves transmit through water better than light waves. Sunlight cannot penetrate deeper in the ocean than about 600 feet. A bright beam of light from a submerged exploring craft at a depth of 600 feet is absorbed within a distance of 12 feet.

Sound, on the other hand, is readily transmitted by water. The speed of sound is about five times faster in water than in air, and is transmitted over greater distances. Whales, for instance, are believed to make long low-pitched calls that can be heard for hundreds of miles.



The pitch of a sound wave is its frequency. Frequency is the number of waves made per time interval, usually stated as vibrations per second. The wavelength is the distance from one point on a wave to the same corresponding point on the next wave. The frequency of a wave and the length of a wave are inversely related. The lower the frequency, the longer the wavelength.

The low frequency and long wavelength sounds made by whales travel better in water than do higher frequency waves. Long wavelengths do not reflect as well as short ones. Whales apparently are designed to generate long sound waves in harmony with wavelength frequencies. The waves are less likely to be reflected by fish or other obstructions in the water; thus, whales can communicate across vast distances under water.

On the other hand, captains of submarines want to detect obstructions in the water. They cannot use ***radar*** as airplanes do because electromagnetic waves do not carry under water. Instead, submarines use sound waves. A device aboard the submarine sends out a sound that goes through the water, strikes an object and reflects (echoes) back. The receiver on the submarine can calculate the direction and distance to the object from its echo. The ***echolocation*** is known as ***sonar***, a word made from the letters of **So**und **Na**vigation and **R**anging. Range is the distance from one object to another object.

Echolocation methods such as sonar use short wavelengths. Short sound waves reflect more readily from small objects. The shorter the wavelength, the more accurate the information about the location of an object. Bats navigate by emitting high frequency waves of short wavelengths. Short waves reflect better than long ones. A long wave would wash over a tiny flying insect; thus, the insect's location would not be revealed to the bat. However, the bat sends out very short waves that reflect readily from the tiny flying insect. The bat detects the insect's location and flies directly to the insect.

Geologists use sound waves to search for underground oil. One method used is a hydraulic lift that drops a massive weight on the ground. The impact sends sound waves through the Earth. Where the rock layers change in density, the sound waves are

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

reflected. A series of seismographs receive the reflected waves. A skilled geologist can interpret the results to determine the type of rock layers deep in the Earth. The type of rock layers is a clue as to whether oil may be trapped in the layers.

Doctors use the concept of echolocation to "see" into the human body. A crystal that vibrates rapidly produces sound waves. The sound is of so high a frequency it cannot be heard by human ears. Sound with a frequency greater than human hearing is known as *ultrasound*. The transmitter is placed on the body. Usually, a jelly-like substance is smeared on the transmitter and the skin to improve contact so the sound is transmitted better.

Small differences in densities at the boundaries between tissues reflect sound waves. A receiver picks up the sound and sends it to a computer that produces an image that can be photographed or displayed on a monitor. An image produced by sound waves is a ***sonogram***.

Suppose a patient notices a bump below the skin on his back near his kidneys. He visits a doctor. The doctor does an ultrasound test. He finds that a cyst, a bag of water, below the skin, causes the lump. The ultrasound shows that the cyst is harmless. An X-ray would not be able to show the cyst or determine if it contained water or was a mass of cancerous cells. High frequency electromagnetic waves such as X-rays go right on through soft tissues. X-rays give a view of a body that differs considerably from that produced by ultrasound. X-rays show bones while ultrasound shows soft body tissues.

One common use of ultrasound is to monitor the growth and development of a baby before it is born. Until the development of ultrasound sonograms, doctors could not examine a growing unborn baby (fetus) because doctors were reluctant to use X-rays. Examining a baby with X-rays while still in the mother is dangerous because X-rays damage human tissue. X-rays change DNA, the genetic material that controls how a baby develops. Instead, ultrasound is used during pregnancy to monitor the growth, development and well being of the baby. Unlike X-ray photographs, ultrasound is safe during pregnancy, and poses no known risk to the baby or the mother.

A sonogram can identify the sex of the child, show whether twins will be born and reveal defects that require special medical treatment. The sonogram has helped doctors monitor the growth and development of unborn children from a few weeks after conception to birth. Modern technology enables parents to see how the child matures as the head, hands, heart and vital organs develop during the nine month preparation time. Sonograms have verified that a fetus only a few weeks old is actually a living organism, well defined as a human.



"Listen to advice and accept instruction, and in the end you will be wise."

—Proverb of King Solomon

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

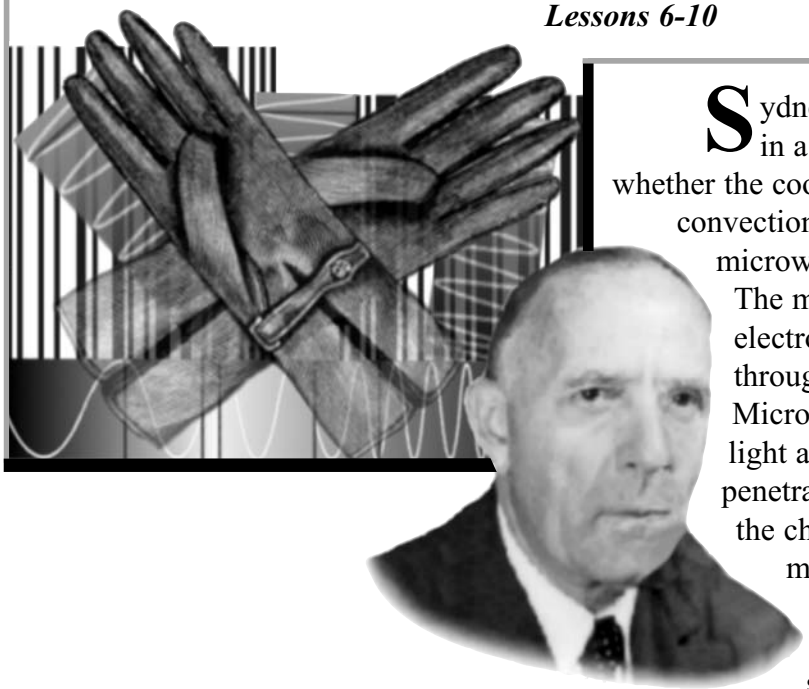
Lesson 8
Light & Sound

Chapter 12

LIGHT

Section 2

Lessons 6-10



Sydney prepared popcorn by putting it in a microwave oven. She wondered whether the cooking process was by radiation, convection or conduction. The action of a microwave oven is primarily by radiation. The microwave oven generates electromagnetic waves that penetrate throughout food placed inside the oven. Microwaves are like but longer than light and infrared waves. Microwaves penetrate to the atoms and molecules of the chemicals of food. The atoms and molecules of food absorb the microwaves. Microwaves cause the atoms and molecules to vibrate so rapidly they gain heat energy.

When microwave ovens were first sold to the public, one of the ways to demonstrate their unique properties was to pop kernels of popcorn inside a clear bag made of plastic. The plastic allowed the waves to pass to the corn but did not absorb the heat from the microwaves. The kernels absorbed the microwaves and popped. People were astonished that the corn became hot, but the plastic stayed cool and did not melt. Some materials such as certain plastics are not affected by the microwave radiation because plastic atoms do not absorb microwaves. Foods, especially those that contain water, do absorb the waves and are affected.

Microwaves are part of the electromagnetic spectrum. The use of light and other electromagnetic waves is a part of our everyday activity. At the check out counter of a grocery store, the clerk at the register passes the purchases over an *optical scanner*. An optical scanner uses laser light to detect regions of light and dark, enabling the scanner to determine ***bar code*** information. Each product contains a bar code that

VOCABULARY

Bar code: a series of wide and narrow lines that represent numbers
Wave equation: an equation that relates speed, frequency and wavelength
Wave: any disturbance traveling through a medium by which energy is transferred from one part of the medium to another without causing permanent displacement of the medium itself

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

identifies the product by a number. The bar code is known as the Uniform Product Code (UPC). The *UPC* identifies the manufacturer and the type of product. After the bar code is read, a computer matches the product identification number with its price stored in the computer. The price can change, but the UPC stays the same. If the computer has been programmed correctly and the information is up to date, then the cash register will charge the customer the correct price.



A bar code scanner has a system of several laser beams so that the bar code can be read in several possible directions at once, as you have probably witnessed at supermarket checkout counters.

In addition to food purchases, bar codes are used to track books and video disks checked out of libraries and video rental stores. Bar codes on boxes also track inventory from the time a shipment leaves the warehouse until it is received at its destination. Package delivery companies such as United Parcel Service (UPS) and Federal Express (FedEx) use bar codes to track packages. Railroad companies print codes on the sides of boxcars that are read automatically as trains roll along the track and pass a scanner. The geographic locations of boxcars are maintained by computer databases.

Laser light is emitted at a set frequency. Frequency is the number of waves that are made every second. Frequency is given in waves per second or cycles per second. The wavelength is from one point on a wave to the same point on the next wave. Wavelength and frequency are inversely related by the ***wave equation***: *velocity of a wave = frequency * wavelength*. If the velocity does not change, then the higher the frequency, the shorter the wavelength.



In the electromagnetic spectrum, the longest wavelengths and lowest frequencies are radio broadcasts. Their frequencies range from about 500 to 1,500 cycles per second with waves that are hundreds of thousands of meters long. The long wave radio band is followed by FM radio and television waves. They can have frequencies in the hundreds of thousands of waves per second with wavelengths of about 1.0 meter. Shortwave radio also operates in this region of the electromagnetic spectrum. Next, in the spectrum is microwave radiation, which includes waves used in microwave ovens and signals broadcasted from Earth by geosynchronous satellites. Infrared heat is next on the spectrum, then followed by visible light. These frequencies are in the millions of cycles per second with correspondingly very short wavelengths. Next in sequence are ultraviolet tanning rays of the Sun and tanning beds. X–rays are next, followed by gamma rays, which have the highest frequencies and shortest wavelengths of all electric waves.

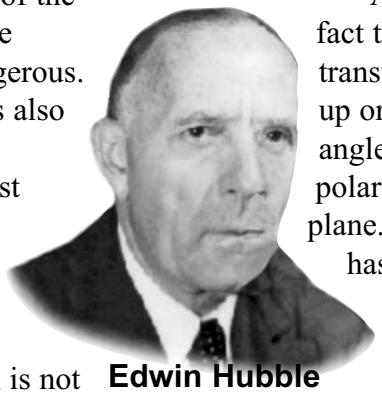
One of the great changes taking place at the start of the 21st century was the introduction of many different ways for information to be received and transmitted in homes. Information can be exchanged by telephone, pagers, cellular telephones, e-mail over the Internet, fax machines, cable television service and satellite dishes. All of these devices use some part of the electromagnetic spectrum.

Other electromagnetic devices include Doppler radar for weather forecasting and to measure the speed of winds in thunderstorms.

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

The Doppler effect is the observation that a moving source or observer causes a change in the apparent frequency of wave motion such as sound or light. Doppler radar emits radio waves of precisely known frequencies which reflect from thunderstorms. The motion of air inside thunderstorms changes or disrupts frequencies when they bounce back. Receivers send signals to computers that calculate and display motion inside thunderstorms. Usually the information is displayed on television monitors so that red, for instance, shows the area of the greatest movement where the thunderstorms are most dangerous.

The Doppler effect is also used in scientific studies, especially in astronomy. Most stars rotate in a manner similar to Earth on its axis. The Sun rotates in 27 days at Earth's equator. Because the Sun is liquid, its rotation is not the same near the Sun's poles, which take 31 days to rotate. Astronomers discovered the speed of the Sun's rotation by watching the motion of sunspots. Other stars are so far away that sunspots, if they existed, could not be seen. A star rotating on its axis causes changes in the spectrum. By measuring the Doppler shift in frequency (color), astronomers can measure the speed of rotation of the star. Stars vary in their speed of rotation considerably. Some take a day or less. Others like the Sun, take a month or more.



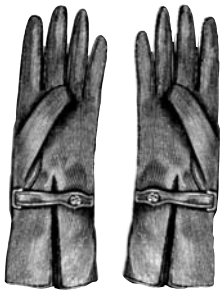
Edwin Hubble

In the 1920s, American astronomer Edwin Hubble studied light from distant galaxies. Galaxies are island universes of stars like the Milky Way. A galaxy has from 200 million to 600 million stars. Except for a couple of nearby galaxies, Hubble found that light from galaxies was always shifted toward red on the light spectrum. This indicated that stars were receding from Earth. Hubbel announced his discovery: the greater the distance of a galaxy, the faster it was receding from Earth. This discovery became known as *Hubble's Law*. Hubble interpreted his discovery to mean that the universe was expanding. In 1990, the United States put a large telescope in orbit around Earth. The telescope was named the Hubble Space Telescope in honor of Edwin Hubble. In 1999, U.S. scientists repaired the telescope to improve its efficiency.

Another useful property of light is the fact that it can be polarized. Light is a transverse ***wave***. Light waves can vibrate up or down, left or right, and all the angles in between. When light becomes polarized, waves vibrate in only one plane. Polarization of light is a tool that has many applications in physics and chemistry. For instance, polarized light passing through glass reveals areas under stress. Polarized light can identify stress in optical glass that may not be suitable for large telescopes.

In chemistry, polarization of light led to the remarkable discovery that some chemicals are *optical isomers* of one another. Isomers are molecules composed of the same elements in the same proportions but have different chemical and physical properties. Optical isomers are isomers that are revealed by their effect on polarized light.

Imagine a small child as she struggles to put on her gloves. If she tries to put the right glove on the left hand, then the thumb does not fit. Gloves are left and right-handed. No matter how you twist, turn or hold a left-handed glove, it will not fit on the right hand properly. Gloves are mirror images of one another. A right-



©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

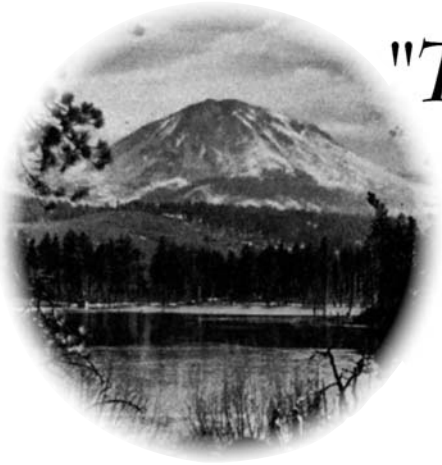
handed glove held up to the mirror will appear to have the thumb and little finger reversed.

Some molecules are mirror images of each other, too. One example is lactic acid. Lactic acid has three carbon atoms that can be arranged in two different structures. The two molecules are mirror images of one another and cannot be turned or twisted so one is the same as the other. Like gloves, they appear identical only when one is viewed in a mirror. Optical isomers were first detected because solutions of them caused light to be polarized differently.

Whether or not a molecule is left-handed really matters in some cases. Glucose ($C_6H_{12}O_6$), the sugar used by the body, has several isomers. One of the isomers is a mirror image of glucose. Living things can tell the difference between a molecule and its mirror image. The body ignores the mirror image variety. The glucose molecule that the body uses is the right-handed variety, dextro-glucose. *Dextro* is a Latin prefix meaning *right*. Glucose is sometimes called dextrose. The other optical isomer is galactose. The human body changes glucose to carbon dioxide, water and energy that power the body's cells. Galactose, the mirror image version of glucose, must be modified before it can be used by the body.

Many food substances exist in two mirror image forms. The body always uses one but not the other. If a person's diet were limited to the wrong food forms, he would starve to death no matter how much he ate. Some diet sugars contain isomers that fool the taste buds so the person receives the sweet taste. However, the digestive system ignores the mirror image molecule.

LIFE PRINCIPLE



"There is always room at the top"

—Anonymous

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

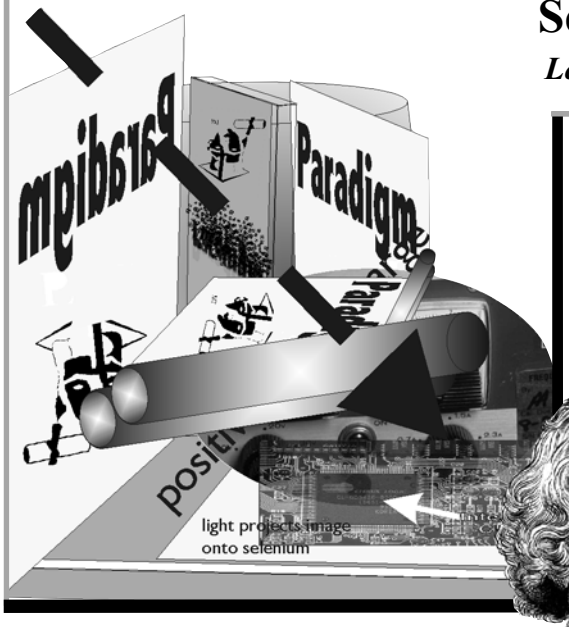
Lesson 9
Energy

Chapter 12

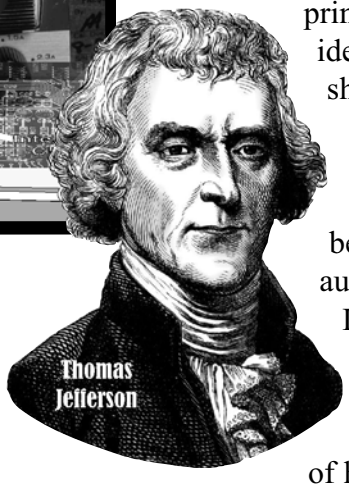
ELECTRICITY

Section 2

Lessons 6-10



Sydney and her mother planned a special party at their home. They prepared a sheet that gave the date, time and directions to the party location. The sheet of paper was composed on a home computer, and multiple copies were printed on a laser printer. The printer easily produced several identical copies of the instruction sheet. Copies could have been duplicated on a photocopy machine at a local printing company.



Making copies has always been important. Thomas Jefferson, author of the Declaration of Independence and the 3rd American President, experimented with several ways of keeping records of the letters he had written. One of his inventions had two quill pens mounted together on mechanical arms. As Jefferson moved one pen, the mechanical linkages moved the other pen in the same way and traced out the same message. However, this device did not work very well. Another method he used was to finish a letter and then dampen it. Jefferson then pressed the damp letter against a blank sheet of paper. The special ink he used transferred to the other paper. Although a reverse or mirror image was formed and the letters were blurry, he could read the words by looking at the page from the back or by holding the page in front of a mirror.

Thomas Edison invented the mimeograph machine which made multiple copies of the same page. The original page was first prepared on a special type of paper known as a stencil. Ink flowed through the cutout letters in the stencil and reproduced the letters on copy paper. Many other devices have

VOCABULARY

Xerography: an electrostatic copying process
Solar cell: a device that generates an electric current as light falls on the surface of a semiconductor, also known as photocell
Base unit: a basic unit of measurement in the metric system (International System) that is used to define all other (seven) units of measure, also known as *fundamental unit*

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

been used at one time or another to make copies. Various copy devices included spirit duplicating machines, carbon paper, blueprints and photographic processes.

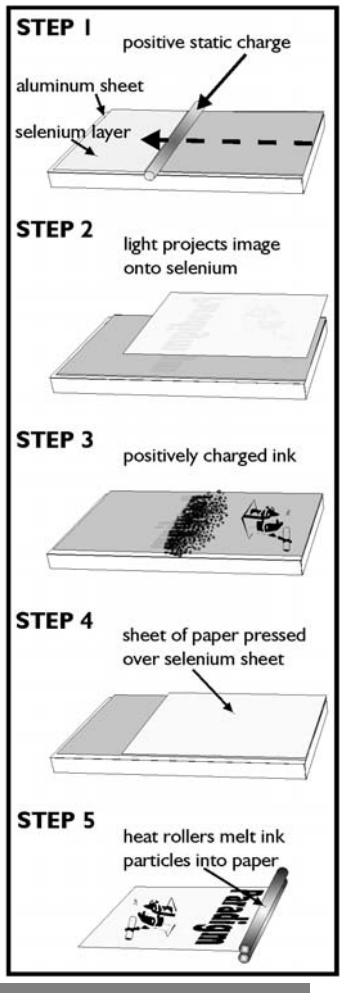
Today, electrostatic copiers are the most common way to make copies. ***Xerography*** makes use of static electricity. Either too many or two few electrons produce static electricity. If an object has too many electrons, the charge is a negative one. If the object has too few electrons, the charge is a positive one.

Whether objects will attract or repel one another depends on the static charge. Two objects will attract one another if they have unlike charges. Two objects will repel one another if they have the same charge, either both negative or both positive. If one object is not charged and the other one does have a charge, then the charged object will attract the uncharged object. The three rules concerning how static charges behave were first discovered by colonial statesman and inventor, Benjamin Franklin, and are known as the Three Laws of Static Electricity.

An insulator is a substance that does not readily conduct electricity. Most nonmetals are electrical insulators. The exception is carbon. Although it is a nonmetal, carbon does conduct electricity which classifies carbon as a *conductor*—a substance that conducts electricity. Most metals are electrical conductors. The best electrical conductors include gold, silver, copper and aluminum. Because of cost and weight, most electrical wires for carrying electrical currents are made of either copper or aluminum. A few substances are intermediate in their electrical conductive particles. These elements, which include silicon, selenium and germanium, are described as semiconductors.

The breakthrough in copying came with the discovery that some semiconductors change their electrical conductivity when exposed to light. American inventor, Chester F. Carlson, discovered that some metals, such as selenium and germanium, act as nonconductors in the dark, but act as conductors in light. He used this discovery to make a copy machine.

Chester F. Carlson began with an aluminum sheet coated with a layer of selenium. Aluminum is always a conductor, but selenium conducts electricity only when exposed to light. First, Carlson gave the selenium a positive static charge. Then he projected an image of the page to be copied on the sheet of selenium. Where the light struck, electrons flowed from the aluminum into the selenium and neutralized the charge. Where no light struck it, the selenium layer kept its positive charge. Where the original page was white, the selenium lost its charge. Where the original page had dark writing, the selenium kept its negative charge.



The third step was to sprinkle positively charged ink particles over the sheet of selenium. The ink clung to areas of the selenium that had a negative charge because the unlike charges attracted one another. At this point, the ink on the selenium sheet exactly matched the original page. Ink particles were absent from those areas

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

where the original page was bright white. Ink had gathered where the original page had black writing.

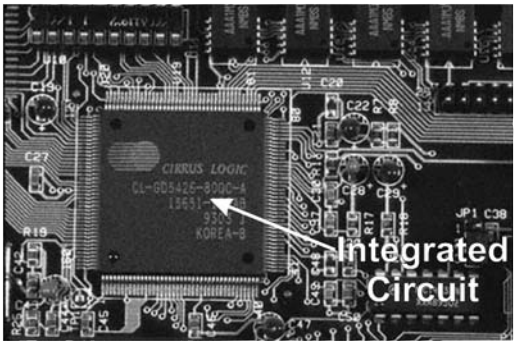
Next Carlson pressed a sheet of paper over the selenium sheet. Finally, heat was applied to melt the ink particles into the paper. The result gave a copy identical to the original. Chester Carlson patented his process as Xerography. A company in Rochester, New York, developed the invention. The invention became so successful, the company changed its name to the Xerox Company.

Laser printers used with computers are electrostatic copiers. Laser printers use a method similar to a Xerox machine. A beam of laser light controlled by the computer rapidly draws the image of the page to be printed onto a photosensitive drum that has a static charge. The laser light eliminates all of the electric charge except on letters and pictures, which attract the ink particles. The static electric charges attract and hold the dry ink particles. A charged sheet of paper moves across the drum and picks up the ink. The paper is fed through heated rollers that melt the ink onto the paper.

The electrostatic copier and laser printer make use of the fact that light gives electrons on the surface of certain materials enough velocity to travel elsewhere. The photoelectric effect has a variety of uses. Cameras have electric light meters to give the proper exposure. Electricity flows when the cell is exposed to light. The brighter the light, the stronger the electric current. The camera adjusts the exposure time based on the amount of light needed to capture the photo image.

One growing use of the photoelectric effect is in the production of ***solar cells*** for generating electricity. Solar cells are made from crystals of silicon or other semiconductor materials. Crystals are cut into thin wafers. Sunlight striking the surface puts electrons in motion and generates an electric current. The efficiency of solar cells is about 30 percent: they change a little less than one-third of solar energy into electrical energy.

Solar cells, also known as *photocells*, are coming into greater use because of advances in electronics which have reduced the amount of electricity required to run electrical devices during the past fifty years. Liquid crystal displays require less energy than light emitting diodes that were used in the first hand-held calculators. Integrated circuits require less energy than individual transistors, resistors and capacitors that were found in the first electronic devices. Many hand-held calculators, watches and other small electronic devices receive all of their power from thumbnail size photocells.



Because of the cost of semiconductor materials, solar cells cannot yet compete as a replacement for electricity generated for everyday use by electric power stations. Solar cells still have their greatest application in areas where other sources of electricity are difficult to obtain. Remote weather stations and devices that report river levels are powered by solar cells, as are buoys in shipping channels and gates on remote ranches. Most of these instruments have battery backup for nighttime and when heavy clouds hide the Sun.

Satellites in orbit and other spacecraft draw their power from large arrays of photocells. The Hubble Space Telescope has a solar array with an area equal to the roof

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

area of a large home (3,120 square feet). The Hubble solar cells generate about 5,500 watts of electricity. For comparison, an electric hair dryer draws about 1,200 watts.

Static electricity has other important uses. Pollutants from smokestack exhausts at factories include ash, dust and smoke particles. One way of removing pollutants is to give them a static charge. They are then attracted to electrostatic precipitators with the opposite charge. The fine particles are captured before being discharged into the air.

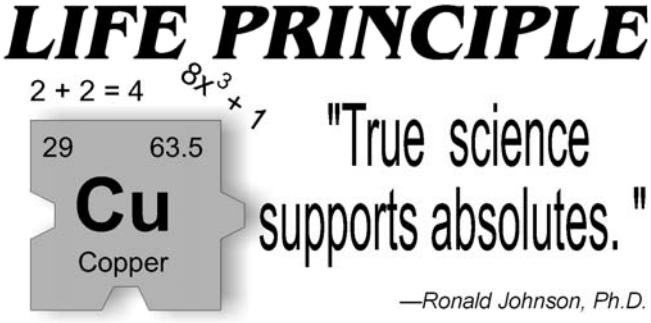
Development of primary devices required accurate measurements. Scientists used a variety of units of measurement. The coulomb is the unit for measuring electric charge. The coulomb was first defined by measuring the weight of metal that flowing current removed from solution. Later, this charge was found to be equal to the charge of 6.25×10^{18} electrons. Today, charge is defined in terms of the ampere, a measure of current. The ampere is a ***base unit*** that is used to define other electrical terms such as coulomb (charge) and watt (power).

Scientists have agreed upon seven base units. The basic metric units include the *meter* (distance), *second* (time), *kilogram* (mass) and *Kelvin degree* (temperature, same as Celsius degree), the *mole* for measuring the number of atoms (6.02×10^{23} atoms=1 mole), the *candela* for measuring the brightness of light and the *ampere* for measuring electric current.



Scientists make an effort to keep the number of fundamental units at a minimum. Other units are named by combining the fundamental units. Imagine all of the quantities that scientists measure such as speed, acceleration, density, frequency, force, work, power, electrical resistance and many others. All of these quantities are called *derived quantities* because they are obtained from, or can be stated in terms of, base quantities.

Notice how the base units can be combined to give other units. *Speed* is stated in meters per second. *Acceleration* is stated in meters per second squared. *Force* is a combination of mass and acceleration. *Work* is a combination of force and distance. From the seven units, all of the other measurements in science are made. A *coulomb* (charge) is a derived unit because it can be defined in terms of the base units, ampere and second. A coulomb is the charge in one ampere of current that flows for one second. A *watt* (power) is a derived unit because it can be defined in terms of the base units, ampere and time. A watt is the number of amperes per second delivered by an electric circuit.



©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

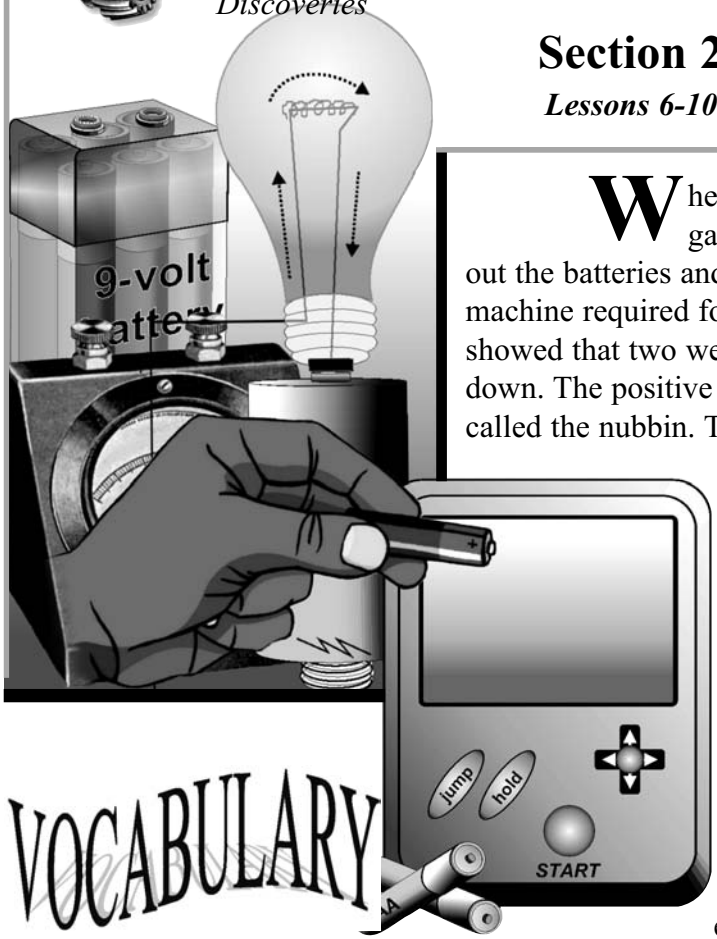
Integrated Physics & Chemistry

Chapter 12

Lesson 10
Inventions & Discoveries

Section 2
Lessons 6-10

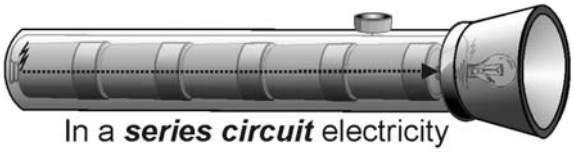
SERIES AND PARALLEL CIRCUITS



When Adam put fresh ***batteries*** in his portable game machine, it did not operate. He took out the batteries and looked at the battery diagram. The machine required four AA size batteries. The diagram showed that two went in sequence with the positive terminals down. The positive terminal of a battery is the raised end, called the nubbin. The other two batteries went in the other way. The flat or negative end went in first, and the raised or positive end was at the top.

Sometimes batteries are installed in sequence facing the same way. A *series circuit* has all devices connected in a single path. (A parallel circuit has more than one path available.) Flashlights with long handles take as many as five batteries inserted in series in the handle. The batteries are put in one after the other so that the negative end of one touches the positive end of the other. They form a single circuit. The electricity goes through all five batteries and then to the flashlight bulb. Other devices have holders designed to alternate the direction of battery alignment.

The difference is determined by the voltage requirements of the electrical device. A single battery such as the small AAA ***cell*** provides 1.5 volts. Larger cells, such as AA or C or D cells, also provide 1.5 volts. Using a larger cell does not increase the voltage. To increase voltage, cells are put in series.


In a ***series circuit*** electricity flows through a single path (batteries are end to end).

VOCABULARY

Battery: a number of cells connected as either a series or parallel circuit, in ordinary usage, a battery may refer to a single cell

Cell: also voltaic cell, an arrangement of a container with two electrodes and an electrolyte for producing the flow of electrons by a chemical reaction

Resistance: the load on a circuit that resists the flow of electrons, a resistance does work and generates heat

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

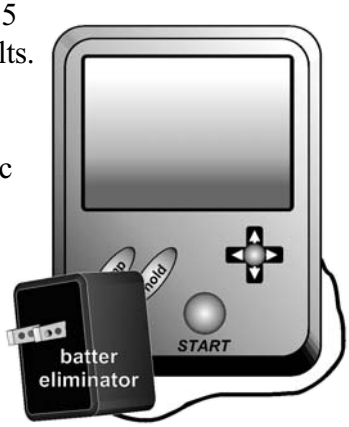
Cells are in series if the negative pole of one connects to the positive pole of the other. Instead of being one after another, the battery holder may be wired so the negative pole of one battery connects to the positive pole of the other. Regardless of how it is done, if the batteries are connected so that electricity goes through the entire system of batteries, then the batteries are in series.

Replacing one battery with two batteries in series increases the voltage. Voltage is electromotive force. Batteries set electrons in motion around the circuit. By placing batteries in series, the first battery gives a certain amount of force to the electrons, and the second battery adds to that force. Increased voltage from the two batteries will push more electrons through the circuit, so the current increases, too. The difference in voltage from the positive terminal of the first battery to negative terminal of the last battery is equal to the sum of the voltages of each of the batteries.

Voltage is sometimes called voltage drop. From one side of a battery to another, the voltage drop is 1.5 volts. The idea of voltage drop can be explained by thinking of electric current as a river. Imagine a river that flows as a single stream and falls down two waterfalls one after another. Each waterfall puts the molecules of the river in motion. If the first one causes the water to fall 150 feet and the second one drops another 150 feet, then the total fall is 150 feet + 150 feet = 300 feet.

In the same way, if one battery gives a circuit a drop of 1.5 volts and the second one gives it another 1.5 volts, then the total voltage drop is 1.5 volts + 1.5 volts = 3.0 volts. The total voltage in a series circuit is equal to the sum of the individual voltages: $V_T = V_1 + V_2 + V_3 + V_4$, with V_T the total voltage and V_1, V_2, V_3 and so on the individual voltages of each battery in series.

If two batteries of 1.5 volts are connected in series, then the total voltage is V_T = 1.5 volt + 1.5 volt = 3.0 volts. A device that needs 6.0 volts can get that voltage with four batteries connected in series. Four batteries with a voltage of 1.5 volts that are connected in series (positive pole of one to the negative pole of the next) will deliver 6.0 volts: V_T = 1.5 volt + 1.5 volt + 1.5 volt + 1.5 volt = 6.0 volts.



Adam had a battery eliminator that plugged into an electric outlet, which provided 110 volts. The transformer at the game machine reduced the voltage to 6.0 V, six volts. Adam could have used four batteries of 1.5 V each to provide the needed six volts.



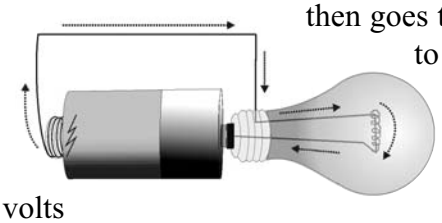
Nine-volt batteries power some portable radios. Inside the package of a 9-volt battery are individual cells stacked together in series. Although small, they combine to produce a total of 9-volts. A 9-volt battery has six cells because 6 * 1.5 volt = 9-volts.

The other quantities of an electric circuit are current and ***resistance***. Current is the total amount of electricity that flows. Resistance, measured in ohms, acts against the flow of electrons. The resistance of a circuit is sometimes called the load. Light bulbs, filaments, electric motors, heating elements and similar devices are the parts of the circuit that present resistance.

Current, voltage and resistance can change one another. As you have learned, Ohm's Law relates current, voltage and resistance: *The current that flows through a conductor is directly proportional to the voltage and inversely proportional to the*

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

resistance. If the voltage increases, the current increases. If the resistance increases, the current decreases. Ohm's Law is written as $I = V/R$ with I the current in amperes, V the voltage in volts and R the resistance in ohms.



The two ways of controlling the current in a circuit are by changing the voltage and changing the resistance. Most flashlights are series circuits. When the flashlight is switched on, electricity flows from the negative base of the battery through a wire to the light bulb through the filament to the base of the bulb and to the positive top of the battery. The electricity has but one path. Every electron follows exactly the same route and goes through every device in the series circuit.

Now examine Ohm's Law, $I = V/R$ and see how current can be changed. Current and voltage are directly related. Doubling the voltage will send twice as much current flowing through the flashlight bulb. Adding more batteries in series increases the voltage. The bulb burns brighter.

Replacing one battery with two batteries in series does not change the resistance. The internal resistance of copper wires and batteries is usually too slight to matter. The batteries are a source of current and voltage but not of significant resistance. The light bulb is the source of resistance to the flow of electricity. Because the number of light bulbs has not changed, the resistance of the circuit is the same whether the flashlight has two batteries or one.

Current and resistance are inversely related. Doubling the resistance cuts in half the current that flows. Suppose a flashlight is modified to hold two light bulbs that draw power from a single 1.5 volt battery. The electricity leaves the battery, goes through the first bulb, then goes through the second bulb and back to the battery. Because of the increased resistance, only half as much current flows, and each bulb burns less brightly.

Light bulbs are the resistance of the flashlight circuit. Doubling the number of light bulbs doubles the resistance. By placing resistance in series, the total resistance is equal to the sum of the individual resistance: $R_T = R_1 + R_2 + R_3 + R_4$. R_T is the total resistance and R_1, R_2, R_3 and so on the resistance of each individual resistance in series.

The current in a series circuit can change provided the resistance or the voltage changes. However, once a circuit is built with a set number of batteries and a set number of light bulbs, the current is constant throughout the entire circuit. In a series circuit, all of the electrons travel the entire path of the circuit. The current at any one location in the circuit is the same as the current at any other location in the circuit. As an equation, $I_T = I_1 = I_2 = I_3 = I_4$, with I_T the total current, and I_1, I_2, I_3 and so on the measured current at different points of the circuit. Notice that I_T and I_1, I_2, I_3 and so on are related by equality, not summation.

Remember, for a series circuit, total voltage is equal to the sum of the voltages of each battery in the circuit; total resistance is equal to the sum of the resistances in the circuit; total current is the same at any point along the circuit. For a series circuit, total current is the same at any point along the circuit.



Electrical engineers measure the current, voltage and resistance with a device called a *galvanometer*. You will recall that electricity, flowing through a coil of wire,

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

generates a magnetic field. In a galvanometer, the coil is attached to a pointer and put between two magnets. The flow of electricity sets up a magnetic field in the coil. The two magnetic fields interact and cause the coil to rotate. The pointer attached to it moves across a dial, showing the amount of electricity.

By design a galvanometer operates on a tiny amount of current so that taking a measurement does not change the quantity being measured.



©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

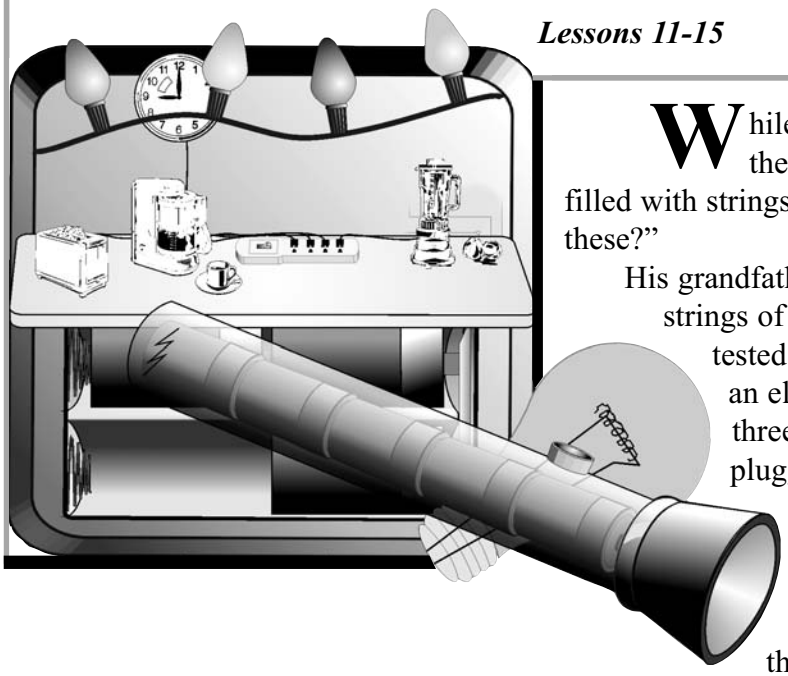
Lesson 11
Energy

Chapter 12

PARALLEL CIRCUITS

Section 3

Lessons 11-15



While helping his grandfather clean out the storage shed, Samuel found a box filled with strings of lights. Samuel asked, "What are these?"

His grandfather explained that the box contained strings of Christmas lights. His grandfather tested each string by plugging each one in an electric wall outlet. Every light in three of the strings came on. When he plugged in the fourth string, not a single light glowed.

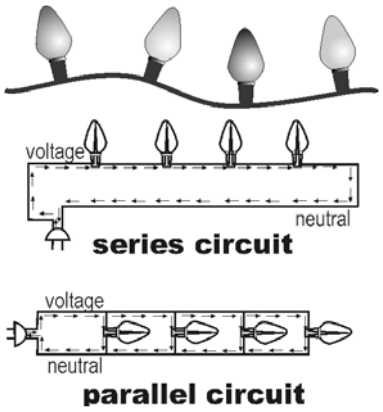
"Are all of the bulbs burned out?" Samuel asked.

"No," his grandfather said. "In these old-fashioned strings of lights, if a single bulb burns out, then the entire string goes dark."

Grandfather took a spare good bulb and, in turn, tested each bulb in the bad string. He had to unscrew each bulb and screw in the test bulb. Finally, he replaced the one bad bulb with the good one. Then every bulb in the entire string came on.

Samuel remembered the lights he had helped his father put up the previous Christmas. "Our lights are not like that. When one goes out, the others keep burning."

In the old fashioned string, the bulbs were connected in series. In a *series circuit*, electricity goes along one path around the entire circuit. A break in a series circuit stops the electric current. The bulbs in the series circuit were connected one after another. Electricity had to go through one bulb before it could go to the next. Whenever the filament in one bulb burned out, the electricity stopped



VOCABULARY

Reciprocal: the product of a number and its reciprocal gives 1, the reciprocal of 4.0 is 0.25 because 4.0 * 0.25 = 1.0, if *N* is the number then *1/N* is its reciprocal, the reciprocal of a number is found by dividing 1 by the number, the reciprocal of 4 is $^1/_4$.

Logic: in computer science logic has to do with principles governing how "yes" and "no" decisions are made

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

flowing and all of the bulbs went dark. A series circuit can be compared to two towns connected by a single highway. If a bridge on the highway washes out, then traffic cannot travel along that route between the two cities.

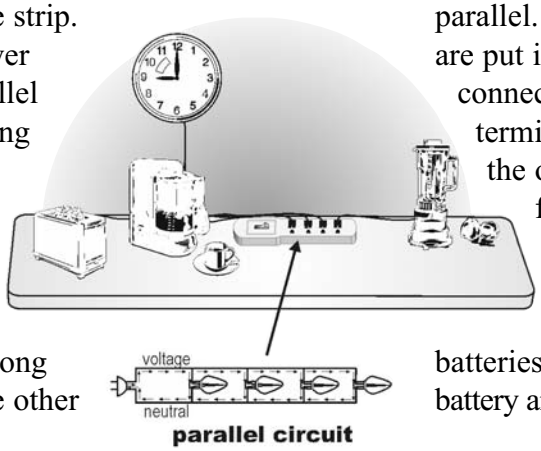
A *parallel circuit* has two or more paths that electric current can follow. Electrical devices in a parallel circuit connect across the two wires. A parallel circuit can be compared to two towns connected by two or more different routes. If a bridge on one of the highways washes out, traffic can continue to travel between the two cities by taking the alternate route.

A parallel circuit has that name because the two wires run parallel to one another like the tracks of a railroad. Today, most strings of Christmas bulbs are connected in parallel circuits. For a string of bulbs in parallel, each bulb connects across the two wires. Should one bulb burn out, only the flow of electricity across that one bulb would cease. All others continue to receive electricity.

As an analogy of a parallel circuit, think of a ladder with the two side rails as the two wires and the rungs (crosspieces where one steps) as the bulbs. If any one rung breaks, the other rungs are still good.

At Samuel's house, his mother had a fused power strip on her kitchen counter. Several devices, such as a blender, coffee maker, toaster and electric clock were plugged into the strip.

The power strip was a parallel circuit. One prong of the blender's power cord plugged into one side of the power strip, and the other prong plugged into the other side. Each of the other devices were arranged in the same way. When electricity flowed, it crossed from one side of the circuit through the device to the other side of the circuit. Suppose the toaster and the coffee maker were both operating at the same time, and the toaster stops working. The coffee maker would have continued to operate because it was plugged into a parallel circuit.



parallel circuit

Ohm's Law states that current is directly proportional to voltage but inversely proportional to resistance. The current, resistance and voltage differ in series and parallel circuits.

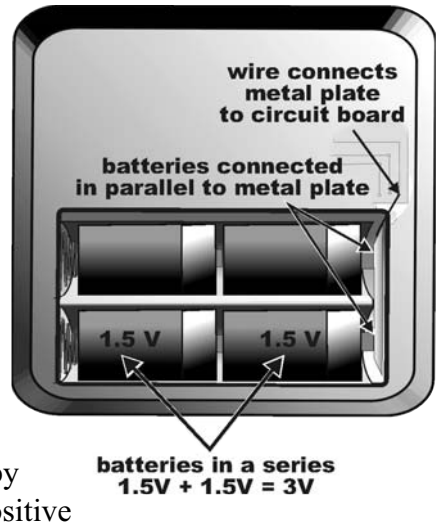
OHM'S LAW

"Current is directly proportional to voltage but inversely proportional to resistance."

$I = V/R$

Batteries are put in series by connecting the positive terminal of one to the negative terminal of the other. The total voltage is the sum of the voltages of each battery in the series.

Adam's CD player took two batteries, but the port to plug in the battery eliminator, was marked 1.5 V. The voltage for two batteries in series should be 3.0 V not 1.5 V.

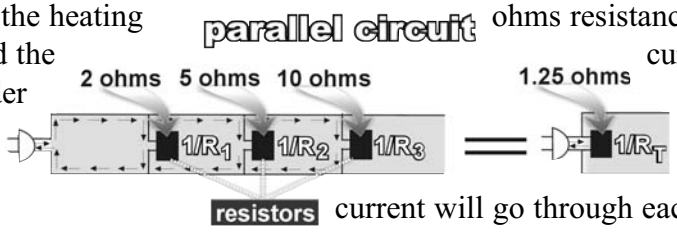


batteries in a series
1.5V + 1.5V = 3V

The two batteries were connected in parallel. Batteries are put in parallel by connecting the positive terminal of one to the positive terminal of the other and the negative terminal of the first battery to the negative terminal of the second battery. Putting batteries in parallel does not change the voltage. The purpose of putting two batteries in parallel is that they act as a larger battery and provide electricity for a longer time.

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

The resistance of a circuit is called the load, the part that does the work. The filament of a light bulb, the heating elements of a toaster and the electric motor in a blender are examples of loads (resistances) that are in electric circuits.



The voltage, current and resistance vary in a parallel circuit because the voltage drop across any device is the same for any of the devices in the circuit. In the equation $V_T = V_1 = V_2 = V_3$, V_T is the total voltage, and V_1, V_2, V_3 is the voltage drop across devices 1, 2, 3 (blender, coffee maker, toaster). Notice that they are related by equality (=), not summation (+). Imagine a river that separates into three streams as it comes to a cliff. The water falls over the cliff in three separate streams and comes back together as a single flow in the valley. The distance the water falls (voltage) is the same for each stream.

Current is not the same. In a parallel circuit, electron flow separates into different streams inversely proportional to the resistance. The path with the least resistance carries the most current. Suppose the three items in the parallel circuit are three light bulbs, and each one has the same resistance. In that case, the current will separate into three identical streams to go through each bulb. Each path will carry the same amount of electricity. Each will carry 1/3 of the total. If 2.0 amps of current goes through one path, then 2.0 amps of current goes through the other two as well. The total is 3 * 2.0 amps = 6.0 amps. If one bulb has more resistance than the other two, less electric current will flow through the bulb with more resistance than the other bulbs.

Suppose the resistance is not the same. Look at a parallel circuit with three paths with resistances of 2 ohms, 5 ohms and 10 ohms. More current will go through the lower 2 ohms resistance than the greater 5 ohms resistance, while even less current will go through the 10 ohms resistance. However, some current will go through each of the three resistors. As an analogy, if a large auditorium has two wide double doors on either side, then the people will file out with about half going through one exit and half going through the other exit. If there is a small side exit with a long flight of stairs, a few may take that route but not as many as the easier route at the back of the auditorium.

For a parallel circuit, the total current is given by the formula $I_T = I_1 + I_2 + I_3$. I_T is the total current while I_1, I_2 and I_3 represents the current through each parallel path. The formula shows only three paths, but is true regardless of the number of paths; the total current is equal to the sum of the currents in each of the parallel paths.

Resistance is also a factor. The mathematical formula for resistance is easily derived from Ohm's Law. First, the current is given by $I_T = I_1 + I_2 + I_3$, but $I = V/R$, so the equation can be written as $V_T/R_T = V_1/R_1 + V_2/R_2 + V_3/R_3$. In a parallel circuit the total voltage is the same as the individual voltages, so V_1, V_2 and V_3 are equal to V_T. Divide both sides of the equation by V_T and the result is $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$.

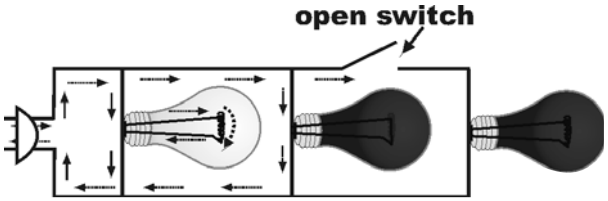
For a parallel circuit with three resistances, the total resistance is given by the mathematical formula $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$. In a parallel circuit, the ***reciprocal*** of the total resistance is given by the sum of the reciprocals of each individual resistance.

As a specific example, suppose three resistors with a resistance of 2 ohms, 5 ohms and 10 ohms are in a circuit. A single resistance could replace the three individual

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

resistances: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 = 1/2 + 1/5 + 1/10 = 0.50 + 0.20 + 0.10 = 0.80$; $1/R_T = 1/.80$ ohms; or, $R_T = 1.25$ ohms (1 divided by 0.80 is 1.25).

A circuit that is *open* is one in which electricity will not flow. A circuit that is *closed* is one in which electricity will flow.



(This can be confusing because it is the reverse of a door. An open door is one that allows a person to pass, while a closed door prevents a person from walking through the opening.) The terms *open* and *closed* for electric circuits came into use because of the setting of electrical switches. An open switch is one in which a gap exists in the circuit. No electricity can flow through an open switch. A closed switch is one in which the gap has been closed by the switch. Electricity can flow through the closed switch and completes the circuit.

A study of open and closed switches by students at MIT (Massachusetts Institute of Technology) led to the development of the principles governing how computers work. Many students at MIT during the 1990s had model train sets that were combined and set up in the basement of the electrical engineering building. Soon the vast array of switches, trains and tracks were programmed to answer simple questions in ***logic***.

As an example, suppose a track has four switches in series. For a train to go along the track, all of the four switches would be closed. If a single switch is open, the train cannot pass. Suppose the train has a choice of four parallel tracks, and along the length of each track is a switch. If a single switch is open, the train can still pass by taking any one of the other three tracks. The only way to keep the train from going to its destination is to open the switches on all four of the parallel tracks.

Summary—Series Circuit

The current at any point of the circuit is equal to the current at any other point in the series circuit: $I_T = I_1 = I_2 = I_3$ and is given by Ohm's Law: $I_T = V_T/R_T$.

The total voltage drop for the entire circuit is equal to the sum of the voltage drop across each of the resistances in the series circuit: $V_T = V_1 + V_2 + V_3$.

The total resistance is equal to the sum of all of the resistances in the series circuit: $R_T = R_1 + R_2 + R_3$.

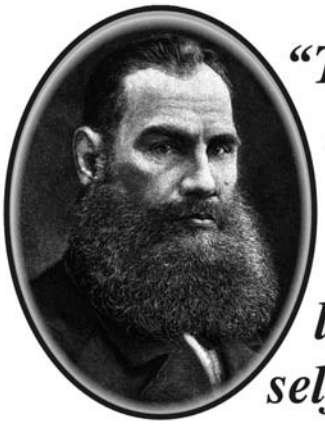
Summary—Parallel Circuit

The total current is equal to the current that flows in each path: $I_T = I_1 + I_2 + I_3$.

The total voltage drop is equal to the voltage drop across any one of the paths of resistance in a parallel circuit: $V_T = V_1 = V_2 = V_3$.

The reciprocal of the total resistance is equal to the sum of the reciprocals of the resistances through each resistor in a parallel circuit: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$.

LIFE PRINCIPLE



"There has never been, and cannot be, a good life without self-control."

—Leo Tolstoy

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

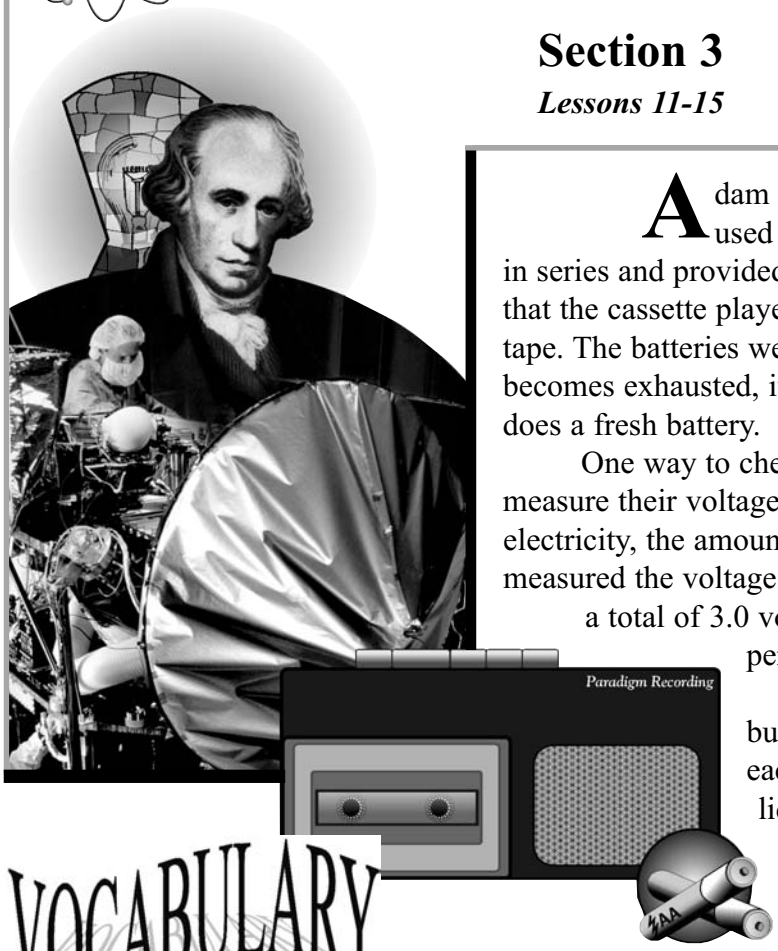
Lesson 12
Energy

Chapter 12

CURRENT AND POWER

Section 3

Lessons 11-15



Adam had a small cassette tape player that used two batteries which were connected in series and provided 3.0 volts. One day Adam noticed that the cassette player was taking a long time to rewind a tape. The batteries were running down. When a battery becomes exhausted, it cannot produce the same voltage as does a fresh battery.

One way to check the freshness of batteries is to measure their voltage. As they lose their ability to provide electricity, the amount of voltage decreases. If Adam had measured the voltage, he would have found that instead of a total of 3.0 volts, the batteries were delivering perhaps only 2.4 volts or less.

The batteries that Adam used had built–in battery testers. On the side of each battery was a strip containing liquid crystals. Other batteries are sold in packages with a single built-in liquid crystal battery tester. Liquid crystals have molecules that can slide past one another as if in a liquid. However, crystals tend to face in a set direction as in a solid. Pressure, heat or electricity can change the direction molecules face.

The built-in battery tester included the type of liquid crystals that changed color when heated. Pressing the battery tester completed a circuit from the negative terminal to the positive terminal of the battery. The electricity flowed through a metallic strip that was wider at one end than at the other. If the current was weak, then only the narrow part of the metallic strip became warm, and the color showed the battery was weak. If the battery had more voltage, the greater current through the resisting strip of metal heated the wide part of the metallic strip. The liquid crystals then changed color, indicating the battery was good.

VOCABULARY

Power: rate that work is done, measured in units of work per unit of time; called *watt* in the metric system and *horsepower* or ft-lbs/sec in the English system

Pound (lb.): English unit for force; the force of gravitational attraction between Earth and an object that weighs one pound

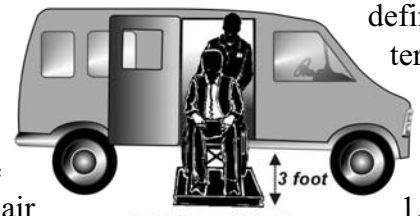
Foot-pound (ft.-lb.): English unit of work; a force of one pound acting through a distance of one foot

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

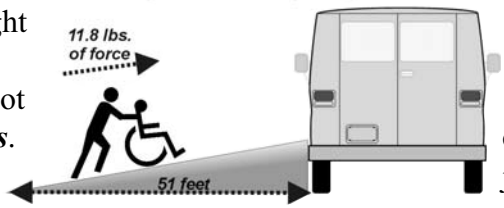
Some devices can function with reduced voltage while others fail entirely. For example, Adam's cassette player continued to produce good sound, but the motor that pulled the tape through the tape player operated slower and slower. The speaker and tape cassette motor have different ***power*** requirements. Rewinding a tape from one end to the other consumes a certain amount of energy. To do it quickly consumes extra energy or power.

Power is how quickly work is done. Recall that work in physics is the distance that a force acts to move an object: $E = F * d$, with E being the work (or energy), F being the force and d being the distance.

Work does not depend on time. As an example, suppose a wheelchair and its occupant equal a total weight of 200 ***pounds***. The wheelchair can be raised to a platform or a van by an electric lift at a speed of three feet in three seconds. The work in lifting the chair and person a distance of three feet straight up is E = F * d = 200 pounds * 3 foot = 600 ***foot-pounds***. Time is not a factor.



200 lbs. * 3 foot
equals 600 foot-pounds.



11.8 lbs. * 51 feet
equals 600 foot-pounds.

Suppose that instead of taking the electric lift, the person in the wheelchair is wheeled up a long ramp with a mechanical advantage of 17. Using the ramp takes 25 seconds. The ramp enables the wheelchair operator to move the wheelchair with only 1/17 as much force, or 200 pounds / 17 = 11.8 pounds. The ramp is 51 feet long. The work or energy is force times distance: E = F * d = 11.8 pounds * 17 = 600 foot-pounds (rounded). Going up the ramp takes longer than using an electric lift, but the work is the same.

The *foot-pound* is the English unit of work or energy. It is the force of one pound acting through a distance of one foot.

In the metric system, the unit for work or energy is the *joule,* which is defined as a force of 1.0 ***newton*** acting through a distance of 1.0 meter. This is the mechanical definition of work because it is stated in terms of the movement of physical objects. In electrical terms, a joule is equal to the work done by 1.0 ampere of electric current passing through a resistance of 1.0 ohm for 1.0 second. Heat energy is usually stated in terms of *calories*. A calorie is the heat energy required to raise 1.0 gram of water 1.0 degree Celsius. A joule is equal to 4.18 calories. A foot-pound is about 1.36 joules. All of these quantities—joule, calorie and foot-pound—are measures of work or energy.

Power is how quickly work is done. Power does depend on time. Power is expressed as work per unit time: $P = E/t$, with P being the power, E being the work or energy and t being the time. In the examples above, the electric lift and the person in the wheelchair using the ramp illustrated the same amount of work done – 600 foot-pounds. Rolling the wheelchair manually up the ramp took 25 seconds, while the electric

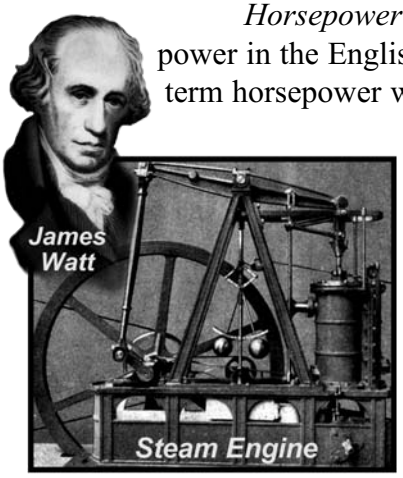
VOCABULARY

Newton (n): metric unit of force, equal to the force required to cause one kilogram of mass to accelerate at the rate of one meter per second per second

Trajectory: a course or path; the curved path of a missile or rocket

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

lift did the same work in only three seconds. The electric lift had more power: P = E/t = 600 foot-pounds / 3 seconds = 200 ft-lbs/sec. Going along the ramp displayed a power of P = E/T = 600 foot-pounds / 25 seconds = 24 ft-lbs/sec. The unit ft-lbs/sec is a unit of power because it involves force times distance (ft-lbs) divided by time (sec).



Horsepower is another unit of power in the English system. The term horsepower was invented by James Watt in the mid 1700s to describe how quickly the steam engines he invented could work. A horsepower is defined as doing 33,000 foot-pounds of work in one minute: 1.0 hp = 33,000 ft-lbs/min.

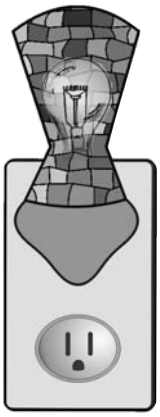
In the metric system, the unit of power is the *watt*, named for James Watt. A watt is defined as the power needed to do 1.0 joule of work in 1.0 second.

Electrical utility companies charge residential customers for electrical use by the *kilowatt-hour*, abbreviated *kwh*. A kilowatt-hour is an unusual unit because it contains the word watt but is not a unit of power. Instead, it is a measure of work or energy. A watt is the flow of 1 joule of electrical energy per second. By multiplying a watt by time, the watt is changed from a unit of power to a unit of work. A kilowatt-hour is the amount of work that can be done by one watt acting for one hour. The electric company does not charge by how quickly the customer uses electricity but by how much electricity is used.

A kilowatt-hour is equal to 1,000 watts of electrical power flowing for one hour. A 100-watt light bulb that burns for 10 hours would consume 1.0 kilowatt-hour of electrical energy (100 watt * 10 hours = 1,000 watt-hours, or 1.0 kilowatt-hour).

The cost of a kilowatt-hour varies from one part of the country to another and by how much electricity is used. When Adam's father paid his electric bill, he was charged nine cents for each kilowatt-hour. The bill showed that during the month Adam's family used 825 kilowatt hours at a rate of 9 cents per hour for a total bill of $74.25: *cost = kwh * price per kwh*.

A typical night-light has a seven-watt bulb with an automatic sensor that comes on when the room in which the light is located becomes dark. Assume that the night-light is on for 10 hours a day. In a month of 30 days, the light will be on for 300 hours: 10 hours/day * 30 days = 300 hours. The number of kilowatt-hours is 7 watts * 300 hours = 2,100 watt-hours or 2.1 kilowatt-hours. Cost = kilowatt-hours * price per kilowatt-hour = 2.1 kwh * 12 cent/kwh = 25.2 cents. The night-light costs about 25 cents a month to operate.



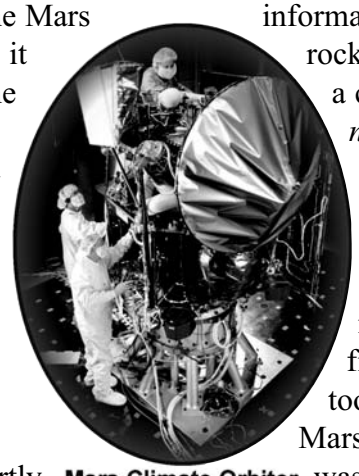
2.1 kwh * 12 cents/kwh = 25.2 cents per month

You might wonder which would cost more to operate, the 7-watt night-light or a 1,200 watt hair dryer for 5 minutes each day for a month. A little arithmetic is needed to determine the cost of operating the hair dryer. First calculate the total number of minutes, then change minutes to hours: 5 minutes per day * 30 days per month = 150 minutes/month or 2.5 hours. Next multiply watts and hours to get kilowatt hours: 1,200 watts * 2.5 hours = 3,000 watt-hours or 3.0 kwh. Finally calculate the cost: cost = kwh * price per kwh = 3.0 kwh * 12 cent/kwh = 36 cents.

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Operation of the hair dryer costs more than operation of the night-light.

Understanding the units in physics is important. In the fall of 1999, NASA engineers prepared to slow the Mars Climate Orbiter spacecraft so it would go into orbit around the planet Mars. The mission navigation team in California sent a signal to the spacecraft telling it how long to fire its engines to put the spacecraft on the right ***trajectory*** for orbit. The craft would dip into the thin atmosphere of Mars and be slowed by air resistance. Shortly after the rockets fired, communication with the craft ceased. Over the next few hours, efforts to make contact with the craft failed. Finally, NASA engineers decided the unmanned craft had burned up in the Martian atmosphere.



Mars Climate Orbiter

An investigation into the failure revealed the cause to be a misunderstanding about the units of force. Normally, a team in Colorado did the calculations and sent the information to the team in California. The rockets were then programmed to provide a certain amount of force measured in *newtons*, the metric unit of force. However, the engineers controlling the spacecraft were given the force in *pounds*. The engineers programmed the computer numbers in newtons rather than in pounds. When the craft fired its rockets, it fell into a path that took it too deep into the atmosphere of Mars. The multi-million dollar spacecraft was destroyed because of the low orbit caused by improper computer programming.

In this case, one team used English units such as feet and pounds while the other used metric units such as meters and newtons for a key spacecraft operation. The confusion led to the loss of an important space mission.

Life Principle



"Nothing in the world can take the place of persistence."

–President Calvin Coolidge

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry

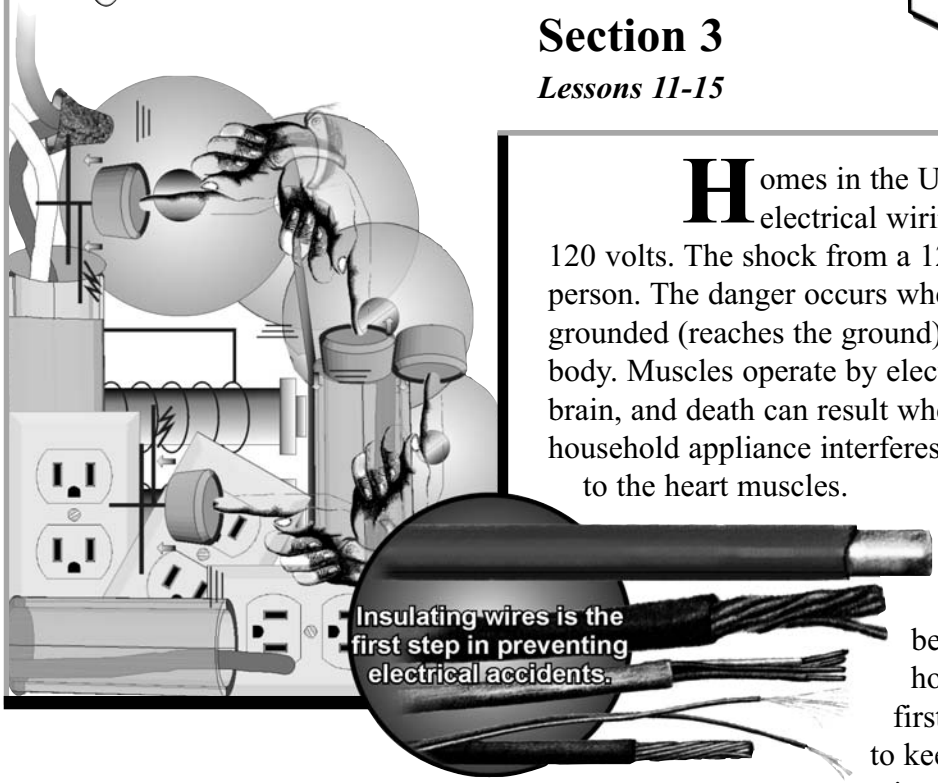
Lesson 13
Energy

Chapter 12

KEEPING ELECTRICITY SAFE

Section 3

Lessons 11-15



Homes in the United States have electrical wiring that carries current at 120 volts. The shock from a 120-volt line can kill a person. The danger occurs when electricity is grounded (reaches the ground) through the human body. Muscles operate by electrical signals from the brain, and death can result when electricity from a household appliance interferes with the signals going to the heart muscles.

To prevent dangerous shocks, electric codes have been written to govern how houses are wired. The first step is to use insulation to keep electricity in the wires. Almost all electrical accidents and fires are caused by faulty insulation that has become old and cracked or the cord has been damaged. For instance, one girl used an extension cord to set up a light in a closet so she could continue to read after lights out. However, she opened and closed the closet door so many times the insulation around the creased wire became worn. The exposed wire started a fire.

Because insulation can fail, the next step is to provide good grounding. Electricians assume insulation will fail at some point. They provide an alternate way for the electricity to reach the ground rather than by going through a human body. The *ground* in electrical terms is a region that can either accept or give up electrons without becoming charged itself. The ground has an electrical potential difference (voltage) of zero. Earth itself is the ground for most wiring in a home.

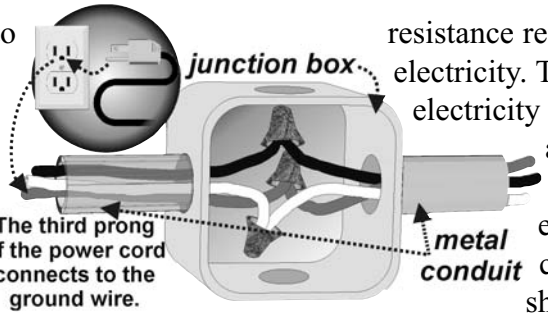
Electric wires are carried throughout the house in metal ***conduit*** that is connected to the ground. Where a wire splits to

VOCABULARY

Conduit: a pipe, tube, or channel through which electric wires are conveyed
Junction box: a metal box which houses and protects electrical wire connections
Electrocute: to kill with electricity

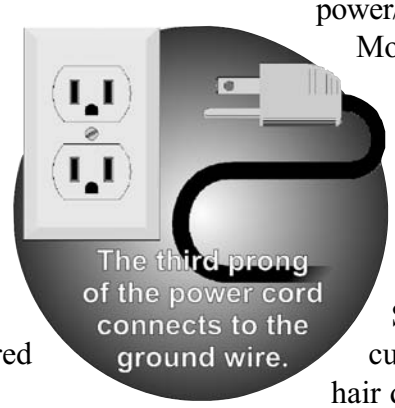
©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

go from one room to another, or where electricity is transferred to home appliances, the wires are enclosed in small, metal ***junction boxes***. Likewise, wiring for light switches and wall outlets are enclosed in junction boxes. Each of the metal boxes is grounded. Should insulation fail anywhere in the house, the electricity would be conducted to the ground by the metal shielding.



Appliances such as washers or dryers need to be grounded in the event their insulation fails. Modern electrical codes call for three prongs in every electric outlet. The third wire, usually green, is the ground. This wire connects to the metal parts of the washer, dryer or other electric device and to the ground through the third prong of the power cord that goes into the wall outlet.

When flowing through a resistance, electricity produces heat. The heating effect depends on the amount of current and resistance. Sometimes the heating effect is desired as in toasters, electric stoves and electric hot water heaters. Sometimes the heating effect is not desired such as in a short circuit.



A *short circuit* is caused when electricity finds a return path that has very low resistance. When an electrical appliance "shorts out," the electricity completes its path without going through the resistance. A short circuit is a low-resistance short cut. According to Ohm's Law, $I = V/R$, if the resistance becomes small, then the current becomes large. A path of no resistance results in a sudden surge of electricity. The uncontrolled flow of electricity can damage or cause a fire in an appliance that has a short circuit.

Power strips and home electrical panels contain fuses and circuit breakers to guard against short circuits. A fuse contains a metal strip that will melt if the circuit receives too much current. Once a fuse blows or a breaker "trips," the device that has the short circuit has to be taken off line and the fuse replaced or reset. A modern circuit breaker includes an electromagnet attached to an on-and-off switch. If too much electricity flows, the electromagnet opens the switch and cuts off the flow of electricity.

Sometimes a fuse burns out or a circuit breaker trips because too many devices are plugged into the same circuit. The heating effect on a circuit is caused by the flow of electric current. The current is given by $I = power/volts = watts/volts$. A 100 watt light bulb carries a current of I = power/volts = 100 watt / 120 volts = 0.83 amps.

Most 120-volt circuits in a residential home are protected by 15 amp fuses. About 19 light bulbs of 100-watts each on the same 15-amp circuit would likely cause the circuit to fail.

Appliances with high amperage usage should be on separate circuits. Some of the devices that draw a lot of current during times of operation include hair dryers, curling irons, electric heaters, toasters, coffee makers and microwave ovens. If too many such appliances are used simultaneously, the circuit breaker in a power strip or one in the electric panel in the home may be tripped.

Suppose a hair dryer rated at 1200 watts and a hair curling iron rated at 750 watts are plugged into the same circuit. The total current is I = (1,200 watts + 750 watts) /

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

120 volts = 1,950 watts / 120 volts = 16.25 amp. Both plugged in the same circuit and operating at the same time would trip a circuit breaker and stop the flow of electricity.

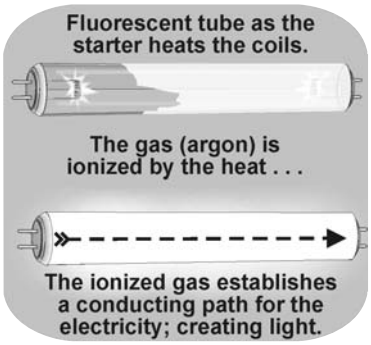
A person who grounds a device and produces a short circuit may be ***electrocuted*** if the fuse does not trip quickly. In some cases, the person is not sufficiently grounded to cause the flow to become great enough to trip a circuit breaker or melt a fuse. Bathrooms and kitchens pose additional electrocution danger because of the presence of water. Although pure water is a nonconductor, water is seldom pure. Water usually contains dissolved salts that make the water a conductor of electricity.

Some building codes require a special type of circuit breaker in wall outlets in bathrooms and kitchens. The circuit breaker, known as a ground fault interrupt, monitors the current that is returning from the device being used. Suppose a hair dryer accidentally fell into a bathtub containing water. The electricity would flow into the water and not make the return trip to the wall plug. A ground fault interrupt senses the lack of return current and turns off that particular outlet.

Electrical appliances are defined in four broad categories: light, heat, mechanical action and electronic devices.

The two main ways light is produced is by incandescent bulbs and fluorescent lights, although some electronic devices have light emitting diodes and liquid crystal displays.

A fluorescent lamp contains a tube filled with low pressure gas, usually argon and mercury vapor. The fluorescent tube is connected to two circuits. The first circuit is the starter. It sends electricity through heating coils at each end of the tube. The filaments ionize the argon so it will conduct electricity. After a couple of seconds, the starter shuts itself off. The other circuit contains a coil of wire known as a *ballast*. When the switch of the other circuit (starter) shuts off, the ballast sends a sudden burst of electricity through the argon that establishes a conducting path for electricity.



Once the electrons have established a path through the fluorescent lamp, the ballast continues to operate but at a reduced voltage. Sometimes the ballast or starter do not operate correctly, and the fluorescent lamp flickers. The lamp can be repaired by replacing the starter or ballast.

Electrons at high voltage stream along inside the glass tube of a fluorescent lamp, striking mercury atoms causing them to gain energy. The electrons give up their energy by releasing ultraviolet waves. The inside of the glass fluorescent tube is coated with a material that converts ultraviolet rays into visible light. A fluorescent bulb requires less energy to provide the same amount of light as an incandescent bulb.

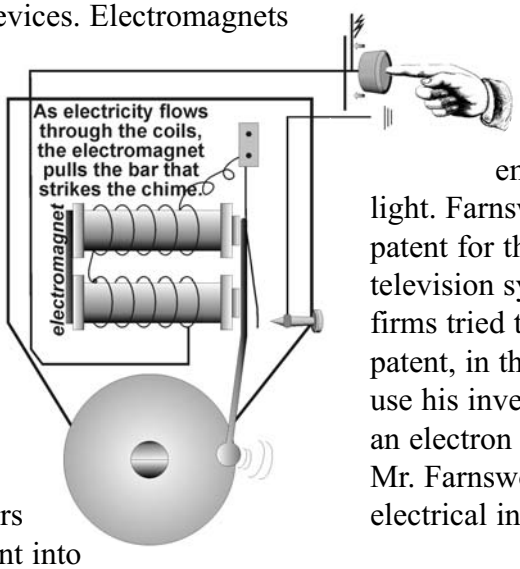
An incandescent bulb is sometimes classified with heating devices because the bulb's operation is essentially that of a filament that gets so hot it glows. The heating effect of a wire is given by the product of the current squared and the resistance*: Heat = I^2R*. Toasters, electric irons, electric heaters, coils on cooking stoves and hot water heaters all make use of the heating effect of an electric current passing through a resistance.

The third type of electrical devices found in homes are those which convert electricity into mechanical motion. The simplest is a doorbell. A doorbell is essentially an electromagnet. When the

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

button is pressed, electricity activates an electromagnet that pulls up a bar that strikes a chime. A spring pulls the bar back so it is ready for the next time the button is pressed.

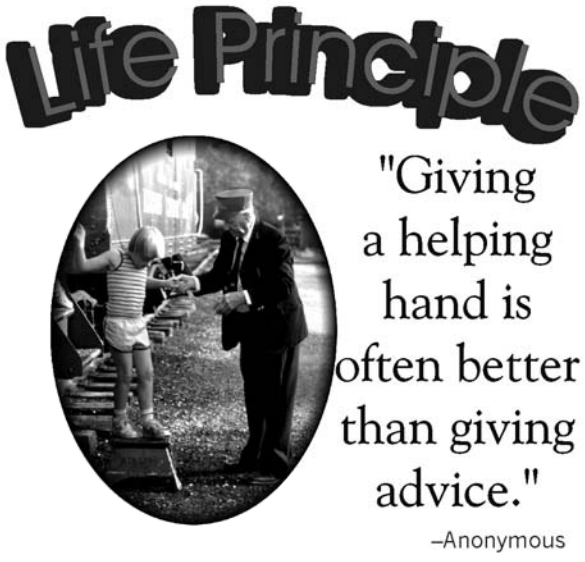
An electromagnet is used in dozens of common electrical devices. Electromagnets process signals to cause metal membranes to vibrate back and forth rapidly. This vibration generates the sound heard in telephones and the loudspeakers of radios, televisions, cassette and CD players.



Electric motors change electric current into mechanical motion. Electric motors are found in such devices as garage door openers, washing machines and vacuum cleaners. Smaller motors give power to electric toothbrushes, spin CDs, pull cassette tapes through tape players or eject VCR tapes from VCR players.

The fourth category of electrical devices includes such appliances as thermostats, radios, telephones and televisions. Probably no electrical invention has impacted culture the last half of the 1900s more than television. Although many electronic firms spend enormous amounts of money to perfect television, a teenage boy named Philo T. Farnsworth made the key invention. Born in Beaver, Utah, in 1906, his family moved to Idaho. At age 11, Philo began experimenting with electricity. By the time he was 14, he had designed a television system that included not only a receiver but also a camera for generating a signal. Other inventors were working on mechanical devices that used rapidly rotating disks with holes in them to "chop up" the scene into series of light bursts that could be changed into electrical signals.

At age 17, Philo Farnsworth found an investor to help him perfect his invention. Rather than a spinning disk with holes in it to convert light into electricity, he used cesium. The element, cesium, emits electrons when struck by light. Farnsworth applied for and received a patent for this essential part of the complete television system. Although several large firms tried to work around the young man's patent, in the end they paid for the right to use his invention. Later, Farnsworth invented an electron microscope. During his lifetime, Mr. Farnsworth gained 165 patents for his electrical inventions.



©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry



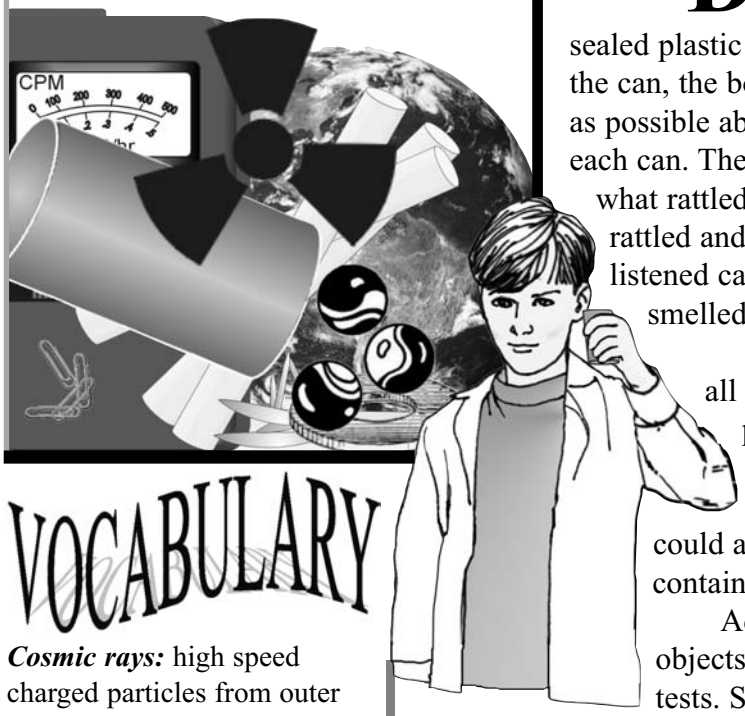
Lesson 14
Inventions & Discoveries

Chapter 12

DISCOVERY BY DESIGN

Section 3

Lessons 11-15



During a science experiment, Adam and Samuel were each given a small, sealed plastic can. Although they could not see into the can, the boys' assignment was to learn as much as possible about the hidden item without opening each can. The boys lifted and shook each can to hear what rattled, and to assess weight. The contents rattled and the weight was slight. The boys listened carefully as they shook the cans. Samuel smelled the can but did not detect an odor.

Adam and Samuel were doing what all scientists do when confronted with a problem. First, they gathered information. The boys used sight, sound and smell to learn what they could about the objects in the small plastic containers.

Adam and Samuel could not identify the objects in the cans without conducting more tests. Since the boys had access to an empty can and an accurate scale, they weighed the empty can and then each of their cans. Adam and Samuel found that the weight of the sealed cans was not the same. From this, they decided that each of their cans contained a different object.

Adam tilted his can until he had worked the object into the shortest dimension. He could hear by the faint rattle that it fit snuggly across one side of the can. This gave him an idea of its size. Adam also noticed that the unknown object slid when held one way but rolled when tilted the other way. Thus, he believed his can held a flat, circular object.

Samuel shook the object in his can and could hear that it moved freely in all directions. From the weight of his can compared to the weight of Adam's can, Samuel believed that his object was smaller than the one in Adam's can. Also, no matter how he held and turned the can, Samuel could not hear

VOCABULARY

Cosmic rays: high speed charged particles from outer space; most cosmic rays are protons traveling at near the speed of light

Background radiation: radiation caused by cosmic rays or by naturally radioactive substances in the soil

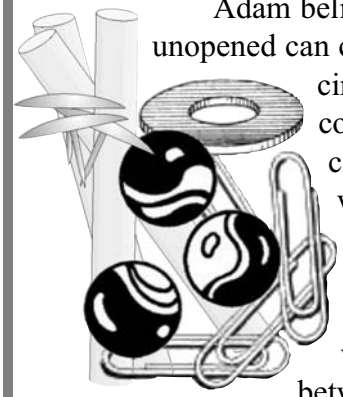
Latitude effect: the observation that the abundance of certain events or physical quantities depends on the latitude (distance from the equator to the North Pole); cosmic rays strike Earth in greater numbers closer to the poles because of Earth's magnetic field

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

his object roll. Instead, it slid as it moved.

These initial tests revealed something about the size, shape and weight of the hidden objects.

At this point, the boys learned additional information. Other students had become impatient and opened their cans. The opened cans revealed six types of items: a paperclip, a penny, a thumbtack, a small piece of chalk, an iron washer and a glass marble. The thumbtack was made of steel, but the paperclip was made of plastic.



Adam believed that his unopened can contained a flat, circular object, so he concluded that the contents of his can was either a penny or metal washer. Both were too nearly alike in weight to choose between them.

Samuel had determined that his object weighed less than the piece of chalk. He eliminated the glass marble, because his object did not roll. His object slid no matter how he turned the can. The object could be a coin, washer, thumbtack or paperclip. Either a coin or a washer was too heavy. The thumbtack and paperclip were too similar in weight to allow Samuel to choose between the two objects.

VOCABULARY

Secondary particles: particles that result from collision of cosmic rays with molecules in the air

Primary cosmic rays: cosmic rays as they are in outer space before striking molecules in Earth's upper atmosphere

Each boy had narrowed his choices to two items. Scientists who reduce options to two choices, look for an experiment that will distinguish between the two choices. The inquisitive boys wondered what experiment could be conducted to reject one choice and to accept the other.

The breakthrough came when Adam thought to use a magnet to test his object. A penny does not respond to a magnet, but an iron washer is attracted by a magnet. Adam brought a magnet near his plastic can. The object made no response to the magnet. He moved the magnet all around the can and felt no tug on the object inside the container. Adam then concluded that his mystery object was a penny.

Samuel tested his choices with a magnet. A plastic paperclip is not magnetic, but a thumbtack made of steel does respond to a magnet. Samuel brought a magnet near his can. He heard the click and felt the attraction as the magnet attracted the object in his can. Samuel concluded that his mystery object was a metal thumbtack. Samuel and Adam opened their containers and were rewarded to see that their conclusions were correct.

One student (Elizabeth) decided to get assistance with her project, so she took her container home without opening it. Since Elizabeth's father was a dentist, he suggested that the dental X-ray machine could help solve the mystery. That afternoon after school she took it to his office, and he X-rayed the container. The shadow of a short length of chalk clearly showed on the X-ray photograph.

The experiments conducted by Adam, Samuel and Elizabeth demonstrate how physicists discover information by design.



©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

As another example of how physicists work, consider the strange case of *cosmic rays*. When scientists first began experimenting with radioactive elements, they developed a variety of tools to detect radiation. Most of the instruments such as the electroscope and Geiger counter responded to ionized (electrically charged) particles caused by radioactivity. But Geiger counters clicked several times each minute even when no radioactive material was present.



This reaction caused scientists to question the source of the radiation. During the first 10 years after discovery of the Geiger counter, scientists assumed ***background radiation*** came from naturally radioactive substances in Earth's crust.

Austrian-American physicist, Victor Franz Hess, decided to study background radiation more thoroughly to determine whether it was coming from radioactive elements in the Earth. If it came from Earth, then at higher elevations, the intensity of the mysterious rays should be less.

During ten balloon flights in 1911 and 1912, Franz Hess tested whether ionization increased with altitude. He used an electroscope invented by Marie Curie. Two gold foil "leaves" were given a static charge, which caused them to repel one another. The mysterious rays passed through the air and caused the molecules to become charged which ionized the air. This conducted away the charge on the gold foil leaves, and they came together. The more intense the ionization, the faster the leaves came together.

Hess conducted tests at ground level and then sent balloons to heights up to six miles. He made ten ascents, himself. If the radiation was coming from Earth's natural radiation, radiation should be weaker at a greater altitude. The foil leaves should take longer to come together.

Instead, the leaves snapped together more quickly. Hess then questioned whether the rays could be coming from the Sun. Hess made five balloon flights at night. The radiation was as strong at night as during the day. Experiments on high mountains gave the same results. At higher elevations, the radiation became stronger whether the Sun was obscured by clouds or shone brightly.

Some background radiation came from naturally radioactive elements in Earth's crust. However, when those sources were eliminated, Hess determined that a certain amount of radiation came from outer space.

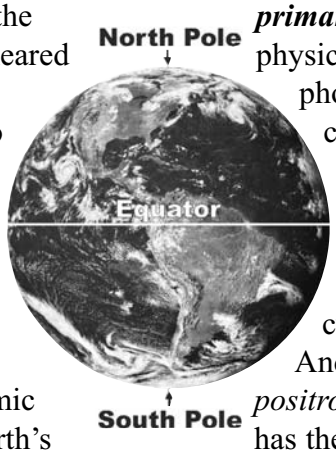
The American scientist Robert Millikan, who had measured the charge on the electron, did additional studies of radiation from outer space and called the force ***cosmic rays***. The word *cosmic* is from a Greek word meaning *the universe*. Millikan tested the strength of cosmic rays from airplanes, balloons and on high mountains. He even lowered instruments into deep lakes.

Millikan was inquisitive about the nature of cosmic rays and whether they were electromagnetic waves. If so, they had more energy than gamma rays, the most powerful form of electromagnetic waves known. He also wanted to know whether they were particles. If so, they traveled faster than any physical object known. Millikan concluded that cosmic rays would have a speed near that of light.

Another American physicist, Arthur Holly Compton, shared an interest in cosmic rays. The Earth has a magnetic field. Suppose cosmic rays were charged particles. As they came into Earth's atmosphere, they would be guided by the magnetic field toward the North and South Poles. Suppose a scientist

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

measured the radiation at different latitudes between the equator and North Pole. If the radiation was the same in all the locations, then the rays were not charged. If the radiation became stronger as one neared the North Pole, then the radiation carried a charge and would have to be a form of matter, not electromagnetic rays.



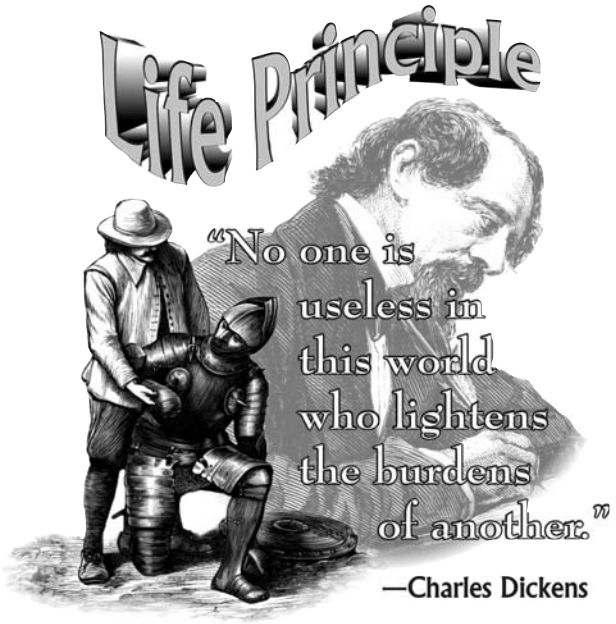
Arthur Holly Compton conducted a series of very careful tests at locations between the equator and North Pole. Compton detected a ***latitude effect***. The cosmic rays near the North Pole struck Earth's atmosphere in greater numbers than rays near the equator. This discovery showed that cosmic rays are particles that carry an electric charge.

Compton also showed that the particles at ground level were not the original particles that came in from outer space. Instead, cosmic rays crashed into Earth's atmosphere and generated a shower of ***secondary particles***. From the energy generated to form secondary particles, physicists concluded that cosmic rays have tremendous kinetic energy.

About 87 out of every 100 cosmic rays are high-speed protons. Most of the others are alpha particles (helium atoms without electrons).

The next question was to identify the source of cosmic rays. That question is still not answered. Despite years of intense study, physicists still cannot account for the presence of cosmic rays in such large quantities. Scientists theorize the particles are given their high speed by being bounced from one magnetic field to another in deep space. (However, what first released the particles has not yet been identified.)

Because of their high energies, cosmic rays act as atom smashers. Scientists installed a cloud chamber on Pike's Peak in Colorado (14,101 feet high). At that elevation, the cloud chamber was struck by ***primary cosmic rays***. In 1932, American physicist, Carl David Anderson, studied photographs taken of a collision of a cosmic ray in a cloud chamber. The cosmic ray collision had released a particle that had a path the same shape as one left by an electron. However, this particle curved in the opposite direction. Anderson had discovered the *positron* or positive electron. A positron has the same mass and other properties of an electron. However, it carries a positive charge rather than a negative one.



©Copyright 2005, Paradigm Accelerated Curriculum
DUPLICATION BY WRITTEN PERMISSION ONLY.

Integrated Physics & Chemistry



Lesson 15
Motion

Chapter 12

A CAREER IN PHYSICS MAY BE FOR YOU

Section 3

Lessons 11-15



Concert halls must have good acoustics



Physics is one of the physical sciences. Some other sciences include chemistry, geology and astronomy. Physicists study the interaction of matter and energy. The main fields of physics include mechanics (matter and the forces that act upon it), heat and energy, electricity and magnetism, light and electromagnetic waves, atomic and nuclear physics, quantum and elementary particles, cryogenics and astrophysics. A physicist may study the smallest subatomic particles or the largest galaxies. A physicist may be concerned with the infinitesimal flow of electricity in integrated circuits or the massive conversion of matter into energy during a nuclear explosion.

Some physicists seek to understand the fundamental laws of nature. Their work is known as *pure* or *theoretical research* because the laws they uncover may have no immediate practical application. Government agencies, universities and some private institutions fund theoretical research. Other physicists may address practical problems such as ways to improve transportation or extract energy from fuel. Their work is known as ***applied research*** because the answers physicists find can be put into immediate use. The military, oil companies, electric generating utilities and private companies fund applied research.

Acoustics, the study of sound, is a major area of research in physics. Large stadiums, movie theaters and concert halls attract large audiences that demand high quality sound. Because of the relatively slow speed of sound, large concerts

VOCABULARY

Applied research: research that attempts to solve a known problem by applying the principles of science
Nondestructive testing: does not harm the object being examined
Magnetic resonance imaging: medical technique that produces images of the human body by use of intense magnetic fields and radio waves

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

require that speakers be placed in the back of the audience to delay sound produced to avoid an echo or reverberation for the listeners far from the stage. People install home entertainment centers and expect quality sound. Companies that manufacture sound equipment and speakers employ acoustical engineers.

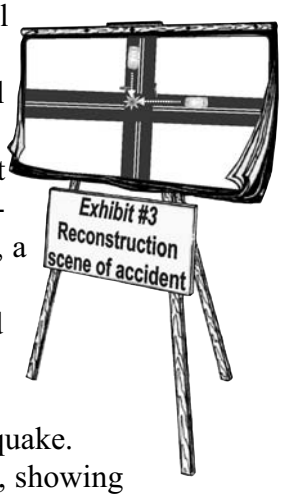
Atomic and nuclear physics continue to be major areas of activity. During the Cold War (1950s-1980s), the United States and Soviet Union built thousands of nuclear weapons. With the signing of treaties and easing of tension between the United States of America and the former Soviet Union, many destructive atomic weapons needed to be disposed of safely. Some of the remaining nuclear weapons are fifty years old. Nuclear physicists attempt to ensure that nuclear material is stored safely or recycled for peacetime purposes. Military leaders now are reluctant to perform below ground testing of the ancient weapons. Instead, nuclear physicists are hired to write computer programs to make simulated tests. The data is then used to determine the best and safest ways to dispose of atomic warheads.

One of the great unfilled challenges of nuclear energy is *cold fusion*. Nuclear theory predicts that fusion of hydrogen atoms can occur at ordinary temperatures. Physicists believe the breakthrough will occur early in the 21st century. The military, government agencies, universities and nuclear power companies employ atomic and nuclear physicists to research and establish ways to use nuclear energy safely.

Cryogenic (low temperature) *research* also holds promise of establishing safe use of nuclear energy. Several substances become extremely good conductors of electricity when their temperatures are lowered to near absolute zero. Superconductors may make possible the development of commuter trains that float on magnetic fields and cross-country communication lines with zero resistance to electric flow. Cryogenic temperatures are also used in medical studies for preserving organ donations and prolonging the useful life of blood. Communication companies and research hospitals employ physicists who conduct cryogenic investigation.

Optics, one of the oldest of the disciplines of physics, continues to advance. Lasers and circuits that use light rather than electricity may replace regular computer circuits. The central processing unit (CPU) of most computers generates so much heat that it must be cooled with radiating vanes and cooling fans. The speed and size of the CPU is limited by the build-up of heat. Light does not generate as much heat as electricity. Replacing the circuits with light guides would enable design and operation of faster and larger computers.

Physics also plays a role in other professions such as the legal field and sports medicine. One of the areas in the legal profession is accident reconstruction. The accident may be a multi-vehicle pile-up on an interstate highway, a disastrous railway accident, an airplane flight that ended in tragedy, or a building or other structure that failed following a fire or an earthquake. Reconstructing the accident, showing what velocities and forces were involved is important during court proceedings and in preventing the loss of life in the future. Accident scene reconstruction, an exciting but exacting field, requires the ability to apply the Laws of Physics to real events and to arrive at conclusions that will stand hard questioning by trial lawyers.

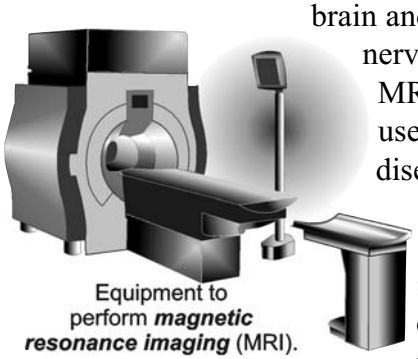


©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.

Another area in which physicists are making differences is in ***nondestructive testing***. In the past, one way to learn information about an object was to destroy it, then analyze the results. People learned the age of a tree by cutting it down and counting the rings. This is an example of destructive testing. Bristlecone pines are believed to be the oldest living trees and possibly the oldest living things on Earth. An ancient bristlecone pine tree was cut down to determine its age. The tree was determined to be 6,000 years old and quite possibly the oldest living thing on Earth. Cutting it down killed the tree, of course. Today, modern tools such as electron microscopes make possible the counting of tree rings from a small core that does not damage the tree.



Physicists invented nondestructive testing tools such as X–rays, ultrasound and ***Magnetic Resonance Imaging*** (MRI). Hospitals employ magnetic resonance imaging for detailed images of the human brain and central nervous system. MRI can also be used to diagnose diseases in other organs. The patient is placed in the center of a coil that creates a magnetic field tens of thousands of times stronger than Earth's magnetic field. The steady magnetic field produces a change in the hydrogen atoms in the patient's body. The hydrogen protons respond to the magnetic field. Next, radio signals are sent into the body to upset the protons. Then, the radio signals are turned off. As the hydrogen atoms in the body return to their original state, they generate radio waves. Receivers of the radio waves give detailed images of the brain that distinguish between healthy and diseased cells.


Equipment to perform ***magnetic resonance imaging*** (MRI).

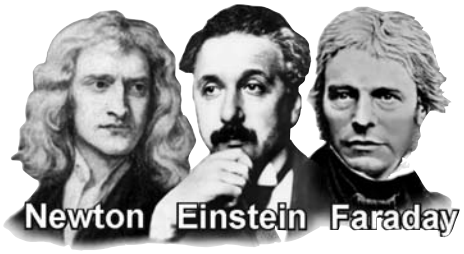
Before the use of MRI, doctors had no choice but to schedule exploratory surgery. In 1975, a girl fell and struck her head on a curb. She appeared unharmed, but a few days later she blacked out. Her doctor was concerned that a blood vessel in the brain may have ruptured. To determine the extent of her injuries, the doctor recommended exploratory surgery. Surgeons drilled a hole in her skull to check for bleeding. Today, such surgery is seldom necessary because tools such as MRI can check for brain injury.

Nondestructive testing reveals weakened support structures in buildings and large stadiums. Many of the bridges and elevated highways in the nation have been in place for 50 years or more. Some show signs of damage and may need to be repaired or torn down and replaced. Nondestructive testing helps determine whether the bridges must be replaced or repaired.

Another career field for people with college degrees in physics is in teaching of or writing books about physics. High school physics teachers are in great demand. Some school districts cooperate to hire a physics teacher whose lessons are broadcasted by satellite to students in high schools that have no qualified physics teacher. Publishing companies for books and periodicals hire persons to write or edit literary pieces about physics.

Students who want to pursue a career in physics should have a strong interest in solving puzzles. Most physicists agree that being comfortable with mathematics is helpful. However, the view that a person

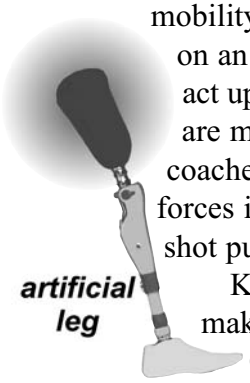
©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.



must have exceptional mathematical ability to be a physicist is not correct. Three of the greatest physicists of all time were Albert Einstein, Michael Faraday and Isaac Newton. Both Newton and Einstein were exceptionally gifted as mathematicians. Michael Faraday, on the other hand, had received only a few months of training in arithmetic. He made his many important discoveries in physics without the benefit of strong mathematical skills. More important than mathematical ability or computer skills is a never-ending curiosity and motivation to discover the wonderful, hidden secrets of life.

Although most physicists specialize in areas of interest, physicists are usually knowledgeable about other branches of physics and other sciences as well. Effective physicists are able to get along with other people, to work well as team members and to speak effectively. Being able to write about technical subjects is beneficial, too.

Even those individuals who seek a career in other fields will find knowledge of physics to be helpful. In medical science, physics enables doctors to build artificial limbs and aid people who have lost physical mobility. Sports medicine depends on an understanding of how forces act upon the human body. Athletes are much more capable when coaches understand how certain forces improve the javelin throw, shot put, pole vault and high jump.



Knowledge of physics can make a person a better citizen. Ordinary citizens can make wise choices to improve fuel efficiency of automobiles. Knowledgeable people can construct homes that are easier to heat and cool. Citizens can be more knowledgeable when they vote on environment laws or bond issues for new power plants. Some politicians appeal to voters' ignorance or groundless fears while other elected officials base their campaigns on solid scientific data. The voter who investigates and knows the difference will be able to make wise choices among issues or candidates who campaign for public office.

Life Principle



"It is not good to have zeal without knowledge, not to be hasty and miss the way."

–King Solomon

©Copyright 2005, Paradigm Accelerated Curriculum DUPLICATION BY WRITTEN PERMISSION ONLY.