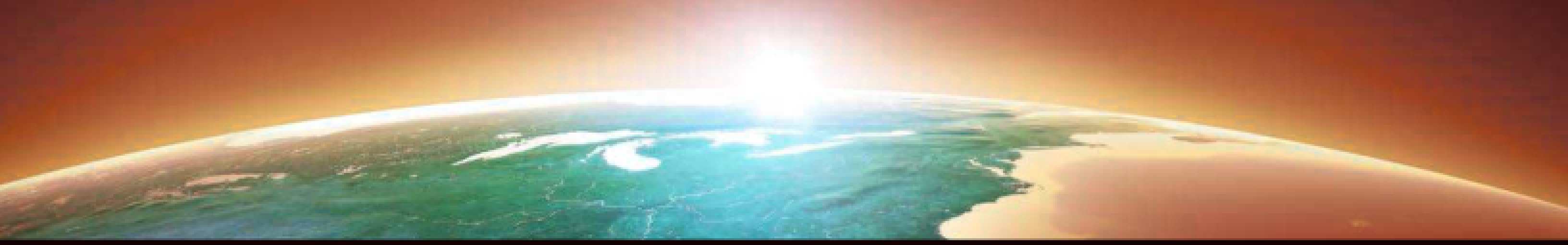
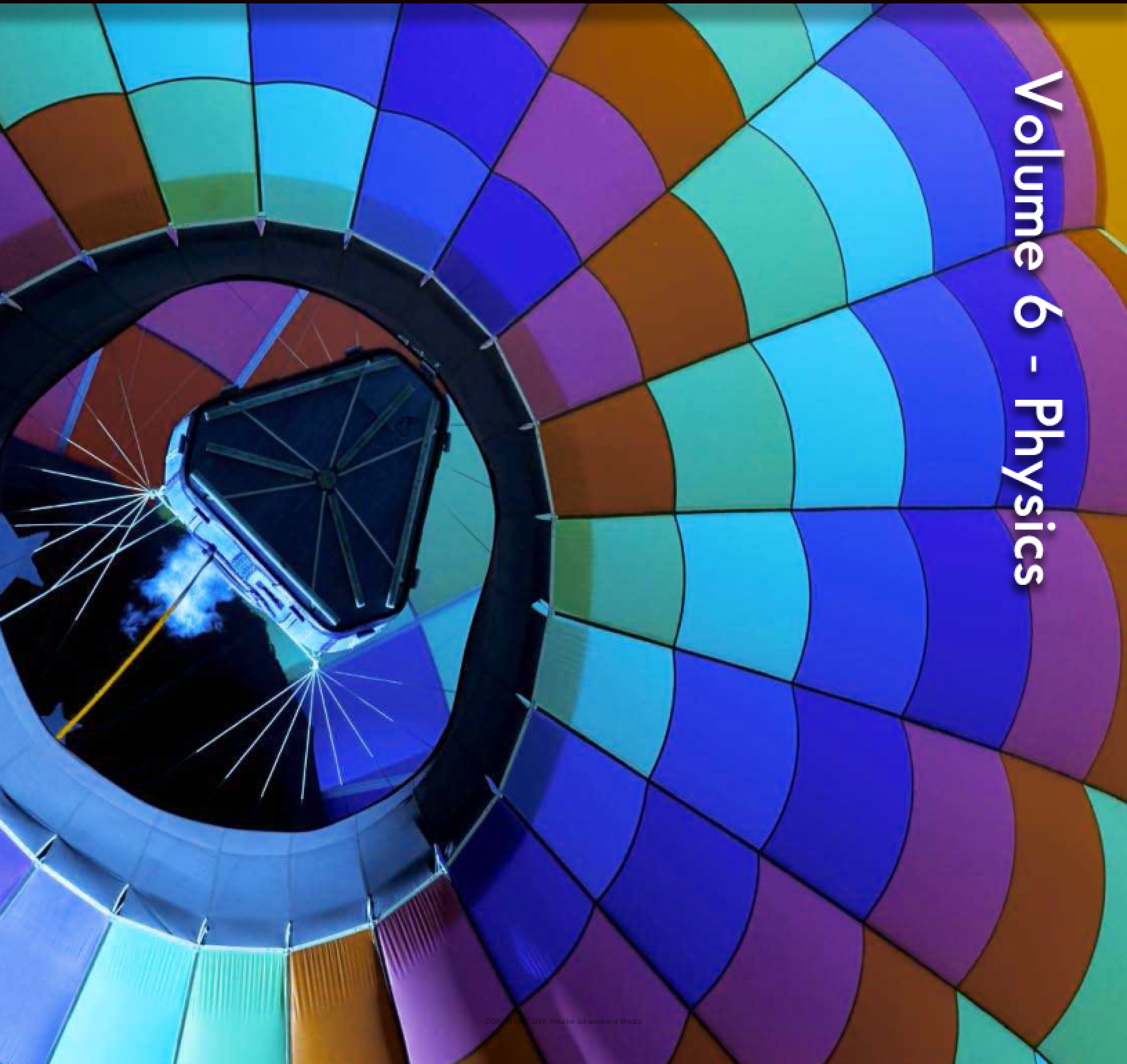
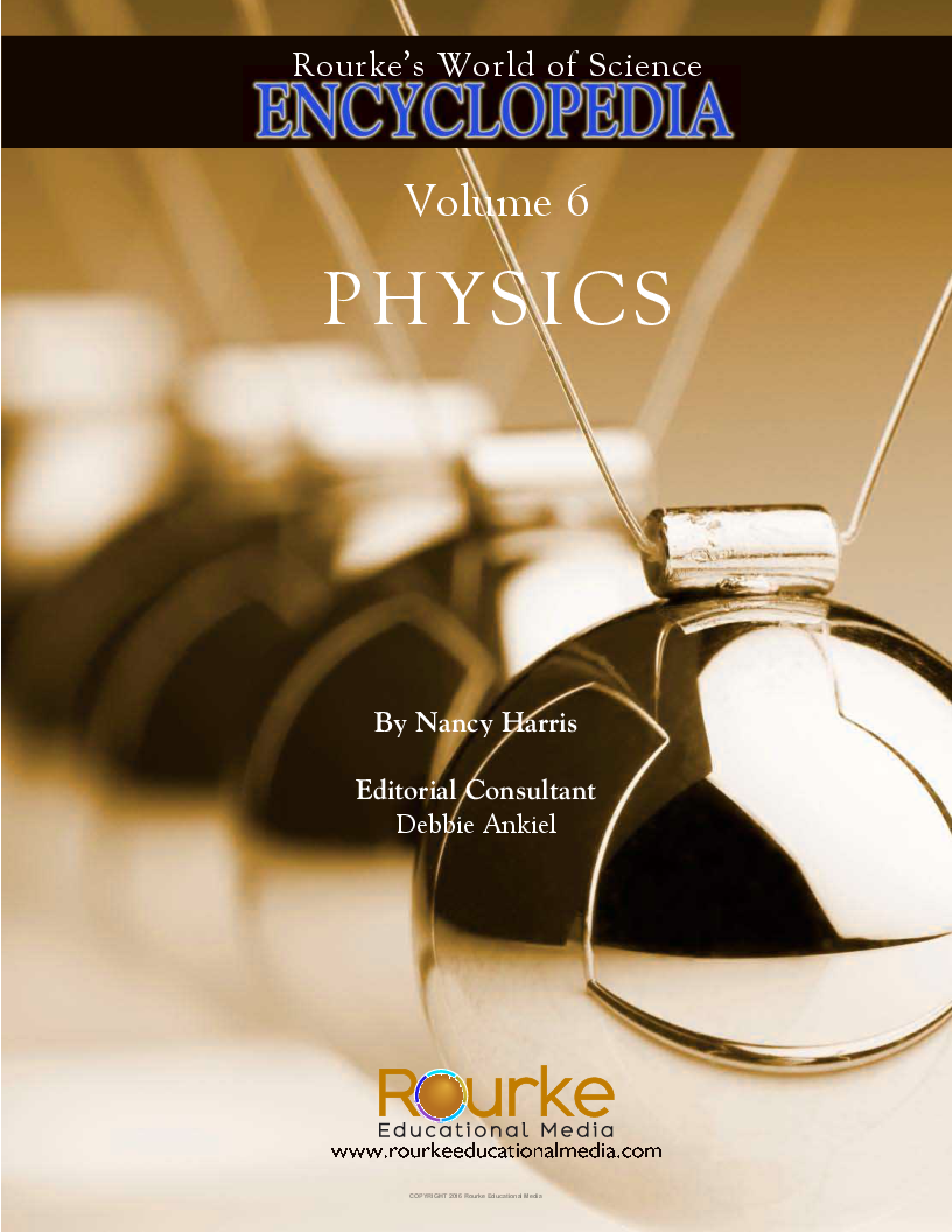


Rourke's World of Science

ENCYCLOPEDIA



Volume 6 - Physics



Rourke's World of Science

ENCYCLOPEDIA

Volume 6

PHYSICS

By Nancy Harris

Editorial Consultant
Debbie Ankiel

Rourke
Educational Media
www.rourkeeducationalmedia.com

www.rourkeeducationalmedia.com

Photo credits: Page 4 © Sourav and Joyeeta Chowdhury; Page 4b © Michael Onisiforou; Page 4c © Sebastian Kaulitzki; Page 5 © Linda Bucklin; Page 6 © Sourav and Joyeeta Chowdhury; Page 7 © wikipedia; Page 7b © Andre Nantel; Page 8 © Michael Chamberlin; Page 9 © Alan Freed; Page 9b © wikipedia; Page 10 © Orla; Page 10b © Sergey I; Page 11 © Julie Hagan; Page 12 © Iuri; Page 12b © courtesy of NASA; Page 13 © CHEN WEI SENG; Page 14 © courtesy of NASA; Page 14b © wikipedia; Page 15 © Amos Struck; Page 15b © Jenny Horne; Page 16 © courtesy of NASA; Page 16b © Peter Kovacs; Page 17 © Shmeliova Natalia; Page 17b © Stephanie Frey; Page 18 © Glenda M. Powers; Page 18b © Denise Kappa; Page 18c © Denise Kappa; Page 19 © wikipedia; Page 19b © wikipedia; Page 19c © wikipedia; Page 19d © Orrza; Page 19e © wikipedia; Page 20 © dlsphotos; Page 20b © courtesy of NASA; Page 21 © Edyta Pawlowska; Page 21b © Charlotte Erpenbeck; Page 21c © Stephen Aaron Rees; Page 21d © Adam Borkowski; Page 21e © No Credit; Page 23 © Nir Levy; Page 24 © demarcomedia; Page 25 © No Credit; Page 25b © Ovidiu Iordachi; Page 26 © Thomas Mounsey; Page 26b © Colin & Linda McKie; Page 27 © wikipedia; Page 28 © wikipedia; Page 28b © Foto Factory; Page 28c © courtesy of NASA; Page 29 © Alex Staroseltsev; Page 30 © Sebastian Duda; Page 30b © Mushakesa; Page 31 © CAN BALCIOGLU; Page 32 © Bob Fehringer; Page 32b © Bernhard Lelle; Page 33 © Michael C. Gray; Page 34 © Armentrout; Page 34b © Armentrout; Page 35 © Fir0002; Page 35b © Nicholas Picillo; Page 36 © Margot Petrowski; Page 36b © Armentrout; Page 36c © Brett Mulcahy; Page 37 © Roger McLassus; Page 38 © Jean Schweitzer; Page 38b © doctor_bass; Page 39 © Roni Lias; Page 39b © Terry Underwood Evans; Page 40 © Joy Brown; Page 40b © Yakobchuk Vasyl; Page 41 © Marek Slusarczyk; Page 41b © iconex; pg 58a © esemelwe; pg 58b © Anatoly Vartanov; pg 58c © esemelwe; pg 58c © Royce DeGrie; pg59 © Brad Wieland; pg62a © Alex Slobodiein; pg 62b © Stephen Morris; pg 62c © Andres Balcazar; pg 62d © Anna Sirotina; pg 62e © Tor Linelqvist; pg 62e © Matjaz Boncina; pg 62f © Niels Laan; pg 62g Miodrag Gajic.

Editor: Debbie Ankiel

Cover design by Rhea Magaro

Library of Congress Cataloging-in-Publication Data

Rourke's world of science encyclopedia / Nancy Harris ... [et al.].
v. cm.
Includes bibliographical references and index.
Contents: [6] Physics --
ISBN 978-1-60044-646-7
1. Science--Encyclopedias, Juvenile. 2. Technology--Encyclopedias, Juvenile. I. Harris, Nancy
Q121.R78 2008
503--dc22
2007042493

Volume 6 of 10
ISBN 978-1-60044-652-8

Rourke Educational Media

rourkeeducationalmedia.com

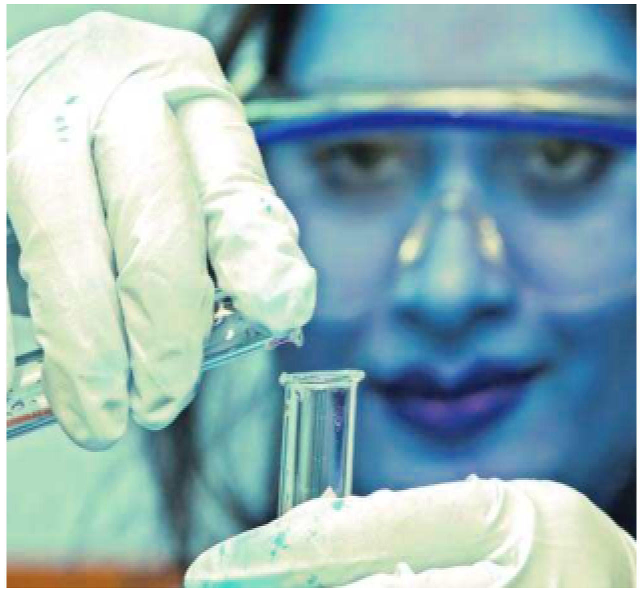
customerservice@rourkeeducationalmedia.com • PO Box 643328 Vero Beach, Florida 32964

TABLE OF CONTENTS

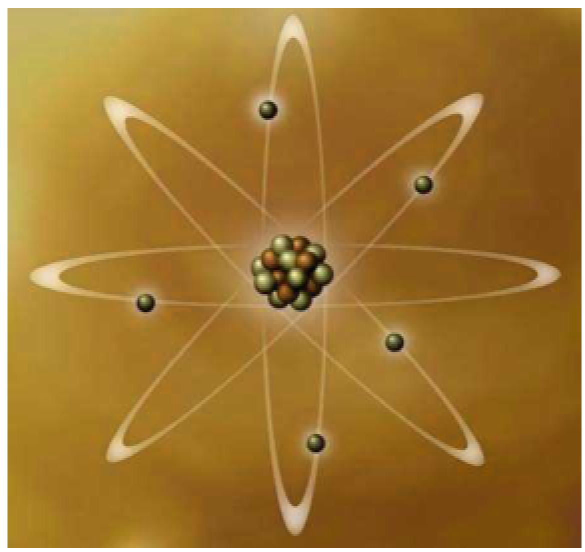
What Is Physics?

Physics is the science of how the universe works. It is a science based on experiments, observation, and measurement. Experiments involve making things change. Observation is when scientists watch what they are studying very carefully. Measurement is describing things by their weight, size, or temperature.

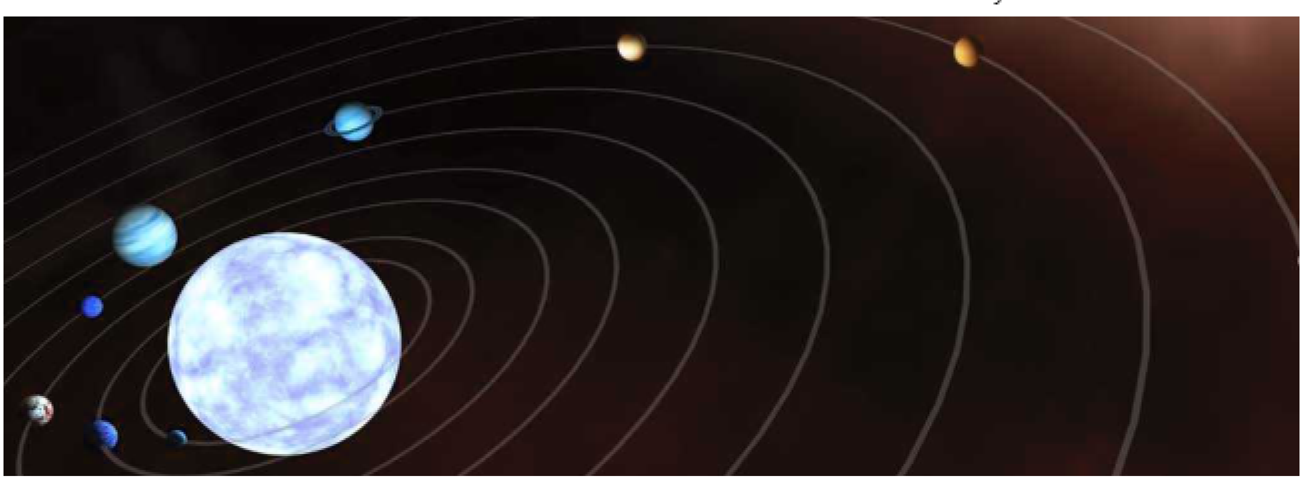
Physics looks at how tiny atoms are put together. Atoms are tiny particles that make up everything in the universe. Physics looks at how huge planets and stars move. It helps scientists understand the way matter acts. Matter includes the solids, liquids, and gases in the universe. Physics also helps scientists understand how energy acts.



A physicist uses precise measurements.



The protons and neutrons in the nucleus of an atom are surrounded by a cloud of electrons.



Astrophysicists are physicists who study the stars and planets.

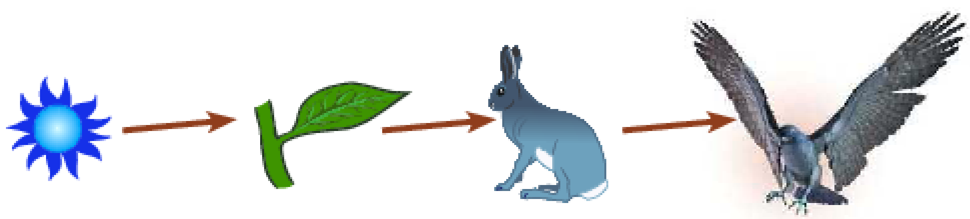
Energy

Energy is everywhere. Energy is the ability to do work. It takes on many different forms. Energy is stored inside atoms. Light and sound are forms of energy. People who study physics study how energy is used. They study how energy changes.

Scientists are constantly improving the understanding of the basic, or fundamental, laws of nature. New discoveries are being made every day. These discoveries have a big effect on how people live and what they do.

Mass, Length, and Time	
Mass	measures the amount of material in an object
Length	measures how long something is
Time	measures how long changes take

Plants get their energy from the sun. Animals get their energy from plants or from eating other animals.



Mass, Length, and Time

The laws of physics can be described in simple terms. These terms explain the way the universe works. Scientists use units of measurement to describe what they do. This is done so that all scientists can understand each other's results. The three fundamental units of measurement they use are mass, length, and time.

Words to know

atom (AT-uhm): very small part of an element

energy (EN-ur-jee): the ability to do work

experiment (ek-SPER-uh-ment): trying to make substances change and recording what happens

matter (MAT-ur): anything that takes up space and has mass (size)

measurement (MEZH-ur-ment): saying how big something is, how much it weighs, or how hot it is

observation (ob-zur-VAY-shuhn): when scientists watch what they are studying very carefully and write down what they see

physics (FIZ-iks): the study of matter and energy

In physics, the International System of Units is used to measure things. This system is based on the metric system. The metric system uses specific units of measurement. The International System Unit of mass is the kilogram. The basic unit of length is the meter. The basic unit of time is the second. Scientists can describe almost everything by using these units in different combinations.

International System of Units	
Kilogram (kg)	used to measure mass
Meter (m)	used to measure length
Second (s)	used to measure time

Words to know

International System of Units (in-tur-NASH-uh-nuhl SISS-tuhm uhv YOO-nitz): a standard way of measuring something

force (forss): what causes something to change its speed or it's direction of movement

mass (mass): the amount of material in an object

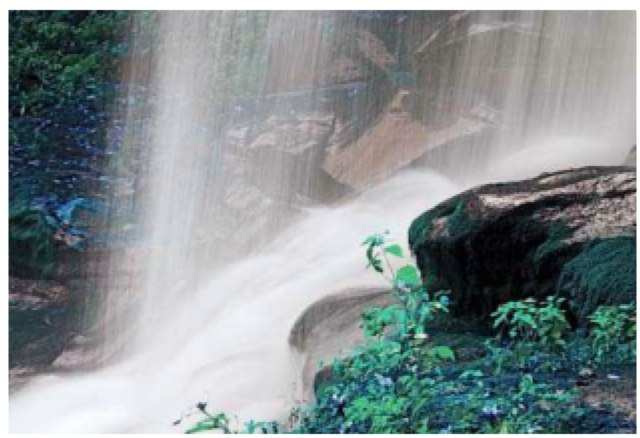
metric system (MET-rik SISS-tuhm): a system of measurement based on tens that uses basic units such as the meter, liter, and gram

motion: (MOH-shuhn): when something is moving

Motion and Force

Motion

Everything is in motion. Both small things and big things move. People and animals move about on the surface of the Earth. The Earth itself rotates (turns) and moves in an orbit (circles) around the sun. The largest view that we can have is to look at the entire universe. Scientists often choose a certain point of view, or frame of reference, when studying physics. This allows them to study specific actions in the universe.



The water in a river is in constant motion.

Force

Forces are at work everywhere. A force is anything that affects the movement or shape of an object. Objects can be so small that you cannot see them with the naked eye. They can be bigger than planets

In physics, the International System of Units is used to measure things. This system is based on the metric system. The metric system uses specific units of measurement. The International System Unit of mass is the kilogram. The basic unit of length is the meter. The basic unit of time is the second. Scientists can describe almost everything by using these units in different combinations.

International System of Units	
Kilogram (kg)	used to measure mass
Meter (m)	used to measure length
Second (s)	used to measure time

Words to know

International System of Units (in-tur-NASH-uh-nuhl SISS-tuhm uhv YOO-nitz): a standard way of measuring something

force (forss): what causes something to change its speed or it's direction of movement

mass (mass): the amount of material in an object

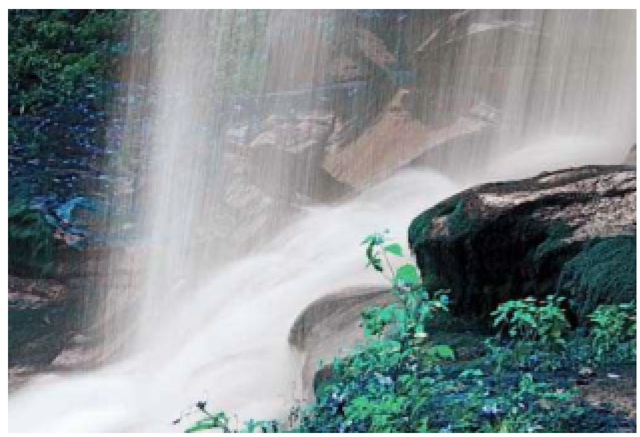
metric system (MET-rik SISS-tuhm): a system of measurement based on tens that uses basic units such as the meter, liter, and gram

motion: (MOH-shuhn): when something is moving

Motion and Force

Motion

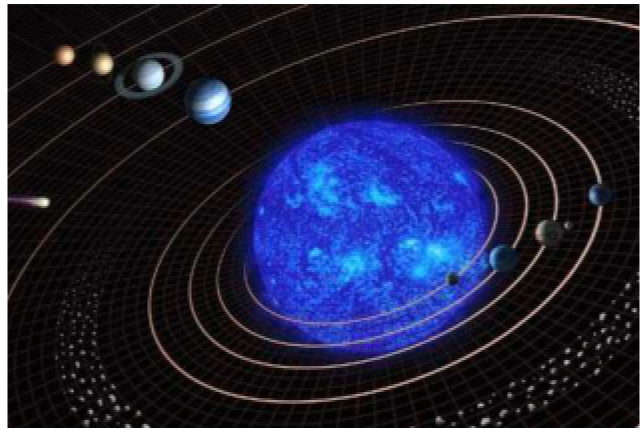
Everything is in motion. Both small things and big things move. People and animals move about on the surface of the Earth. The Earth itself rotates (turns) and moves in an orbit (circles) around the sun. The largest view that we can have is to look at the entire universe. Scientists often choose a certain point of view, or frame of reference, when studying physics. This allows them to study specific actions in the universe.



The water in a river is in constant motion.

Force

Forces are at work everywhere. A force is anything that affects the movement or shape of an object. Objects can be so small that you cannot see them with the naked eye. They can be bigger than planets and stars. Some forces pull objects together. Other forces push objects apart. Forces also affect people.



Gravitational force keeps the planets in orbit around the sun.

The Four Fundamental Forces

There are four basic, or fundamental, forces in nature. They are the gravitational force, the electromagnetic force, the strong nuclear force, and the weak nuclear force. These forces pass through us and exist within us. They hold everything together. All forces in nature are related to one of the four fundamental forces. Each of these forces serves a different purpose.

Gravitational Force

The gravitational force is the force of attraction, or pulling together. It is powerful enough to hold the Earth in its orbit around the sun. Still, it is the weakest of the four fundamental forces. The gravitational force of the Earth is often called gravity. Gravity keeps things on the surface of the Earth from flying off into space. It keeps the ground on the Earth and your feet on the ground. Everything that has mass has gravity. In deep space, the force of gravity is very weak. This is because objects with mass are so far apart.

Gravity pulls this diver into the water.

Electromagnetic Force

The electromagnetic force is either an attraction, pulling toward, or a repulsion, pushing away. The electromagnetic force occurs in many forms. Except for gravity, most of the forces in nature are caused by electromagnetic forces.

Small pieces of iron are attracted to the magnet.

Words to know

electromagnetic force (i-lek-tro-mag-NET-ik forss): a combination of electrical and magnetic forces that attract (push towards) or repel (push away)

escape velocity (ess-KAPE vuh-LOSS-uh-tee): how fast something needs to travel to leave the Earth's gravity

gravity (GRAV-uh-tee): a force that pulls things toward Earth

nucleus (NOO-klee-uhss): center section of an atom made of protons and neutrons

radioactive decay (ray-dee-oh-AK-tiv di-KAY): when the center of an atom breaks apart

subatomic particles (suhb-a-TOM-ik PART-tuh-kuhls): the smaller parts of an atom including the protons, neutrons, and electrons

Strong Nuclear Force

The strong nuclear force is the strongest of the fundamental forces. It only works within atoms. The strong nuclear force keeps the nucleus (center) of an atom from coming apart. It is like a glue holding the subatomic particles (or smaller parts of the atom) together. The strong nuclear force gets weaker the further the particles are from the center of the atom.

Weak Nuclear Force

The weak nuclear force causes the nuclei (centers) of some atoms to break apart. These atoms are radioactive, or unstable. They give off tiny particles over time. These are called beta particles. The weak nuclear force causes the subatomic structure, or smaller parts of some atoms, to change. This process is called radioactive decay. The weak nuclear force does not happen in all nuclei.

Velocity and Acceleration

The speed of an object is called velocity. The velocity of an object is how fast it is moving at a point in time. Velocity is measured in distance traveled per unit of time. For example, cars may drive 62 miles per hour (100 kilometers per hour). Most people can walk at a speed of 2 miles per hour (3 kilometers per hour) and run at a speed of 17 miles per hour (27 kilometers per hour). They can only run this fast for a short time. Scientists often measure velocity in kilometers per second (km/s).

Escape Velocity

In outer space, velocity is measured in a specific way. It is measured by how fast something is moving away from or toward the Earth. An object must travel a certain speed to escape the gravitational force (pull) of a planet or a moon. This is called the escape velocity. This speed depends on the mass of the planet or moon. It also

The Space Shuttle launches into the night sky.

depends on the distance of the object from the center of the planet or moon. The escape velocity from the surface of the Earth is about 6.6 miles (11 kilometers) per second. This is almost 25,000 miles per hour (about 40,000 kilometers per hour).

Acceleration

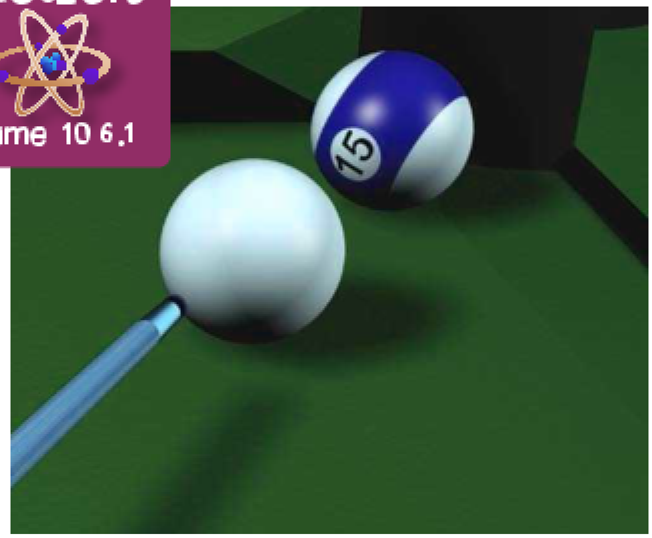
Acceleration is a change in velocity over a certain time. In physics, anything that is speeding up is accelerating. The speed of a car changes when it starts to move. The car is accelerating. When it slows down, it is decelerating (also called negative acceleration). A dropped object accelerates as it falls. This acceleration is caused by gravity. Gravity keeps things on the surface of the Earth from flying off into space. The acceleration caused by the gravity of the Earth is sometimes called *g*. At the surface of the Earth, the acceleration caused by gravity is equal to 1*g*.

SheiKra, a roller coaster in Florida, pulls 4g.

PROJECTS
Volume 10 6,1

Newton's Three Laws of Motion

All objects follow certain rules. These rules are called laws because they apply to everything everywhere. Isaac Newton discovered the three laws of motion. These laws help scientists understand how objects move.



Newton's first law states that an object will stay still unless something pushes or pulls it.

First Law of Motion

Newton's first law of motion is sometimes called the Law of Inertia. It says that an object that is not moving will stay still. It will stay still unless something pushes or pulls it. It also says that an object that is in motion will keep moving. The object will travel in a straight line at a constant speed. Its movement will only change if it is affected by a force. On the Earth, gravity is a big force that affects objects. Without gravity, all objects would stay still or keep traveling in a straight line. The moon would fly off its orbit if the Earth's gravity did not pull on it. It is easier to see the law of inertia in outer space. A tool released by an astronaut floats away until it bumps into something.

Second Law of Motion

The second law of motion says that acceleration is caused by a force acting on an object. The acceleration (increased speed) of an object depends on the amount of the force acting on it. It also depends on the mass of the object. Light objects, like pens and pencils, are easy to pick up. They require very little effort, or force, to lift. Heavy objects, like a refrigerator, require a lot of force to move.

The second law of motion says that acceleration is caused by a force acting on an object.

Sir Isaac Newton (1643-1727)

Getting to know...

Isaac Newton was born in England in 1642. At first, he was not a great student and ran the family farm. He began to show genius when he returned to school.

Newton went to Cambridge University. In 1665, Cambridge was closed because of a deadly disease called the plague. Newton went home for a year to think about science. During this time, he discovered the law of gravity and the three laws of motion. He also discovered a type of mathematics called calculus. He invented the reflecting telescope. He learned about optics, the science of light.

Newton was elected to the famous Royal Society of London. He entered politics and was elected to Parliament. Newton was made a knight in 1705.

When a force acts on a mass, acceleration is produced. The greater the mass, the greater the amount of force needed to accelerate the object. One way of writing the second law of motion is to say that force (F) is equal to mass (m) times acceleration (a).

$$F = ma$$

You experience Newton's third law when you play tug of war.

Third Law of Motion

Newton's third law of motion says that every action causes a reaction that is equal and opposite. A cup on a table pushes down on the table with the force of gravity. The table pushes up with an equal force to keep the cup from moving. A person pulling on a rope is using force on the rope. This is called the action force. The rope uses the opposite force on the person. This is called the reaction force.

Words to know

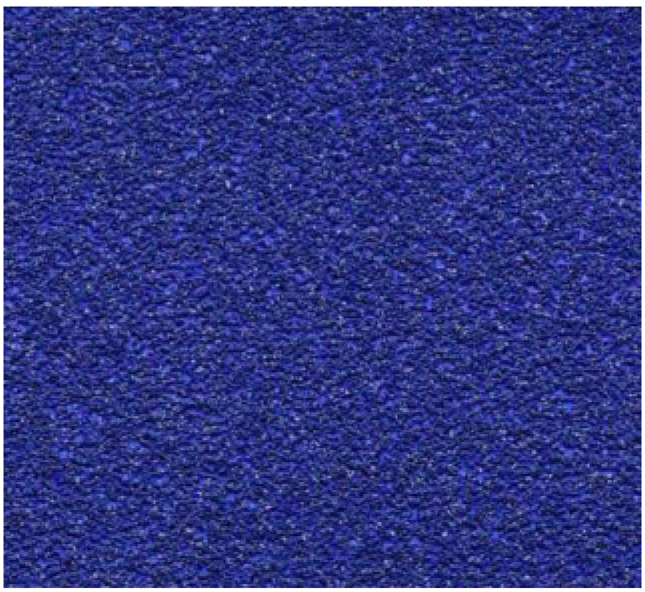
action force (AKT-shuhn forss): the force that is acting on something, for example someone pulling on a rope

inertia (in-UR-shuh): an object at rest will stay at rest and an object in motion will stay in motion, unless acted on by an outside force

reaction force (ree-AK-shuhn forss): a force that reacts against a force being put on it

Friction

Friction is the force that slows objects down when they rub against each other. Friction holds objects in place until the forces acting on them become bigger than the force of friction. Friction depends on the mass and the types of surfaces being rubbed. Different materials cause different amounts of friction. Rubbing sandpaper on wood causes a lot of friction.



Rough surfaces create more friction.

Wind Resistance

Friction keeps people from sliding around when they walk. The gases in air cause friction on moving objects. Air molecules, or the small parts of air, cause wind resistance when they bump against objects. Airplanes and cars have smooth surfaces to decrease (slow down) wind resistance. The brakes on cars and bicycles use friction to slow the cars and bicycles down. Spaceships returning to Earth are slowed down by the friction between the atmosphere and the moving spaceship. This type of friction is called drag. It causes the outside of the spaceship to get very hot.

Heat-resistant tiles protect the space shuttle during re-entry to Earth's atmosphere.

Find out more

Friction Slows Down Spaceships

Spaceships must travel very fast to reach other planets like Mars and Jupiter. They need to slow down when they get there. One way they slow down is by flying through the upper atmosphere of the planet. Using friction to slow down a spaceship is called aerobraking.

Friction often causes heat. It causes your hands to get warm when you rub them together. Friction from air resistance makes meteorites (rock or metal from space) get very hot. They burn up in a bright streak across the sky.

Circular Motion

Anything that spins or goes around in a circle is experiencing circular motion. Wheels and tops spin. Windmills and merry-go-rounds go around in circles. Many forces influence objects in circular motion. Every part of the spinning object experiences inertia and wants to fly off in a straight line. One force pulls the object toward the center of the circle. This is called centripetal force. It causes the object to change direction constantly and travel in a circle. Another force is directed out from the circle. This is called centrifugal force.

Centripetal Force

Satellites in space experience circular motion. Gravity is the centripetal force that keeps the satellite in a circular orbit. Momentum keeps it moving forward in the orbit. The inertia of the satellite as it moves forward keeps it from falling back to Earth.

A ball on a string can be swung around in a circle. The pull of the string on the ball is the centripetal force. The force on the string becomes stronger as the ball moves faster and faster.

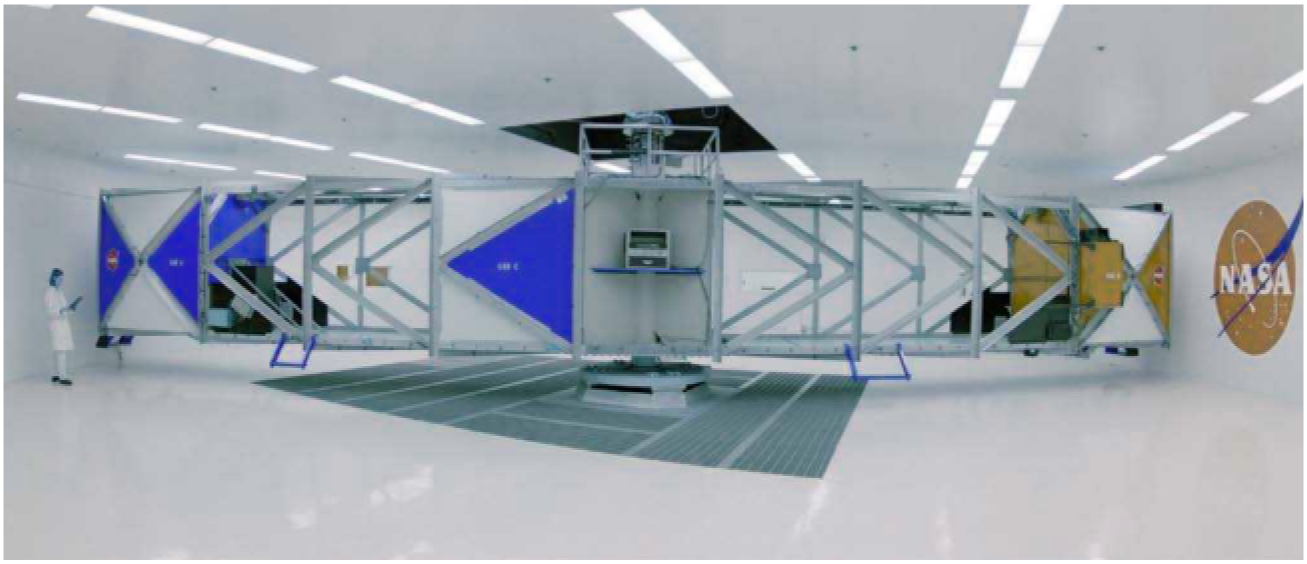
Find out more

Centripetal Acceleration Spins Ice Skaters

Ice skaters experience circular motion when they spin! They can spin very fast by pulling their arms in tight. This increases their centripetal acceleration. They slow down if they stretch their arms out. This causes their centripetal acceleration to decrease.

Centrifugal Force

Centrifugal force is when an object traveling in a circle behaves as if it is experiencing an outward force. The mass of the object, the speed of rotation, and the distance from the center all must occur to have centrifugal force. The more massive the object, the greater the speed of the object, and the greater the distance from the center, the greater the force will be.



NASA uses a 20g centrifuge to test the reactions of pilots and astronauts to acceleration above those experienced in the Earth's gravity.

Words to know

atmosphere (AT-muhss-fihr): the gases around a planet

centrifugal force (sen-TRIF-yuh-guhl forss): a force that pushes you away from the center

centripetal force (sen-TRIP-uh-tuhl forss): a force that pulls you toward the center

drag (drag): slowing something down

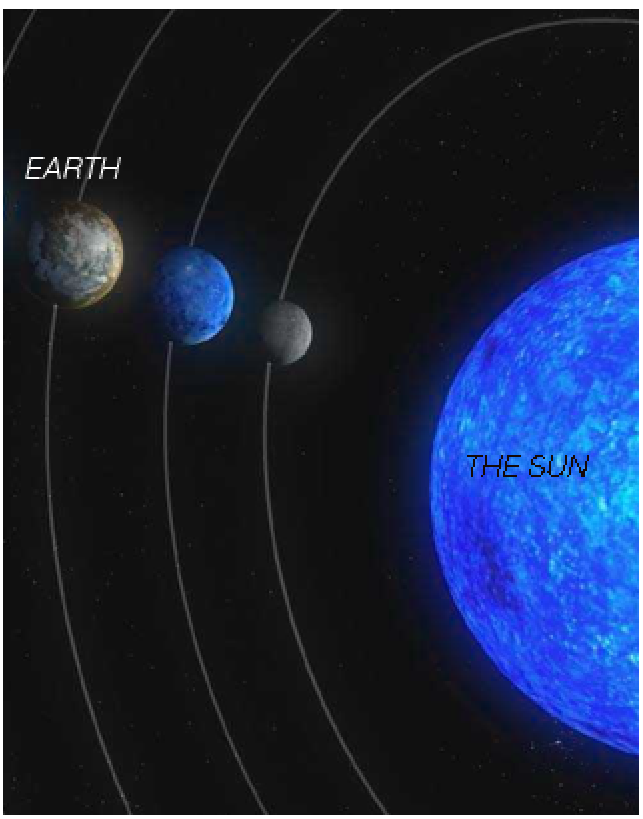
friction (FRIK-shuhn): when things rub against each other, it causes them to slow down

wind resistance (wind ri-ZISS-tuhnss): a force that pushes against another object

Chemists use a centrifuge to separate parts of a liquid.

Gravity

Gravity is a force that pulls objects or masses together. Everything that has mass also has gravity. Gravity keeps the Earth in orbit around the sun. It also holds the moon in orbit around the Earth. The Earth is a strong gravitational source because it has a very high mass. A falling object is pulled toward the ground by the Earth's gravity.



The sun's gravity keeps the planets in their orbits.

Free Fall

An object dropped near the Earth's surface accelerates downward. Its acceleration rate is about 32 feet (9.8 meters) per second for every second that it falls. It is easier to say that the acceleration caused by gravity on Earth is 1g. The mass of the falling object does not matter. All objects fall at the same rate when there is no air resistance to slow them down. This fall is sometimes called free fall. A grape and a watermelon fall at the same rate when they are dropped together from a height. They will smash into the ground at the same time.

Despite their size and weight, a melon and a grape will fall at the same speed.

Weight

Gravity gives a person weight. Mass and weight are different. Mass is the amount of material in an object. Weight is the force of gravity on an object's mass. People weigh a lot less on the moon than they weigh on the Earth.

The gravity on the moon is about one-sixth as strong as the gravity on Earth. The force of gravity is stronger when the mass of the object is greater.

Find out more

Gravity Is Still Felt in Space

A space station orbiting the Earth has some microgravity, or a very tiny amount of gravity. It is traveling fast enough, and is far enough away from the Earth, to orbit (circle) and be in a constant free fall. The Earth's gravity is pulling on the space station, but the space station's forward speed is keeping it from falling back to Earth.

Newton's Universal Law of Gravity

The gravitational attraction between two objects depends on two things. They are the mass of the objects and the distance between them. Isaac Newton suggested that every particle (tiny piece) in the universe attracts every other particle. The force of this attraction decreases as the distance between objects increases.

The moon has a gravitational effect on the Earth even though it is far away. The ocean on the side nearest the moon is pulled toward it. This creates tides. The Earth is also pulled toward the moon. The ocean tides change as the moon orbits (circles) the Earth. The gravitational force of the sun also affects the tides. Twice each month, the sun and moon are in line with each other. The gravitational effects of the sun and moon together cause very high tides.

The moon's gravitational pull causes two high tides and two low tides every day.

Energy

Work

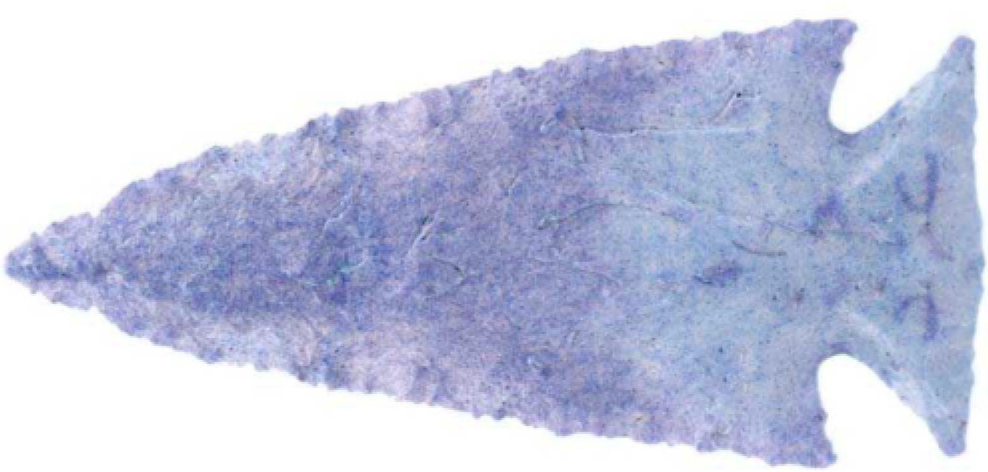
Physics is the study of force and energy. Energy is changed from one form to another when a force acts on an object. This change is sometimes called work. Energy is the ability to do work.

We enjoy many delicious foods with the help of our teeth.

Simple Machines

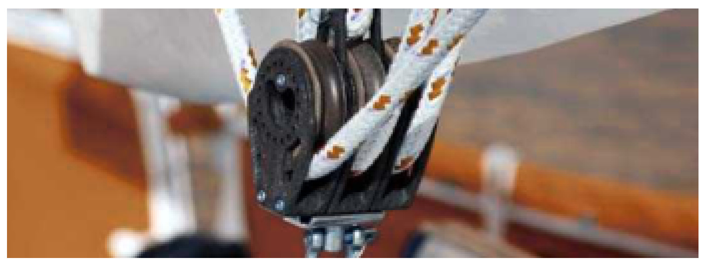
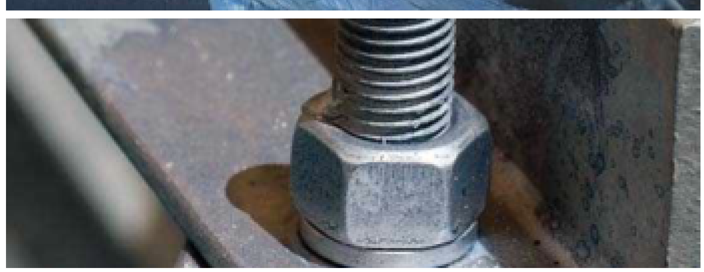
Simple machines are simple tools that make work easier. We have some simple machines built in our bodies. Do you remember when you were missing your two front teeth? Without your built in simple machines (teeth), it's more work to bite and chew. Teeth are simple machines called a wedge. Other simple machines are inclined planes, wheels, pulleys, levers, and screws.

Throughout history people have used different types of simple machines to make their work easier. Think about how early hunters put sharp wedge shapes at the end of a stick to create a weapon.



A stone-tipped spearhead used by early hunters.

Common Simple Machines

Simple Machine	Pictorial Example
inclined plane	
lever	
pulley	
wheel	
wedge	
screw	

A simple machine has very few parts. Some simple machines, such as pulleys, have moving parts. Other simple machines, for example inclined planes, have no moving parts. All compound, or complex, machines are made by putting simple machines together.

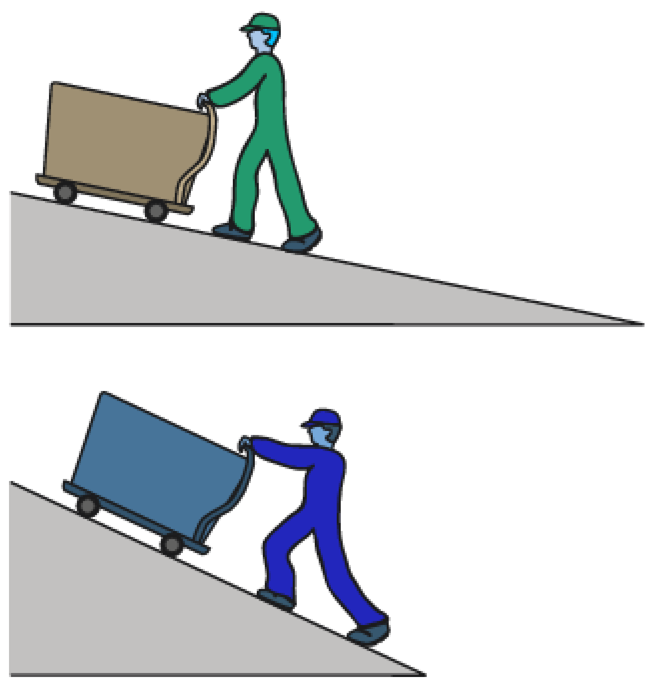
The bicycle is a complex machine that contains many simple machines.

In physics, scientists define work as how a force acts on an object to move it. Another way to write this definition is with a formula.

Work = Force x Distance

The amount of work needed for any job is the same. An example of a delivery driver is an easy way to understand how this formula works. If the driver uses a short ramp, the distance he moves is also short. But a short ramp is steep so the driver would need to use a lot of force to push a big box up a short ramp.

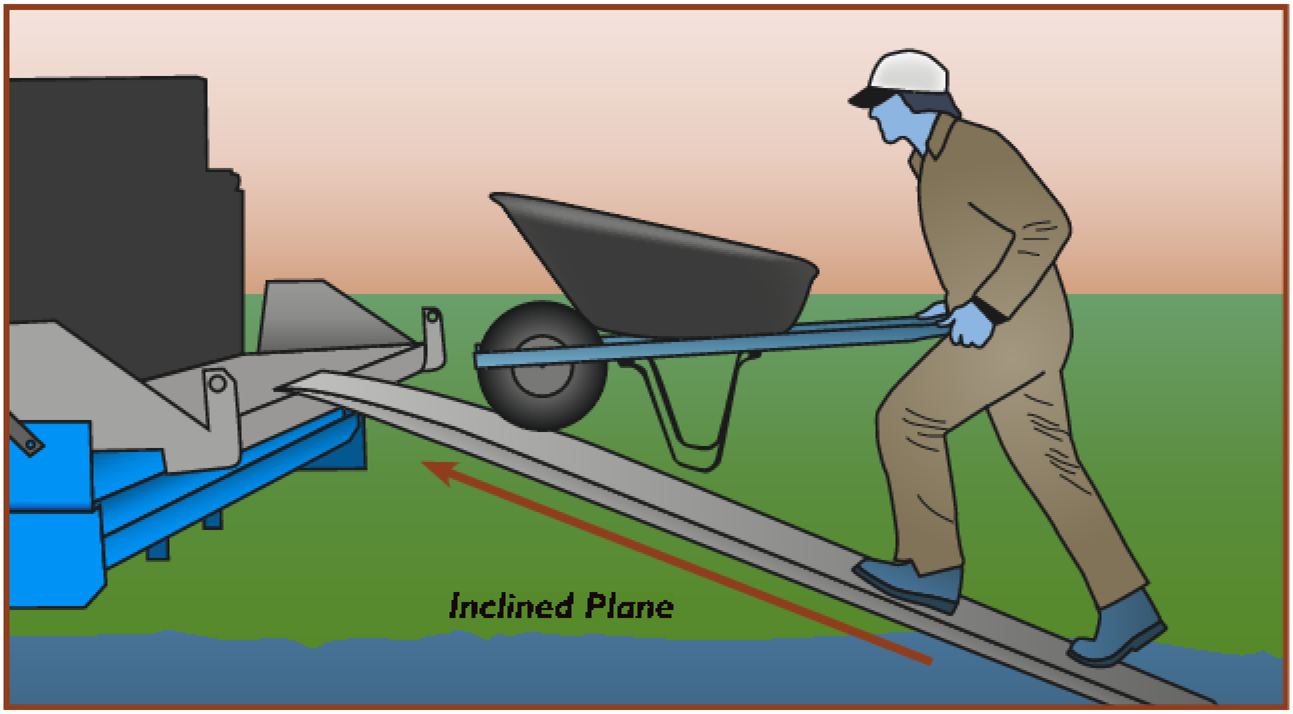
If the driver uses a long ramp, the distance he pushes the big box is farther. But the long ramp is not as steep as the short ramp so the driver would use less force to push the big box up a long ramp.



The first ramp is longer, but its slope is gentler. The second ramp is shorter, but its slope is steep. Both jobs take the same amount of work to complete.

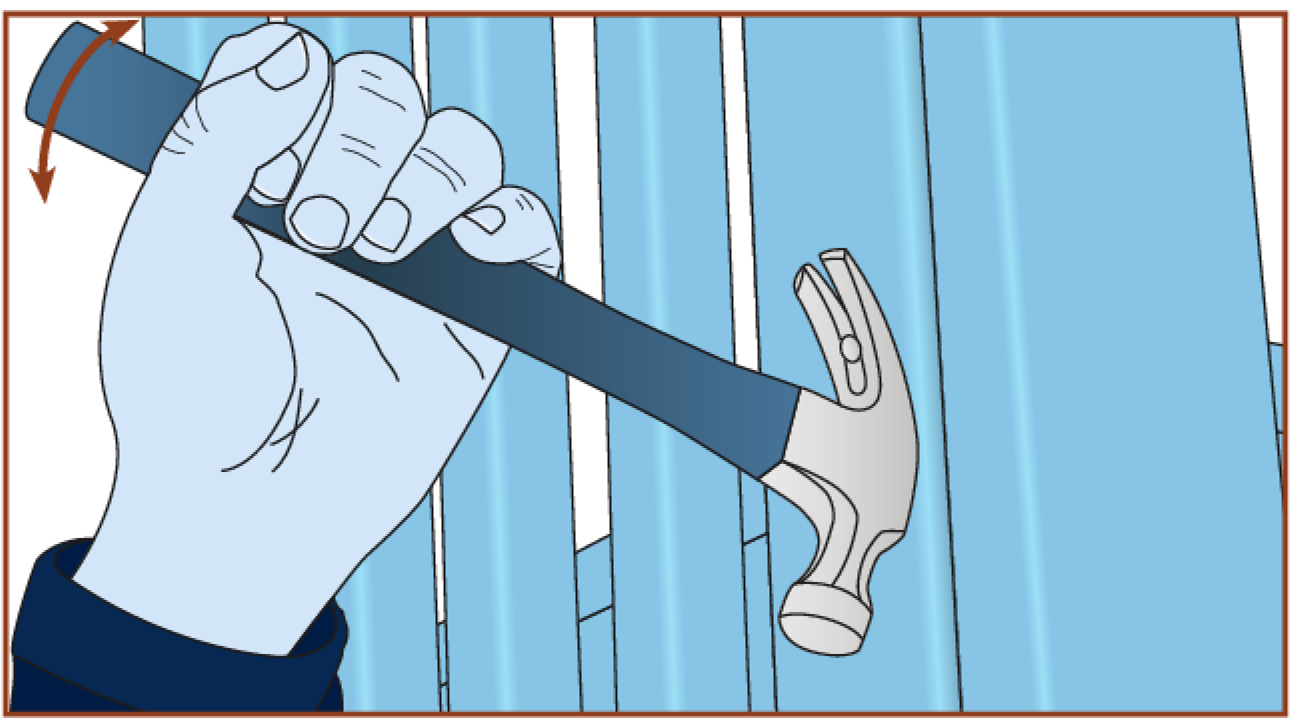
Illustration Example

Inclined Plane



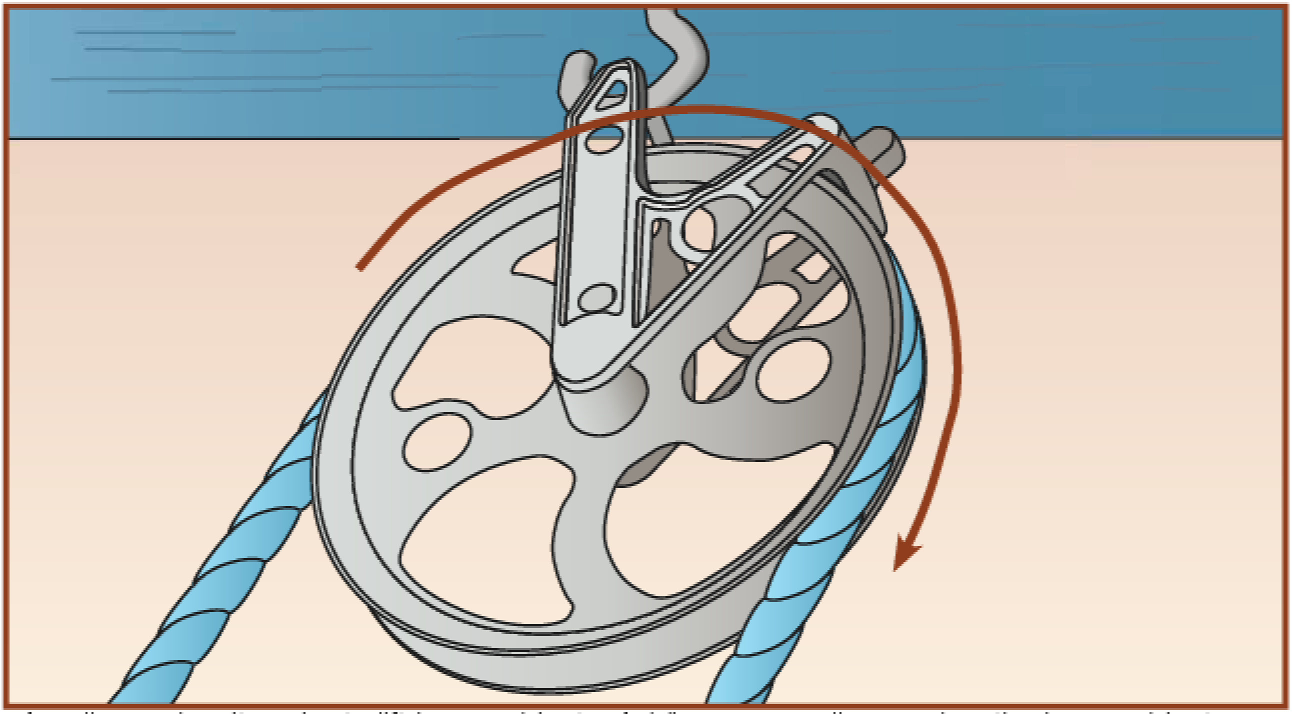
It would be very difficult to lift the wheelbarrow into the truck.

Lever



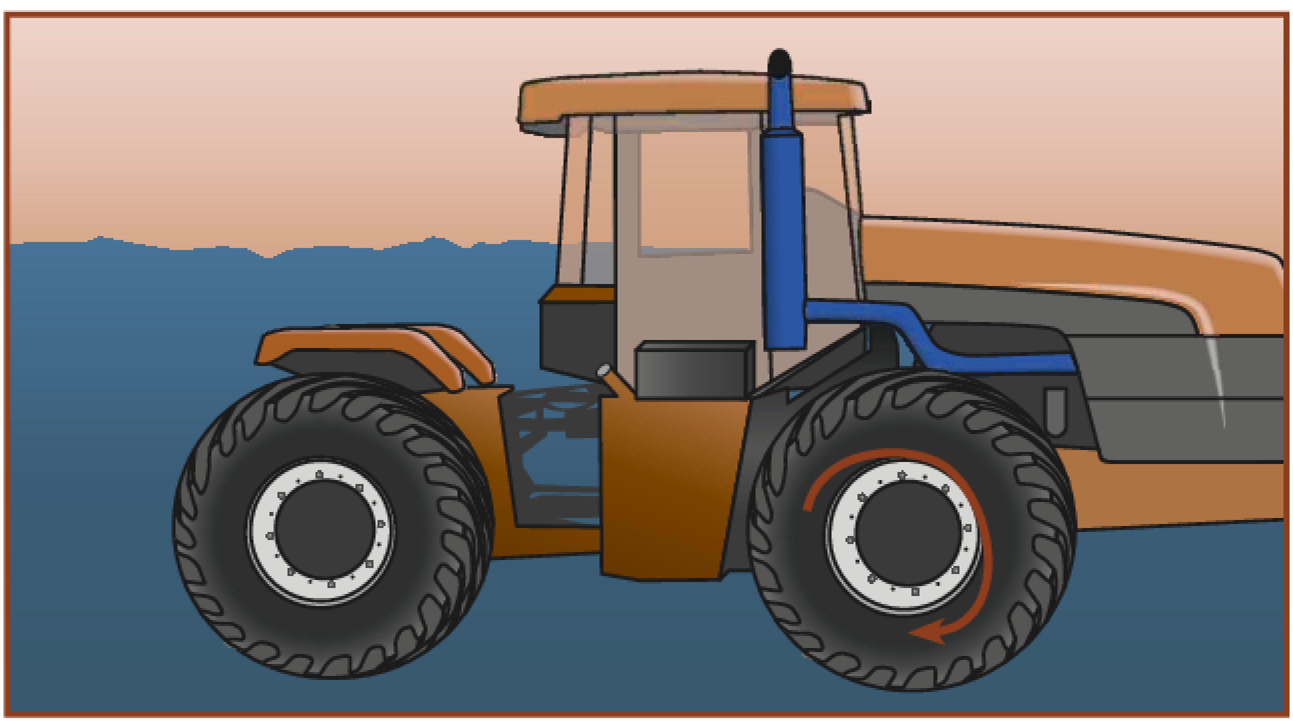
Have you ever used your fingers to pull a nail from a piece of wood? The lever makes the job much easier.

Pulley



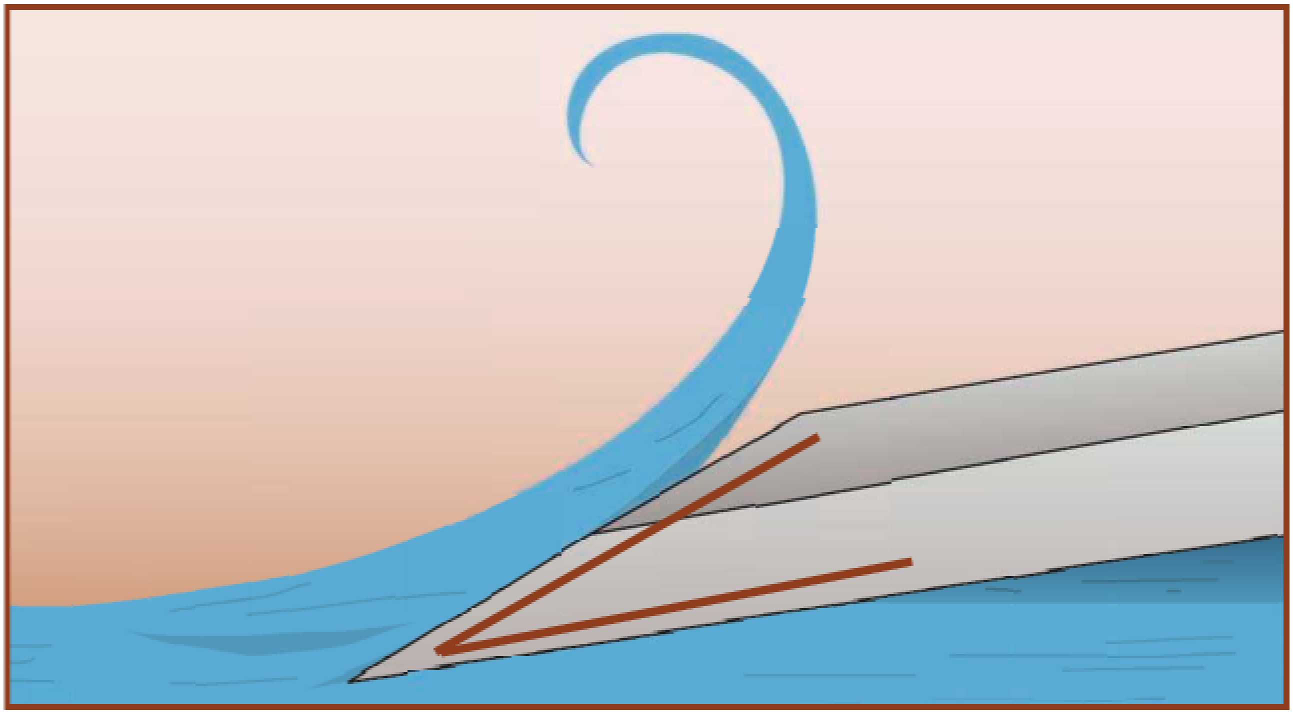
A pulley makes it easier to lift heavy objects. Adding more pulleys makes the heavy object seem even lighter.

Wheel



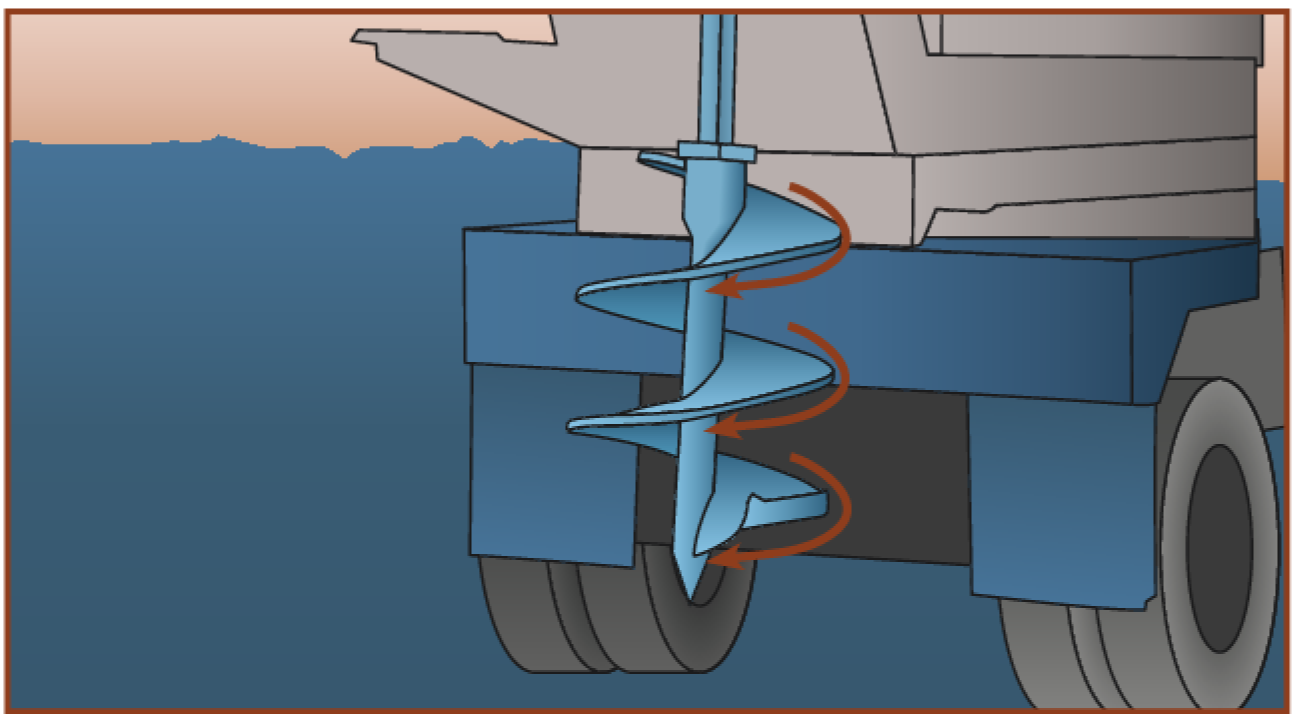
It's hard to imagine life without the wheel.

Wedge



Wedges such as axes, knives, and scissors make it easier to separate or split objects.

Screw



A screw can drill a hole in something, or it can be used to hold two things tightly together.

Forms of Energy

Energy comes in many different forms. You may see and hear energy in the form of light and sound every day.

Every moving object has energy. Even objects that are standing still have energy. Wood put in a fireplace has energy. Some of that energy is released as flames when the wood burns. In fact, everything is a form of energy—even you.

We see light energy in the form of colors.

Every noise is a form of sound energy.

Conservation of Energy

Energy can never be created or destroyed. It can only be converted, or changed, into another form. This principle is known as the conservation of energy. The various forms of energy include mechanical energy, electromagnetic energy, chemical energy, heat energy, and nuclear energy.

Words to know

distance (DISS-tuhnss): the amount of space from one place to another

machine (muh-SHEEN): a device or tool that uses energy to make work easier

work (wurk): a force acting on an object to move it across a distance

All forms of energy are related to one another. Energy can be transformed from one form into another. The total amount of energy stays the same. The electric energy in a battery can be converted into mechanical energy in a motor.

The potential energy in the battery becomes kinetic energy when the toy is turned on.

Potential and Kinetic Energy

Potential Energy

There are many ways to describe energy. Physicists often describe energy in two ways. Energy can be stored up, waiting to be released. This is called potential energy. A ball on the top of a hill has potential energy. A rocket waiting to be launched has potential energy stored up in its fuel.

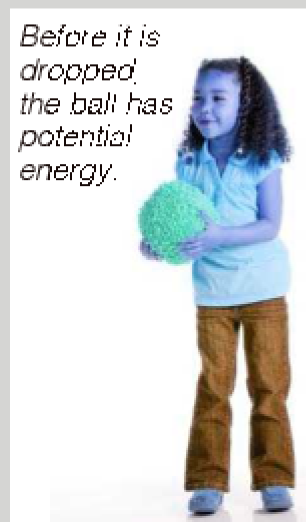
Kinetic Energy

The ball releases energy when it rolls down the hill. This energy in action is called kinetic energy. The rocket has kinetic energy when its engines ignite and lift it into space. An object has more kinetic energy the faster it moves.

Find out more

Example of Kinetic and Potential Energy

A bouncing ball has both kinetic and potential energy. The ball has only potential energy before it is dropped. It has both kinetic and potential energy as it falls. The ball has only kinetic energy when it hits the floor. It gains potential energy again as it bounces back up. Each bounce converts energy to heat, sound, and fast movements called vibrations. Eventually, the ball will lose its energy and stop bouncing.



There Are Many Sources of Energy

Energy comes from many different sources. Solar energy is energy from the sun. The sun provides the Earth with a lot of energy every day. Wind is a form of energy caused by changes in air temperature. Tides in the ocean contain energy as they rise and fall. Water in rivers and lakes also contains energy.

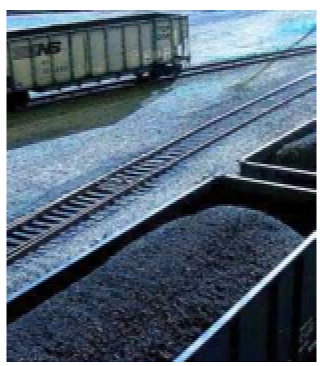
Geothermal Energy

Other forms of energy include geothermal energy from the Earth itself. Heat rises from deep inside the Earth. It escapes through cracks in the crust. Geysers and hot springs are sources of geothermal energy.

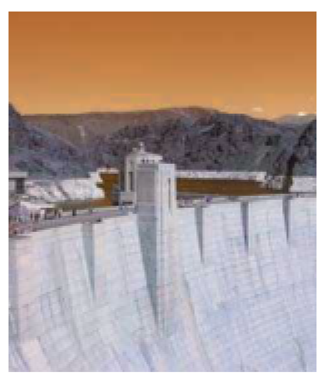
Geothermal energy is now being used in some places to produce electricity.

Renewable and nonrenewable energy sources

Humans use oil and coal from the Earth's crust. Coal and oil supplies will eventually run out. They are nonrenewable energy sources. Other energy sources are renewable. They will never run out. Solar energy is a renewable energy source. Water can be used as a renewable energy source too. Dams are built on rivers to capture hydroelectric power, or power from running water.



Coal and oil are nonrenewable energy sources.



Solar power and water power are renewable energy sources.

Momentum and Collisions

Momentum is another word for inertia. All moving objects have momentum. They keep moving until some force stops them or changes their direction. The momentum of an object depends on its mass (size) and velocity (speed).

Faster speeds produce a greater impact when two cars collide.

Conservation of Momentum

A collision happens when two objects hit each other. A moving object that collides with another object passes on its momentum. The momentum of the two objects stays the same, or constant. When no other forces are affecting the objects, this is called conservation of momentum.

Conservation of momentum is used in the game of pool. The white ball, or cue ball, transfers its momentum when it hits another ball. This ball moves away at a similar speed as the cue ball. Rockets that travel into outer space use conservation of momentum. The rocket gains momentum from the force, or thrust, pushed out of its engine. The thrust goes one way, and the rocket goes the other way.

Words to know

conservation of energy (kon-sur-VAY-shuhn uhv EN-ur-jee): energy can be changed into another form, but cannot be created or destroyed

kinetic energy (ki-NET-ik, EN-ur-jee): energy caused by movement

momentum (moh-MEN-tuhm): the force of something when it is moving

potential energy (puh-TEN-shuhl, EN-ur-jee): stored energy

The larger and heavier a rocket is, the more thrust it will need to lift off.

Electricity and Magnetism

Electricity and magnetism are everywhere. Electricity is a form of energy. Magnetism is also a form of energy. They make it possible for televisions, computers, and many other electronic devices to exist. Medicine uses them to help treat illnesses in humans and animals.

Magnetism stores the data in a computer even when it is turned off.

Electric motors use magnetism to convert electricity into motion. Generators use magnetism to create electricity. Electric forces exist in nature too. They determine phases of matter. For example, electric forces let solids be solids and liquids be liquids.

Electric Charges

The electromagnetic force between particles is one of the basic forces of nature. An electric charge occurs when an atom has too many or not enough electrons. An electron is a particle that moves around the center of an atom. Materials can become electrically charged, or electrified, in many different ways.

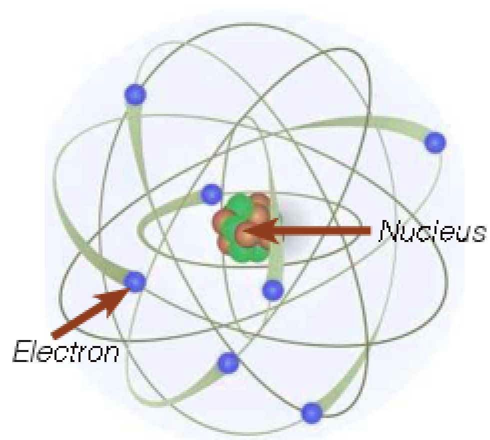
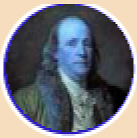


Illustration of a Atom

Water from the dam spins magnets inside copper wire, creating electricity.

Benjamin Franklin (1706-1790)



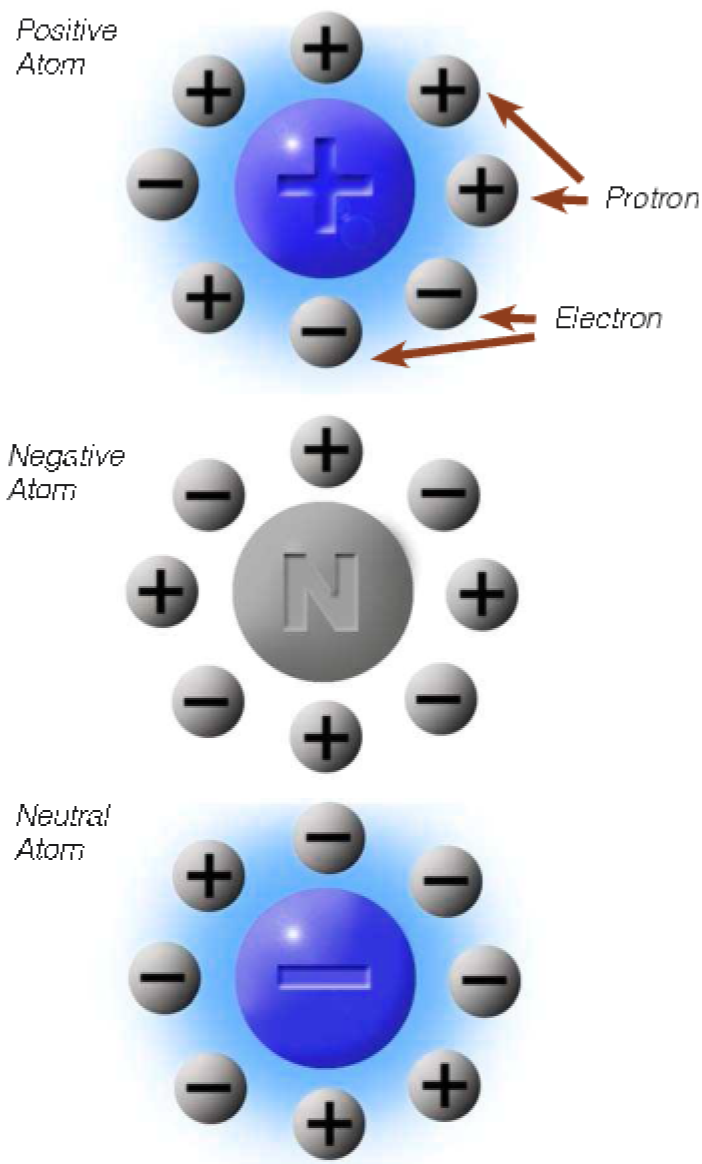
Getting to know...

Benjamin Franklin was born in the city of Boston in 1706. He went to school for only two years. Franklin made candles for his father and worked in a printing shop with his brother. He made money in business in the city of Philadelphia. Franklin invented a wood-burning stove, bifocal glasses, the postal system, and the first public library in America.

Franklin performed many experiments. He was interested in electricity. He thought that objects are positive, negative, or neutral. Franklin flew a kite during a thunderstorm to test his theory. (This is a very dangerous experiment!) He tied a metal key to the string. The key touched a Leiden jar, which stores electric charges. Franklin also invented the lightning rod. This metal pole attracts lightning and keeps it from hitting buildings.

Positive and Negative Charges

There are two different kinds of charged particles, negative and positive. A negative charge comes from electrons. A material that has extra electrons is negatively charged. A positive charge comes from protons. A proton is a particle found in the center section of an atom. A material that loses electrons is positively charged. There are more protons in the material than there are electrons. A neutral atom has the same number of protons and electrons.



You can find out if an atom is positive, negative, or neutral by comparing the number of protons and electrons it contains. Protons are represented as -, electrons are represented as +.

Rubbing a balloon on hair will make the hair stand up. The balloon has picked up a negative electric charge from the hair. The hair will have a positive electric charge. Hair is attracted to the balloon because charges that are opposite attract each other. Two negatively charged balloons will move away from each other. Charges that are the same push away, or repel, one another.

Static Electricity

Electricity that does not flow is called static electricity. Friction between different materials can build up static electricity. Running a comb through hair will charge the comb with static electricity. Then the comb can pick up little pieces of paper. An inflated balloon rubbed on wool will stick to the wall or ceiling of a room.

You can electrify your body with static electricity by rubbing your shoes on a wool rug. The static charge is removed, or discharged, when you sneak up on your friends and zap them. Under the right conditions, you can even see a spark!

Find out more

It is easier to build up static electricity in the wintertime because there is less humidity in the air. When you come in from the cold and take off your hat, your hair becomes electrically charged and stands up. This is because electrons moved from your hair to your hat when you pulled off your hat.

The hairs on your head are all now positively charged. We know that charges that are the same push away from each other, and that's just what the hairs on your head are doing, giving you a hair-raising new look!

Words to know

electron (i-LEK-tron): a particle that moves around the nucleus (center part) of an atom

negative charge (NEG-uh-tive charj): one of the two kinds of electric charges. Negative charge has more electrons and a lower electric potential

positive charge (POZ-uh-tive charj): one of the two kinds of electric charges. Positive charge has fewer electrons and a higher electric potential

static electricity (STAT-ik i-lek-TRISS-uh-tee): electricity that builds up on an object and does not flow

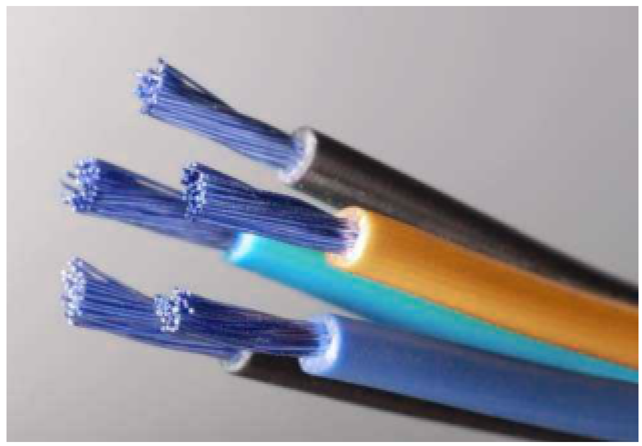
Conservation of Electric Charges

Electric charge is conserved. This means that an electric charge cannot be created nor destroyed. An object can become electrified. This is because the electric charge is transferred from one object to another. One object gains some negative charge. The other object gains the same amount of positive charge.

Current

Circuits

Electricity that flows, or moves, is called electric current. An electric current is usually made of a stream of electrons. The electrons are moving from one place to another. A circuit is the complete path of an electric current. A simple circuit looks like a loop. Metal wires are often used to conduct, or pass on, electric current. Electrons flow easily through metals. Copper is a metal that can be stretched into wires. It is a good conductor of electricity. This is because electrons flow easily through it. Copper wires are used to conduct electricity in houses and other buildings.



Copper wire is used in many electronics and telecommunications products.

Words to know

circuit (SUR-kit): a group of electronic parts that are connected and make a circle

conductor (kuhn-DUK-tur): matter that allows heat to pass through it

fuse (fyooz): a device that stops electricity flowing when there is too much current

volt (vohlt): a unit used to measure the electrical force in a battery

Amps

The amount of electric current flowing through a material is measured in units called amperes. Wires can handle only a certain amount of electricity.

Fuse

The thicker the wire, the more electricity can flow through it. A wire will heat up if too much electricity flows through it. Sometimes, wires get so hot that they melt the insulation protecting them. This can start a fire. A fuse is used to limit the amount of current flowing through wires. The fuse stops the flow of electricity. It does this if the number of amperes, or amount of current, gets too high. The fuse breaks in order to protect wires that cannot handle higher currents.

It is much easier to replace a blown fuse than to repair fire damage or replace damaged electronics.

Circuit breakers protect electrical circuits from damage.

What Provides Current

Many different things provide current. Batteries store chemical energy. Solar panels convert sunlight into electricity. Even the forces inside of an atom can be used to produce energy.

Find out more

Batteries

Batteries are used to store energy in the form of chemical energy. The chemical energy is stored in a battery cell. Each battery cell has two ends, the positive and the negative end. The chemicals inside a battery are called electrolytes.

A chemical reaction happens inside the battery. A chemical reaction is when chemicals combine and change. The chemical reaction makes electrons flow from the positive end to the negative end. Different chemicals can provide different amounts of electricity.

Electrical force is often measured in volts (V). A volt is the force that makes electrons flow around a circuit. Flashlights often use 1.5 volt batteries. Some batteries can be recharged, or charged again, when they run out of power.

Batteries are used as power for many different electronic devices. Tiny batteries are used in watches. Portable computers often use rechargeable batteries. Cars have big rechargeable batteries to start their engines. Some cars even run completely on batteries. They are called electric cars.

Magnetism

Magnetism is an invisible force that brings some materials together or pushes them away from each other. It can also attract or repel other materials. It is usually found in materials containing iron. A magnet is usually made out of iron. Magnets can attract or repel other magnets. They can also attract pieces of iron that are not magnetic. These pieces of iron will become temporarily magnetized, or made into magnets.

Iron filings become temporarily magnetized when they touch other iron filings that are in contact with the magnet.

Poles

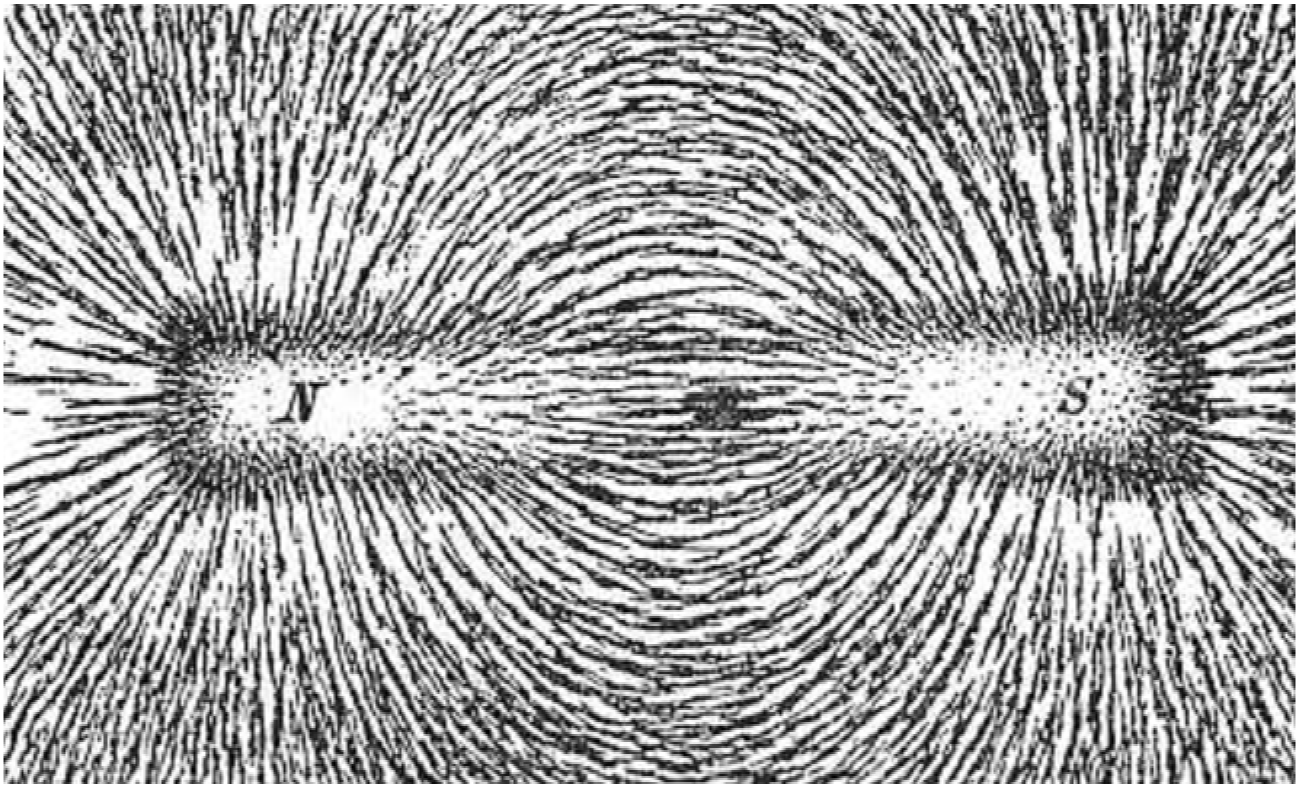
Every magnet has two ends called poles. These poles are called north and south. Poles behave like electrical charges in many ways. Different poles attract each other. North poles are attracted to south poles. South poles are attracted to north poles. Poles that have the same charge repel each other. South repels south, and north repels north.

Like poles repel each other, but in this position they can lie side by side.

Magnetic poles are also different than electrical charges. Magnetic poles cannot be separated from each other. It does not matter how many pieces you cut a magnet into. Each piece will always have a north pole and a south pole.

Magnetic Field

All magnets produce a magnetic field. This is the area around the magnet where the magnetic force can be felt. Magnetic fields travel from the magnet's north pole to its south pole.



Placing iron filings on a piece of paper covering a bar magnet shows the magnetic field.

Find out more

Make Your Own Magnet

Hold a pair of scissors in one hand. Hold a magnet in your other hand. Rub one end of the magnet along the metal scissors. Lift the magnet and repeat the same movement as before. Continue for 10-12 strokes. Remember to always lift the magnet between strokes, and always use the same end of the magnet. Now your scissors should act like a magnet. Experiment to see how many household items you can pick up.

Electromagnet

Magnets can be created with electricity. Every electric current can make a magnetic field. Current flowing through a wire creates a magnetic field around the wire. This can be seen with a compass. Put a compass needle close to an electric wire. The needle will change the direction it is pointing.

Wire that carries a current can be wrapped around a piece of iron to make a powerful magnet. It is called an electromagnet. Magnets can also be used to produce electricity. A magnet that is moved close to a wire can create an electric current in the wire.

Maglev trains use magnetic levitation.

Magnetic discs are used inside computers.

Using Magnets

Magnets are used everywhere. Electromagnets can pick up heavy objects. They are also used in speakers to make sound. Magnets and electromagnets help electric motors spin. Magnetic disks are used to store information for computers.

Videotapes and audiotapes record pictures and sound with electromagnets. Scientists use magnetic fields to study and control subatomic particles, or the smaller particles in atoms.

Words to know

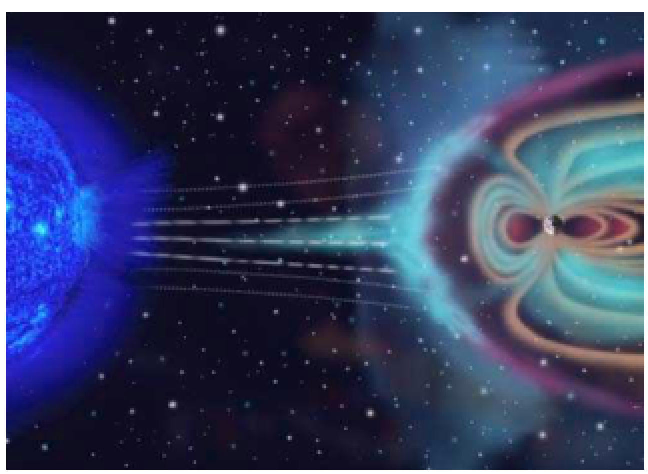
electromagnet (i-lek-tro-MAG-nit): a magnet made by an electric current

magnet (MAG-nit): a metal object that pulls iron or steel toward it

pole (pohl): the north or south end of a magnet

Earth

Earth itself is a giant magnet. Like any magnet, the Earth has a magnetic field. The direction of Earth's magnetic field can be seen with a compass. The compass needle always points toward the north magnetic pole. Earth's magnetic field protects the planet. It protects it from charged particles thrown out by the sun. These charged particles are called solar wind. Some other planets have magnetic fields too.



The magnetosphere shields the surface of the Earth from the charged particles of the solar wind.

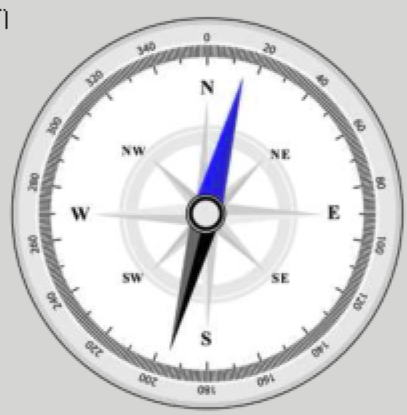
Find out more

Compasses

Have you ever gone for a hike in the woods and lost your sense of direction? You might think you came one way, but as you backtrack, you find yourself in unfamiliar territory and wondering which way to go. Maps are helpful for showing a route, but if we don't know east from west, our map isn't going to be very useful. Knowing that the sun rises in the east isn't much help at noon, when it is directly overhead.

There is a tool that can help us find our way. It is the compass. Many smartphones come equipped with a compass. A compass uses a magnetic needle that spins freely on a post, or pivot point. The needle spins so that one end is always pointing to the Earth's magnetic north pole. We can use the markings on our compass to find our way in any direction.

A compass has four main points: north, south, east, and west. These are the cardinal points. Between these points lie northwest, northeast, southwest, and southeast. Even more detailed are points such as north-northeast, halfway between north and northeast.



James Clerk Maxwell (1831-1879)

Getting to know...

James Clerk Maxwell was born in Scotland in 1831. His mother taught him at home, but she died when Maxwell was eight years old. He was sent to school and did well in mathematics. Maxwell decided to study physics. He went to Cambridge University.

Maxwell began to perform experiments with electricity and magnetism. Physicists wondered how electric charges traveled across space. They wondered how they influenced other charges. They found that charges create electric fields. They found that magnets create magnetic fields. Maxwell joined these fields into a single electromagnetic field. He used mathematical equations now called Maxwell's equations. He showed that electromagnetic energy moves as waves. A wave is energy that moves through air or water. The speed of these waves is the speed of light. Maxwell found that light is made of electromagnetic waves.

Heat

Heat is a form of energy. It is created when molecules (small pieces) in an object move around. The study of heat and how it is used is called thermodynamics. Heat is very important to life on Earth. The sun warms our planet and helps create weather. Heat from our bodies helps them work properly.

Temperature

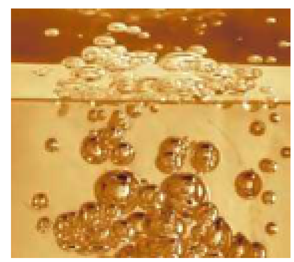
Temperature is how hot or cold something is. The temperature of an object tells us how fast the molecules in the object are moving. Different materials behave in different ways depending on their temperature.

A temperature scale is a system for measuring how hot or cold something is. There are three common temperature scales: Kelvin, Celsius, and Fahrenheit. In the United States, the Fahrenheit scale is used to describe how hot or cold the weather is.

PROJECTS
Volume 10 6.2

Fahrenheit Scale

In the United States, temperature is measured in degrees Fahrenheit. Water freezes into ice at 32 degrees Fahrenheit (32°F). Water boils at 212 °F.



Celsius Scale

Temperature is often measured using the Celsius scale. Celsius (°C) is based on the freezing point and boiling point of water. Water freezes at 0°C, or 0 degrees Celsius. Water boils at 100°C. An average room temperature is about 20°C.

Kelvin Scale

Another way of measuring temperature is to use the Kelvin scale. The Kelvin (K) scale begins at the lowest possible temperature. This is 0 K, or -273°C. Temperatures measured with the Kelvin scale are called absolute temperatures.

	Kelvin	Celsius	Fahrenheit
Absolute zero (precisely, by definition)	0 K	-273.15°C	-459.67°F
Melting point of ice	273.15 K	0°C	32°F
Water's boiling point	373.1339 K	100°C	212°F

Expansion and Contraction

Most things expand, or get bigger, as they get hotter. Most materials contract, or get smaller, as they get colder. The molecules (small pieces) that make up material move faster as they get hotter. They take up more space as they move more quickly. A solid that is heated enough will become a liquid. A liquid that is heated enough will boil. It then turns into a gas, or vapor.

When water boils and becomes steam, it escapes from the kettle.

Rates of Expansion and Contraction

Different materials expand and contract at different rates. Solids and liquids expand only a little bit when they are heated. The alternate expansion and contraction of some rocks makes them crack. This happens when the temperature gets really cold. Many paved streets and sidewalks crack. This happens as they are exposed to temperature changes over time.

Heat

Gases expand a lot when they are heated. Heated air is used to fill hot-air balloons. Hot air rises because it is less dense (lighter) than cooler air. It takes up more space because there is more space between the molecules. This allows the balloon to rise into the sky.

Hot air balloonists control their height by adding hot air to the balloon, or by releasing it.

Find out more

Thermometers

There are many ways to tell how warm or cold it is outside. Humans get goose bumps on their skin when it is really cold. A more accurate way to measure temperature is to use a thermometer. Thermometers are used to measure the temperature of many different things.

Some thermometers are used to control, or regulate, temperature. They are called thermostats. Thermostats in car engines turn on a cooling fan when the engine gets too hot. Other thermostats regulate the temperature of refrigerators and air conditioners. Heaters have thermostats that turn them on or off.

The metal mercury is used in many thermostats. The mercury is kept inside a sealed glass tube. The metal will expand or contract as the temperature changes.

Galileo Galilei (1564-1642)

Getting to know...

Galileo Galilei was born in Italy in 1564. He was an Italian physicist, mathematician, astronomer, and philosopher.

One of Galileo's inventions was the thermoscope. With a thermoscope the temperature is read using the engraved metal disc on each bulb. If there are some bulbs at the top and some at the bottom, but one floating in the gap, then the one floating in the gap tells the temperature. If there is no bulb in the gap then you take the temperature of the bulb at the bottom of the gap, add it to the temperature of the bulb at the top of the gap, and divide the result by two.

Warmer temperatures cause the mercury to expand and rise in the tube. Colder temperatures cause it to contract and fall in the tube. People can use mercury thermometers to measure body temperature. Digital thermometers use electronic parts to measure temperature. People can also use a digital thermometer to measure body temperature. Different types of digital thermometers can be placed in the ear or under the tongue.

We use thermometers to tell us our body's temperature.

Historical Development in the Measurement of Temperature

1597 Galileo Galilei (1564-1642) invented the thermoscope.

1612 Santorio Santorio (1561-1636) applied a scale to an air thermoscope and thus is thought to be the inventor of the thermometer as a temperature measuring device.

1654 Grand Duke of Tuscany, Ferdinand II (1610–1670) made the sealer liquid-in-glass thermometer. His thermometer had an alcohol filling. Although this is a significant development, his thermometer is inaccurate and there is no standardized scale in use.

1714 Gabriel Fahrenheit (1686–1736) made the first thermometer using mercury. The more predictable expansion of mercury, combined with improved glassworking techniques, lead to a much more accurate thermometer. The Fahrenheit scale is still in use today.

1742
The Swedish scientist Anders Celsius (1701–1744) devised a thermometer scale dividing the freezing and boiling points of water into 100 degrees. The Celsius scale is still in use today.

1848 Lord Kelvin of Scotland (1824–1907) proposed the absolute temperature scale, or Kelvin scale. The Kelvin (K) is the current standard unit of temperature measurement.

How Heat Works

Heat is the energy that an object has because the molecules (small pieces) inside it are moving. Heat flows from materials that are hot to materials that are cool. The heat will flow until both materials are the same temperature. The three ways that heat can travel are convection, conduction, and radiation.

Convection

Convection is how heat moves through liquids and gases. Water will slowly start to boil as it is heated. The convection currents of vibrating water molecules cause the violent movement we see in the boiling water.

We see convection in the boiling water, and know to keep our hands away from the hot metal pot.

Conduction

Conduction is how heat moves through solids. Molecules start to vibrate as they are heated. As they vibrate faster, the molecules next to them start vibrating. This vibration conducts the heat energy through the material. A metal spoon dipped in hot water will get hot at the other end because heat energy was conducted through the spoon.

The handle of this ceramic mug will not conduct as much heat as the metal spoon.

Radiation

Radiation is how heat moves through empty space. It travels by electromagnetic waves. Energy from the sun reaches the Earth in this way. All objects emit, or give off, radiation in the form of heat.

An object will emit more radiation the hotter it becomes. A good example of this is how a fire feels warmer the closer you get to it.

A red-hot iron rod will transfer heat to the surrounding environment through radiation.

Insulation and thermodynamics work together to keep your food cool.

The Uses of Heat

Humans use heat in a lot of ways. Car engines use heat from the burning of fuel. The heat energy is converted to a force. The force pushes pistons in the engine up and down. The pistons provide power so that the car can move.

Refrigerators use the laws of thermodynamics when they cool your food. Cooling in the refrigerator is caused by absorption of heat as the liquid freon or refrigerant evaporates. The first law of thermodynamics says that when something is made cold, something else becomes hot. This is why the back of a refrigerator feels warm.

Insulation

Insulation helps prevent heat from shifting. People wear thick clothes in the winter to keep their bodies warm. The clothes act as insulation that prevents heat from leaving the body.

Words to know

conduction (kuhn-DUHKT-shuhn): how heat moves through solids

convection (kuhn-VEK-shuhn): how heat moves through liquids and gases

insulation (in-suh-LA-shuhn): material that keeps heat in or out

radiation (ray-dee-AY-shuhn): how heat moves through empty space

The jacket's insulation helps this girl retain body heat.

Ice chests use insulation to prevent heat on the outside from getting inside. This allows cold food and ice to stay cold.

A well-insulated cooler will keep drinks cold on the hottest of days.

Homebuilders use insulation in the attics and walls of homes so that the homes will stay warm in winter and cool in summer.

Find out more

You can test how well different materials act as insulators or conductors. Gather some cooking utensils, like wooden and metal spoons, from the kitchen. Place the utensils in a bowl or pan. Add enough ice to fill the bowl or pan about halfway. After a few moments, touch the handles of the utensils.

What do you notice about the temperature of each? Do some materials feel colder than others? Compare the temperature of the metal spoon to the wooden. Which is a better insulator? Why do cooks use wooden spoons when they stir boiling liquids?

Superconductivity Moves Energy Fast

Some materials take on special characteristics when they get really cold. They become superconductors. This is because they have very little resistance to electric current. Superconductors can be used to move energy inside computers very fast. They are also used to make some materials float!

Waves, Sound, and Light

Light and sound are two of the most important forms of energy to humans. People see light and hear sound. Light from the sun makes life on Earth possible. Sound is one of the most important ways that animals and humans communicate. Both sound and light travel as waves. Light also behaves like a particle. One of the things physicists study is the way light and sound work.

Waves and Sound

Waves

It is easy to make waves. Drop a stone in a pool of water. Waves of water will form as circles around where the stone fell in.

Waves of water travel in all directions from the source.

The high points of a wave are called crests. The low points of a wave are called depressions. The distance between the crests is the wavelength. How fast the waves move is their speed. How many waves pass a certain point in a second is called frequency. The frequency is higher when the waves are closer together.

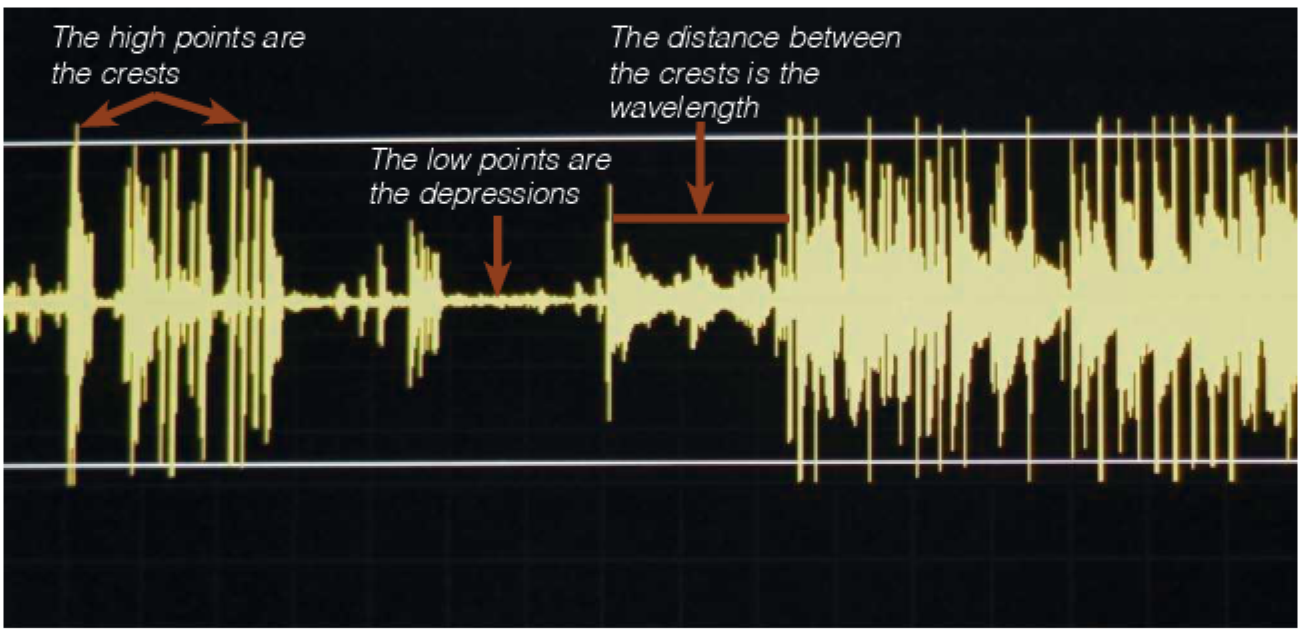
The amplitude is how tall the waves are. Sound waves can have different frequencies and amplitudes. High-pitched noises and sounds have high frequencies. Whistles have high–pitched sounds. The deep noises and sounds that come from drums have low frequencies.

Sounds

Sounds travel by moving molecules of air like a wave. Sound waves behave like water waves. But they move in all directions. Have you ever felt a really loud sound? The force that you are feeling is sound waves moving through air. More air is moved when the sound is louder. A louder sound or noise has a higher amplitude.


Very loud sounds can damage your eardrums.

Sound waves can travel in many different materials. The speed of sound depends on the material it is traveling through. Sound can move faster through denser materials, but it may not travel very far. The energy from the sound wave can be absorbed into the material. This is why it is difficult to talk through a brick wall. The speed of sound through air depends on the air's temperature. At a temperature of 68°F (20°C), sound travels 1,130 feet (343 meters) per second.



Sound Waves

We measure the intensity of sounds in decibels. The same sound will not seem to have the same loudness to all people, though. Age affects the human ear's response to a sound. Your grandparents do not hear like they used to. Sounds of similar intensity may not

Words to know

amplitude (AM-pluh-tood): how tall waves are

frequency (FREE-kwuhn-see): the number of times something moves in a second seem to have the same loudness to them as they would you.

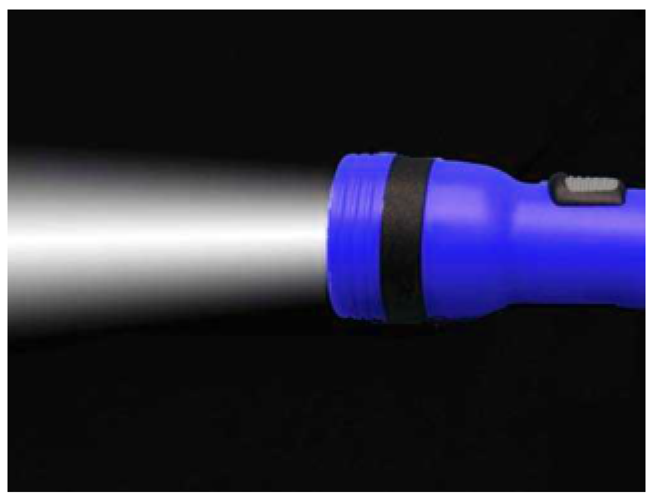
Intensities Of Common Sounds Measured In Decibels	
Source	**Intensity Level**
Rustling leaves	10 dB
Whisper	20 dB
Normal conversation	60 dB
Busy street traffic	70 dB
Vacuum cleaner	80 dB
Large orchestra	98 dB
Front rows of a rock concert	110 dB
Military jet takeoff	140 dB
Instant perforation of eardrum	160 dB

A lawnmower's intensity level is abut 90dB.

The Nature of Light

Speed of Light

Light is a form of electromagnetic energy. The light from a flashlight seems to shine instantly. However, it takes time for light to travel from the flashlight to where it is shining. Light moves very fast. The speed of light is about 186,000 miles (300,000 kilometers) per second. This is called the universal speed limit, because nothing yet discovered can go faster than the speed of light.



Photons shine in a beam of light from the flashlight.

Particles and Waves

Scientists have studied light for many years. A long time ago, they thought that light was made up of tiny particles. Other scientists thought that light behaved like a wave of energy.

Today, scientists believe that light behaves both like a particle and like a wave.

Particles

Particles of light energy are called photons. Photons come from anything that produces light. Stars, like the sun, make a lot of photons. When objects block photons coming from the sun, they make shadows.

It's smart to take a break from the strong rays of the summer sun.

Other physical processes on the Earth can produce light. Chemical reactions from fires release energy as light. Light bulbs of all kinds also produce light.

Waves also play a part. Light acts like a wave. Some forms of light are easy to see. The light that humans can see is called visible light. All visible light makes up the visible spectrum. This spectrum includes all the colors of the rainbow. The order of the colors in the visible spectrum is red, orange, yellow, green, blue, indigo (red-blue), and violet (purple). Other forms of electromagnetic energy are invisible. Light energy above the violet end of the spectrum is called ultraviolet light. Light energy below the red end of the spectrum is called infrared light.

Words to know

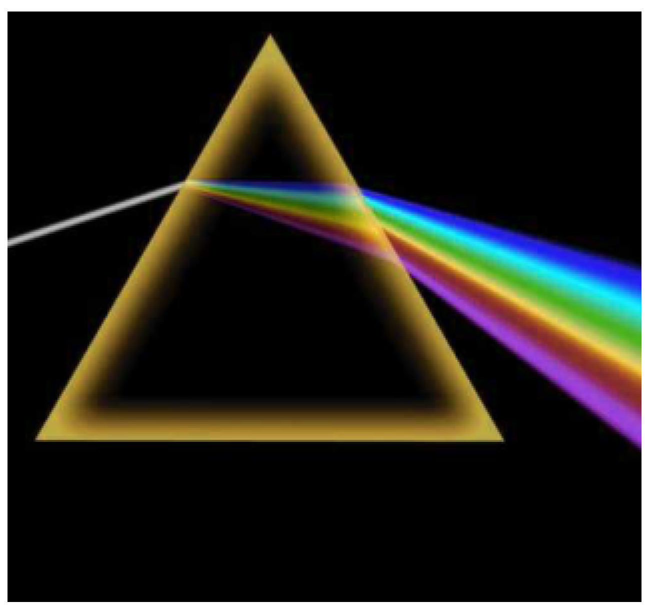
electromagnetic spectrum (i-lek-tro-mag-NET-ik SPEK-truhm): all the forms of energy that travel as a wave

light (lite): a form of energy

microwaves (MYE-kroh-waves): waves that can go through a solid object

photons (FOH-tons): particles or small pieces of light energy

visible spectrum (VIZ-uh-buhl SPEK-truhm): the colors you can see; the colors of the rainbow (red, orange, yellow, green, blue, indigo, and violet)



All the colors of the rainbow appear in the visible spectrum.

Other Energy Forms That Can Travel As A Wave

Visible light is just one part of the electromagnetic spectrum. The electromagnetic spectrum includes all forms of energy that can travel as a wave.

Radio Waves

Radio waves are part of the electromagnetic spectrum. These are the waves received by radios, televisions, and cellular phones.

Microwaves

Microwave ovens use waves called microwaves to heat food. The wavelength of microwaves is just right to cause water molecules to vibrate. Vibrating makes the water molecules give off heat. Any food containing water gets hotter in a microwave oven.

Christiaan Huygens (1629-1695)

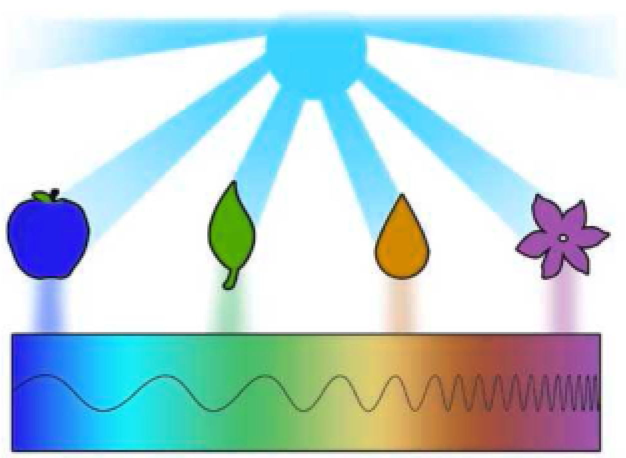
Getting to know...

Christiaan Huygens was born in the Netherlands in 1629. Huygens and his brother built a powerful telescope. He used it to study the planet Saturn. He discovered Titan, one of Saturn's moons. He discovered the rings around Saturn. Christiaan studied the motion of a pendulum and created a pendulum clock.

Huygens suggested the wave theory of light. He thought that light moves in waves that make more waves. They were like ripples of water. He assumed that space was filled with something for light waves to move through. This substance was called ether. Two hundred years passed before scientists realized that ether does not exist.

Where Light Comes From

Electrons orbiting an atom in an electron shell have potential energy. An electron that drops down to a lower orbit changes potential energy into a photon of light. The frequency of light depends on the energy level. The frequency is high when the energy level of the orbit from which the electron came is high.



VISIBLE LIGHT SPECTRUM

Red light has a longer wavelength than green, blue, or violet.

Types of Light

Many kinds of chemical reactions release energy. A chemical reaction happens when chemicals combine and change. Reactions of different materials produce different kinds of energy. Scientists can tell what something is made of from the wavelengths of light that come from the material when it is burned. Gases give off specific wavelengths of light when they are electrified. Materials that are heated also give off light. When the wire in a light bulb gets very hot, it begins to glow.

An electric current passes through the filament in this light bulb and causes it to glow.

Reflection and Refraction

Reflection

Light normally travels in a straight line. Light that meets an object will change direction. It will bounce or bend depending on what it hits. Light that bounces off a surface is reflected. Light is reflected like a ball bouncing off a hard floor.

PROJECTS
Volume 10 6,3

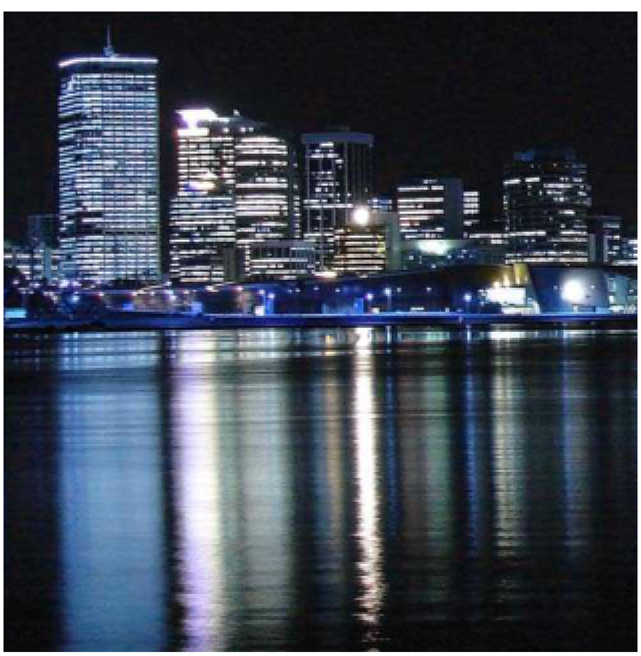
Max Planck (1858-1947)

Getting to know...

Max Planck was born in Germany in 1858. He attended the University of Berlin and was inspired by his physics professors. Planck became a professor himself after college.

Planck began to work on the problem of blackbody radiation. A blackbody is any object that takes in, or absorbs, all light that hits it. A blackbody then gives off, or radiates, light at all frequencies or wavelengths. Planck found a formula that explained all his experiments. For his formula, energy had to be given off in chunks that he called quanta. Quanta depend on frequency and a number called Planck's constant. His idea of quanta of energy helped create the field of quantum mechanics. Planck was awarded the Nobel Prize in 1918.

Smooth surfaces, such as mirrors, reflect a lot of light and give sharp, clear reflections. Bumpy or rough surfaces give fuzzy, or diffuse, reflections. A dull object that is polished becomes smoother and better able to reflect light.



The smooth surface of the water reflects the city's buildings.

Find out more: THE NOBEL PRIZE

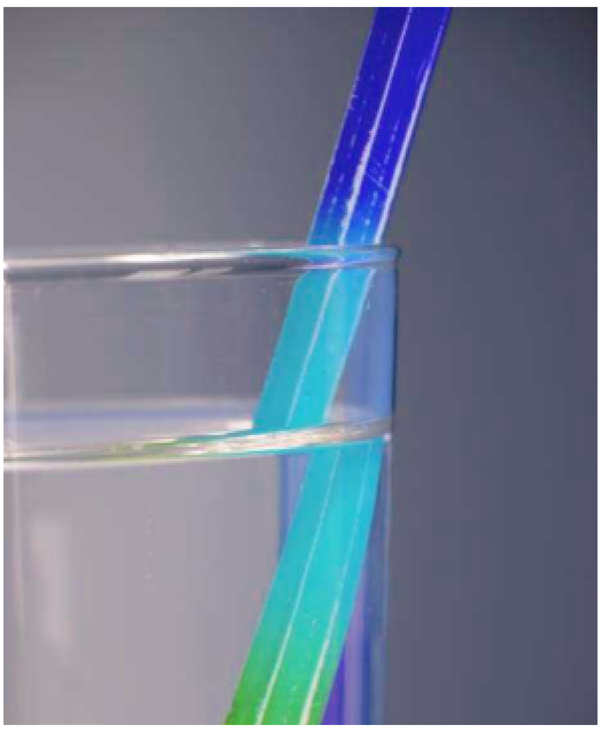
The Nobel Prize is an award that honors men and women *"... who, during the preceding year, shall have conferred the greatest benefit on mankind."*

The Nobel Prize started in 1895 when Alfred Nobel (1833-1896), a Swedish chemist, engineer, innovator, and inventor of dynamite, wrote his last will, leaving much of his wealth to set up the prizes.

Since 1901, the prize has honored men and women for outstanding achievements in physics, chemistry, medicine, literature, economics, and for work in peace. Many of the scientists and doctors who contributed to the advancement of scientific and medical knowledge won the coveted Nobel Prize for their work.

Refraction

Light travels at different speeds through different materials. Light moves slower in water than in air. Its path is bent, or refracted, when light passes from one substance into another one. Refracted light makes a straight stick look bent when part of it is in water.



You might think this pencil has been broken into two pieces!

Lens

A piece of glass shaped to bend light into an image is called a lens. Some lenses magnify things, or make them look closer. Some lenses reduce things, or make them look farther away. Lenses are used in eyeglasses to help people see. Other lenses are used to magnify tiny images in microscopes. Refracting telescopes use lenses to magnify things that are far away.

PROJECTS
Volume 10 6.4

The lenses in telescopes and microscopes allow us to see things we could never see before; constellations from far away and tiny cells invisible to the naked eye.

Words to know

lens (lenz): a curved piece of glass or plastic

prism (PRIZ-uhm): a plastic or glass shape that separates light into the colors of the spectrum

reflect (ri –FLEKT): when light bounces or bends off a surface

refract (ri-FRAKT): when light is bent as it passes through different materials

A prism can separate all the visible colors of light found in sunlight.

Prism

Sometimes, light waves separate into different colors. A prism can separate sunlight into the colors of the spectrum. A prism is a specially shaped piece of glass or plastic. It can separate colors because different wavelengths of light travel at different speeds. Because they travel at different speeds they are bent by different amounts as they pass through the prism.

Find out more

Rainbows Show the Spectrum

Rainbows form when sunlight is refracted through drops of water in the air. The light splits into the seven colors of the visible spectrum: red, orange, yellow, green, blue, indigo, and violet. Rainbows can only be seen when the sun is shining from behind you!

Nuclear Energy

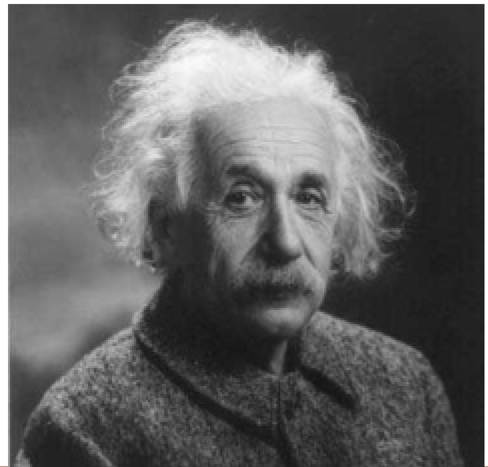
The protons and neutrons of an atom release nuclear energy when they break apart. Every atom contains a lot of energy. The forces that hold the atom together are the strongest forces that scientists know of.

In 1905, Albert Einstein showed that mass can be converted, or changed, into energy. He used mathematics to do this. The reaction can be written as $E=mc^2$. The E means energy. The m means mass. The c^2 means the speed of light squared, or multiplied by itself.

$$E = mc^2$$

$E=mc^2$ is a very big number.

A little bit of mass has a lot of energy. Some of the mass of the starting material is converted into energy in a nuclear reaction. Atoms that are split, or fused together, may weigh less than when they started. The mass that disappeared has been converted into energy.



Albert Einstein (1879-1955)

Getting to know...

Albert Einstein was born in Germany in 1879. Einstein worked as a clerk in a patent office. He thought about physics and how the universe works. In 1905, he published a paper on the special theory of relativity. This theory changed how scientists looked at space and time.

Einstein continued to study space and time. In 1916, he published papers on the general theory of relativity. This theory showed that space, time, and gravity are all related. His theory was proved correct during an eclipse of the sun in 1919. He was awarded the Nobel Prize in Physics in 1921.

In 1933, Einstein moved to the United States to escape the Nazi persecution of Jewish people. He became a professor at Princeton University. Einstein continued to study physics and to work for world peace.

Uses of Nuclear Energy

Nuclear energy is what powers the sun and all the stars in the sky. Nuclear reactions are used to produce energy in nuclear power plants. Space probes (unmanned vehicles) that travel far away from the sun sometimes use nuclear energy as their power source. Nuclear energy can also be used to create gigantic explosions. These explosions can destroy entire cities and kill millions of people.

The space station collects and uses solar energy, which comes from the nuclear reactions of the sun.

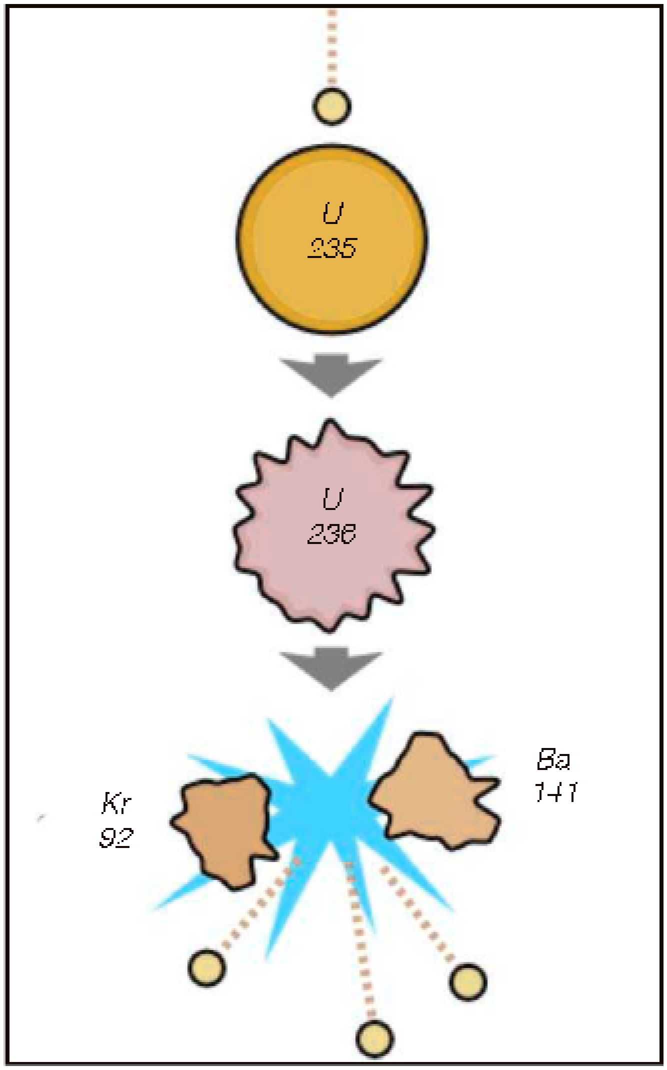
Galileo and Cassini are powered by their own mini nuclear power plants

The Galileo spacecraft was launched in 1989 to explore Jupiter and its moons.

Cassini studies the planet Saturn and its moons.

Fission and Fusion

Nuclear energy can come from two basic types of reactions. Fission happens when the nucleus of an atom is split to form two smaller atoms. Fusion happens when the protons and neutrons of two atoms combine to form a new atom.



Simple diagram of nuclear fission in three steps:

1. *A neutron is about to collide with the nucleus of a U-235 atom.*
2. *The neutron has been absorbed and briefly turned the nucleus into an unstable U-236 atom.*
3. *The U-236 atom has fissioned, resulting in two fission fragments (Ba-141 and Kr-92), three neutrons, and the release of a relatively large amount of binding energy.*

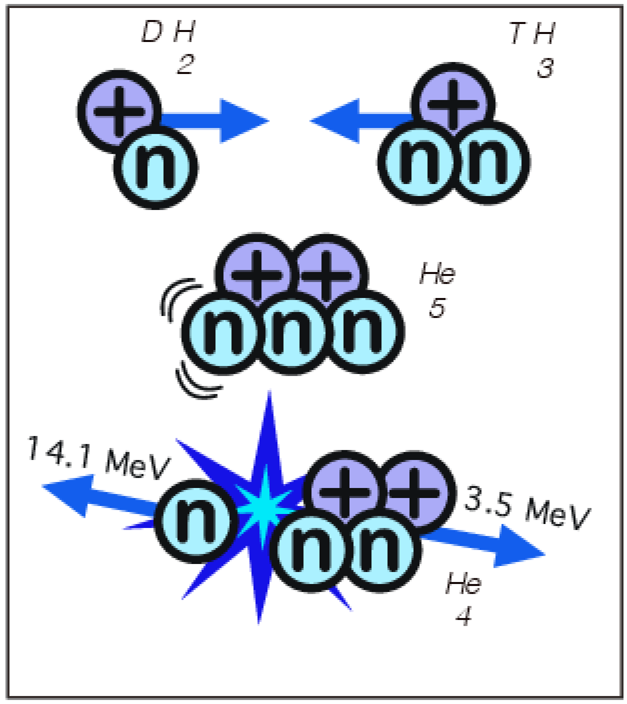


Diagram illustrating deuterium-tritium fusion in three steps:

1. *The D and T accelerate towards each other at thermonuclear speeds.*
2. *This creates an unstable He-5 nucleus.*
3. *The end result is the ejection of a neutron and repulsion of the He-4 nucleus.*

Chain Reaction

Fission reactions begin when a neutron moving very fast collides into the nucleus (center) of an unstable atom. An unstable atom can be broken apart. This reaction requires a lot of energy at the beginning. The collision with the neutron causes the atom to break apart.

Neutrons from the split atom cause other atoms to split if the reaction is not controlled. This is called a chain reaction.

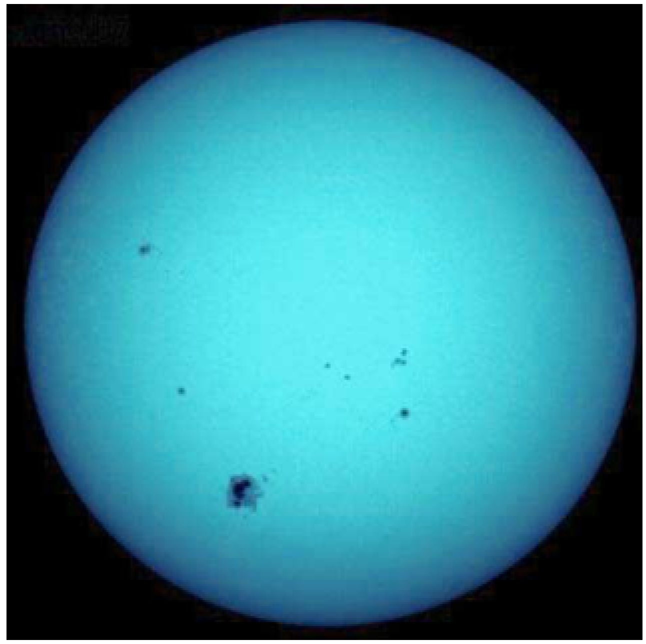
Fission Reactions

Humans use fission reactions inside nuclear power plants. They use it to make nuclear energy.

Water cools in giant towers at the nuclear power plant so it can be used again and again.

Fusion Reactions

Fusion reactions also require a lot of energy at the beginning. Even more energy is released when fusion takes place. The sun's energy is released when fusion takes place. The sun produces most of its light and energy from nuclear reactions.



Nuclear fusion reactions in the sun produce solar energy.

Solar panels convert the sun's energy into electricity.

Words to know

chain reaction (chayn ree-AK-shuhn): when a change keeps happening over and over again until it is controlled

fission (FISH-uhn): when an atom is split into two smaller atoms

fusion (FYOO-zhuhn): when parts of two atoms join together to make a new atom

nuclear energy (NOO-klee-ur EN-ur-jee): energy made when an atom breaks apart

Lise Meitner (1878-1968)

Getting to know...

Lise Meitner was born in Austria in 1878. She earned a Ph.D. in experimental physics. Meitner moved to Berlin, Germany, and met many famous physicists. She studied radioactivity with Otto Hahn.

In the 1930s, Adolf Hitler and the Nazi Party came into power in Germany and then Austria. They wanted to get rid of the Jewish people. Meitner was Jewish, and she had to escape to Sweden in 1938.

Back in Germany, Hahn and Fritz Strassman were hitting uranium with neutrons. They did not understand why they got barium, a lighter element. Meitner realized that the uranium atoms were being split. She also knew that energy was being released. This process is now called fission. Hahn was given the Nobel Prize in 1944 for their work, but Meitner was not.

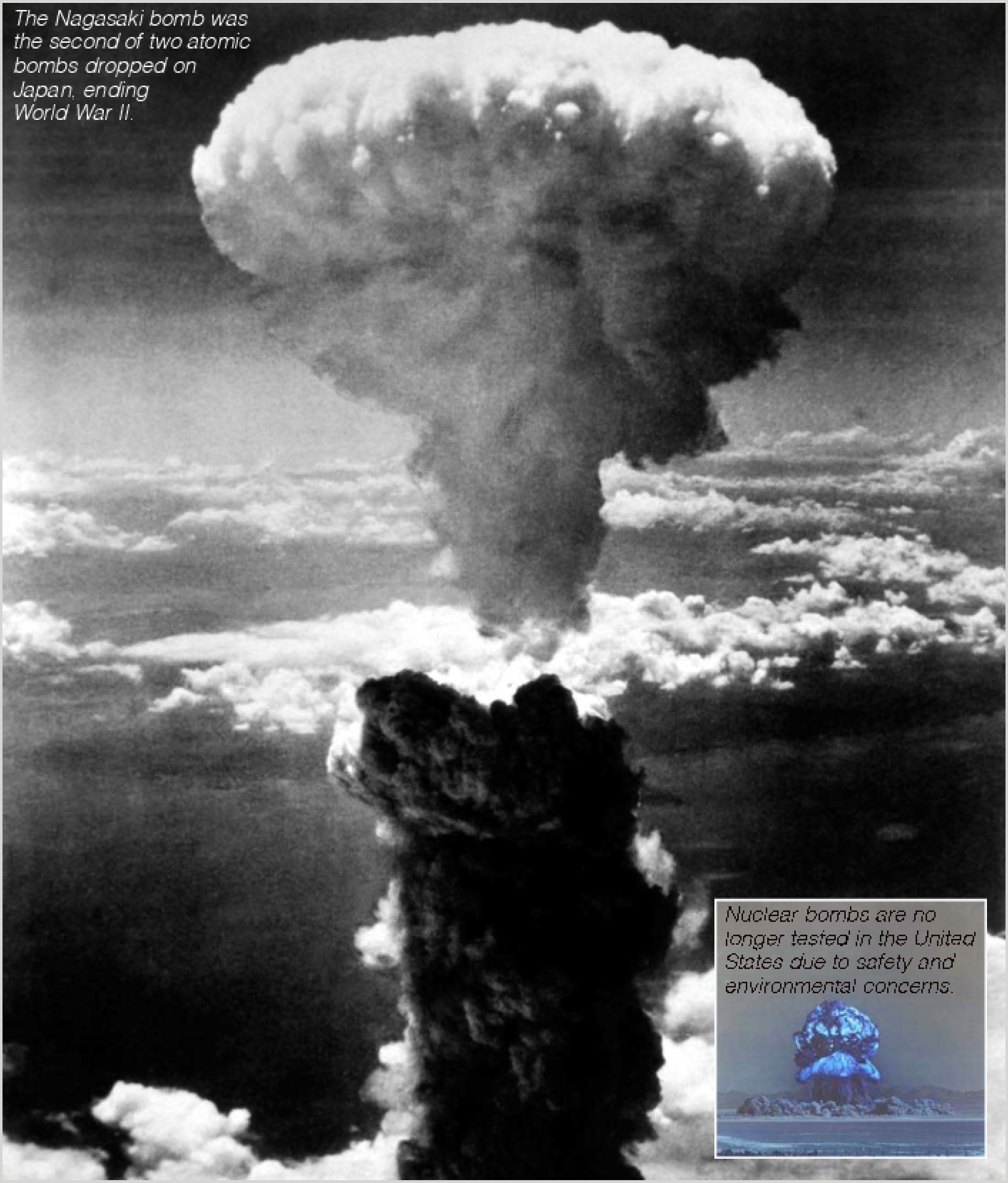
Find out more

The Atomic Bomb

One of the scariest and most powerful weapons in the world is the atomic bomb. In 1945, the United States dropped two atomic bombs on Japan to end World War II. The weapons completely destroyed the cities of Hiroshima and Nagasaki. Thousands of people were killed or seriously hurt by the explosions. Many other people became very sick from the radioactive particles called fallout.

Atomic bombs are also called nuclear weapons. They are made from specially produced uranium and plutonium. When enough uranium or plutonium is brought together it can reach a critical mass. A critical mass means it has enough mass (material) to produce a chain reaction. A chain reaction will take place if the critical mass is hit with neutrons. The chain reaction will lead to a nuclear explosion. Nuclear explosions are very powerful.

Nuclear weapons are tested deep underground. Preventing dangerous radiation from leaking into the air. Computers are also used to test, or model, nuclear explosions. Most nuclear weapons are used in missiles. These weapons are meant to deter other countries, or keep them from attacking. Many people think that nuclear weapons should not exist. Governments around the world are working together to get rid of nuclear weapons.



The Nagasaki bomb was the second of two atomic bombs dropped on Japan, ending World War II.

Nuclear bombs are no longer tested in the United States due to safety and environmental concerns.

Electricity Through Nuclear Power

In the United States, more than 100 nuclear reactors work to make our electricity. About one-fifth of the electricity we use comes from nuclear power.

Physics and Technology

At the power plant, a fission reaction splits uranium atoms. The fission reaction releases energy to heat water. The boiling water produces steam. The steam turns huge turbines. The turbines send power to generators that make our electricity.

Before electricity leaves the power plant, it travels to the transmission substation. The substation uses transformers to change the voltage of the power. Then it sends the power out along high-voltage transmission lines.

When the power reaches a substation, transformers are used to lower its voltage. Then the power is sent off in many different directions. After passing through more transformers, the electricity makes it to our homes. Finally, it travels through wires to our outlets, where we can plug in our favorite toys, radios, and video game systems.

Find out more

Nuclear Medicine

Many doctors use nuclear medicine to diagnose and treat patients. Nuclear medicine is used in many areas of medicine including oncology (cancer), cardiology (heart), neurology (brain), and pediatrics (children).

One form of nuclear medicine is positron emission tomography, or PET scans. PET scans are unique because they give doctors information about the structure and function of the patient's body. Many other scans, such as MRIs (magnetic resonance imaging), only give doctors information on structure.

When a person has a PET scan, he is injected with a drug that contains very small amounts of radioactive materials (radiopharmaceuticals). The PET scanner measures the signals given off by the radioactive materials. The doctor uses the result to diagnose diseases, such as cancer, in patients.

Doctors use other types of radiopharmaceuticals to treat diseases. One common use for radiopharmaceuticals is in the treatment of enlarged thyroid glands, or goiters.

One big benefit of nuclear medicine to the patient is that diagnosis and treatment are painless.

A PET scan gives the doctor information that will help diagnose and treat this patient.

People Who Study Physics

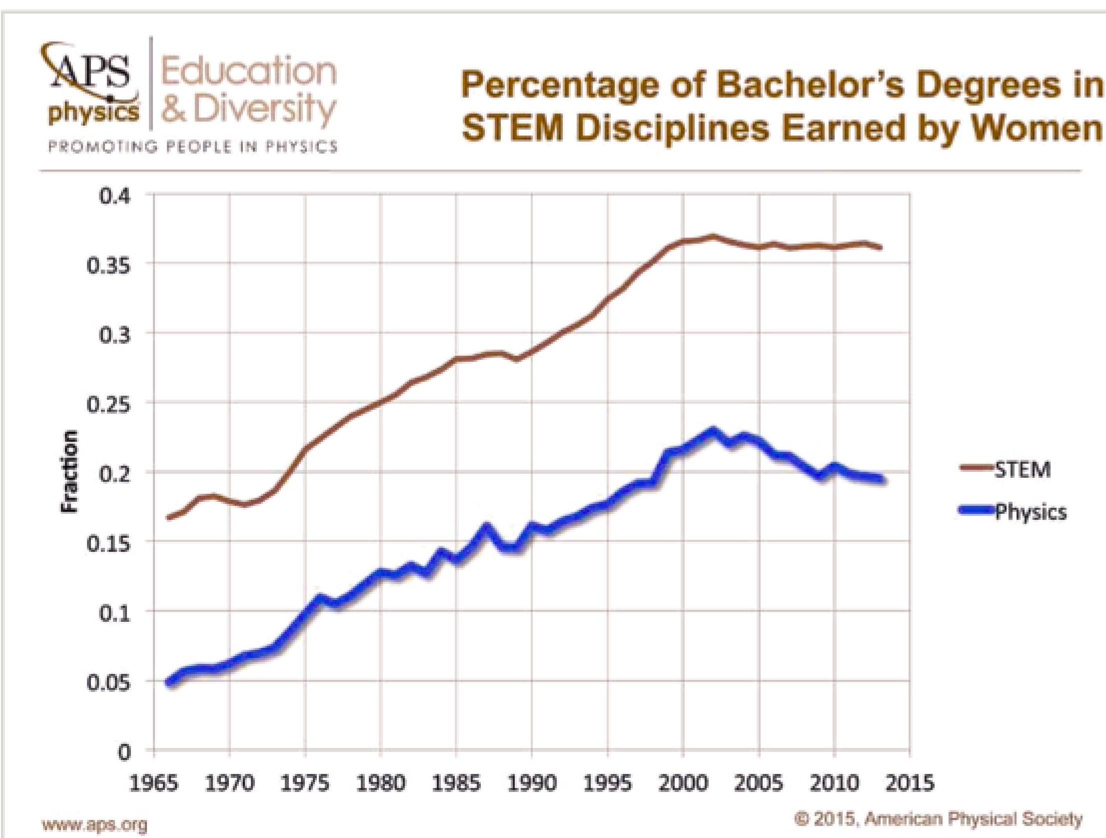
Physics is about how things work. People who study physics are called physicists. They learn about light and sound. They learn about electricity and magnetism. They learn about force and energy. They learn about how everything works, from the tiniest atom to the vastness of space.

Physicists study many different areas of physics.

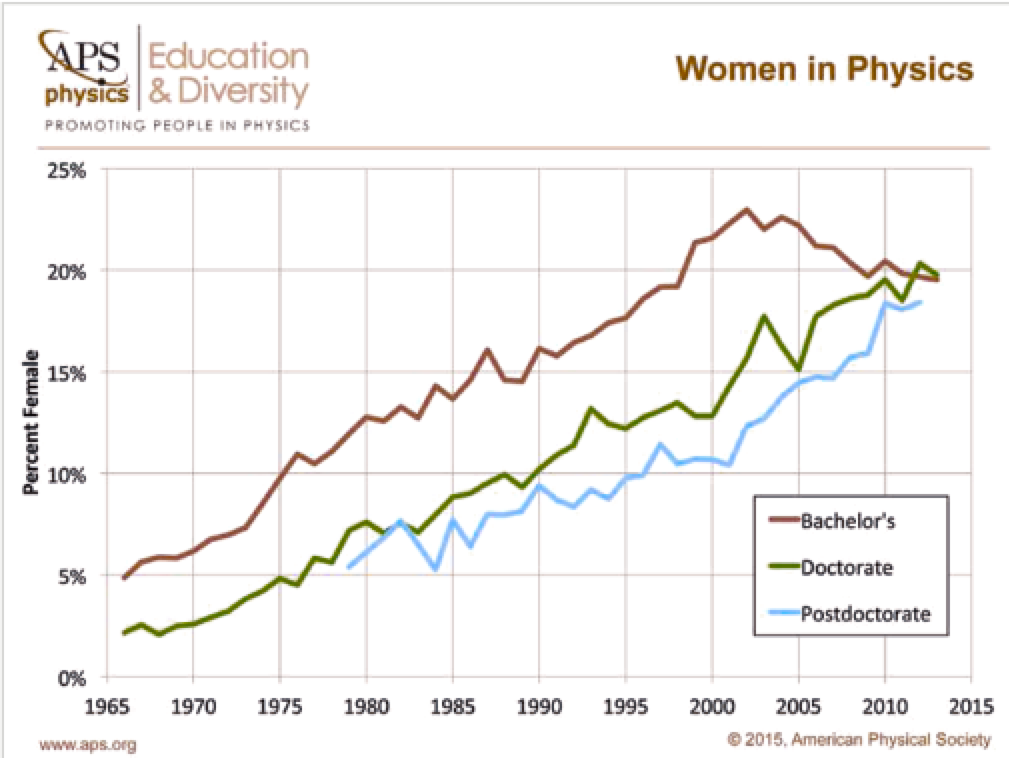
There is atomic physics. This is the study of atoms. There is nuclear physics. This is the study of the nucleus or the center of atoms. There is particle physics. This is the study of the individual particles or parts of atoms. There is solid state physics. This is the study of how atoms are combined together to make a solid object.

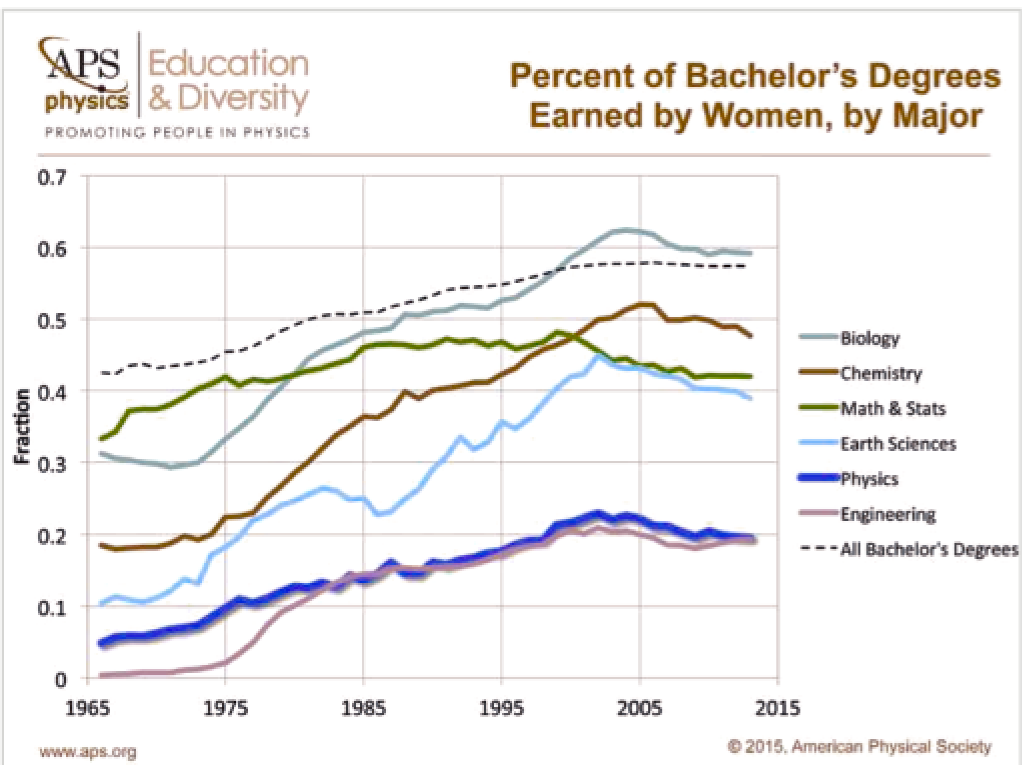
All physicists use mathematics to help figure out how things work. Maybe you can be a physicist too.

Women in Physics



Women in Physics



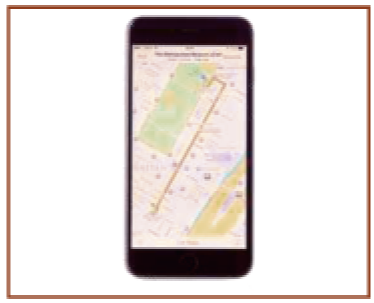


Technology From Physics

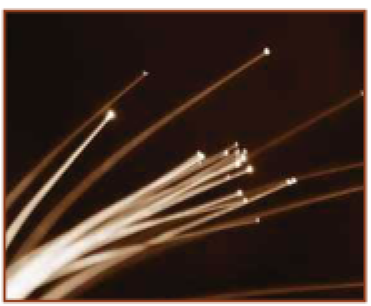
plasma televisions

computers

mp3 players



cell phones



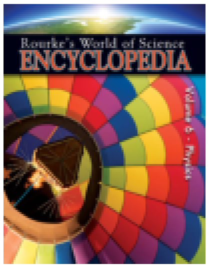
fiber optics

microwaves

radios

world wide web

Book Index



Rourke's World of Science Encyclopedia

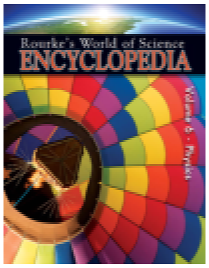
Rourke's World of Science Encyclopedia *Nancy Harris. Vol. 6: Physics. 2nd ed. Vero Beach, FL: Rourke Educational Media, 2016. 64 pp.*

Teaches the essential concepts for elementary school science instruction. Topics include the basic objects in the sky, life-cycles, and properties of earth materials to the more advanced, structures of living systems, forces and motion and science technology. This volume covers physics.

Rourke Educational Media

Index

Book Index



Rourke's World of Science Encyclopedia

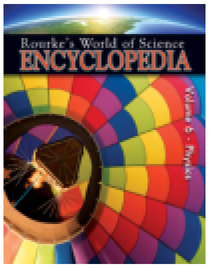
Rourke's World of Science Encyclopedia *Nancy Harris. Vol. 6: Physics. 2nd ed. Vero Beach, FL: Rourke Educational Media, 2016. 64 pp.*

Teaches the essential concepts for elementary school science instruction. Topics include the basic objects in the sky, life-cycles, and properties of earth materials to the more advanced, structures of living systems, forces and motion and science technology. This volume covers physics.

Rourke Educational Media

Index

Book Index



Rourke's World of Science Encyclopedia

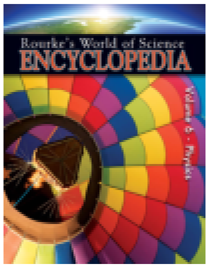
Rourke's World of Science Encyclopedia *Nancy Harris. Vol. 6: Physics. 2nd ed. Vero Beach, FL: Rourke Educational Media, 2016. 64 pp.*

Teaches the essential concepts for elementary school science instruction. Topics include the basic objects in the sky, life-cycles, and properties of earth materials to the more advanced, structures of living systems, forces and motion and science technology. This volume covers physics.

Rourke Educational Media

Index

Book Index



Rourke's World of Science Encyclopedia

Rourke's World of Science Encyclopedia *Nancy Harris. Vol. 6: Physics. 2nd ed. Vero Beach, FL: Rourke Educational Media, 2016. 64 pp.*

Teaches the essential concepts for elementary school science instruction. Topics include the basic objects in the sky, life-cycles, and properties of earth materials to the more advanced, structures of living systems, forces and motion and science technology. This volume covers physics.

Rourke Educational Media

Index