Light Energy
Background Information

OPAQUE, TRANSPARENT, TRANSLUCENT

Often in life, we take many things for granted. Light is something we think will always be there when we need it. Experiencing power failure to a home can cause many problems. One of the problems is what do we do after the sun sets for the day. In a situation like this, we soon realize that without a source of light, we are unable to see any object. We stumble over chairs, bump into walls, knock objects off of tables and trip on stairs. We quickly become bored because we can't read, write or play games.

Now, we truly understand that light is needed in order for us to see objects. What kind of light can we use if the sun has set and the electricity is not working? Most people search for alternate sources of light such as candlelight, firelight, battery operated flashlights, or kerosene lanterns.

In this first lesson of the SciKeys 5th grade light energy module, how light interacts with different types of matter will be explored. Light is a form of energy which is visible to the human eye. Under normal conditions light from distant sources behaves like it travels in a straight line. However, it can be manipulated to take detours, mostly in straight lines.

Students should be encouraged to use flashlights or maglites to explore their surroundings and observe what happens to the light as it strikes an object or material. Objects or materials are usually described as being transparent, translucent or opaque. In some cases, light may be fluorescent.

Students have seen demonstrations of transparent materials when the teacher uses a transparency on the overhead projector in the classroom. Students may not realize that there is actually a light bulb in the projector. This might be a great time to show students the bulb.
Students have been exposed to all types of transparent material such as glass, some plastic, very thin material, water and air. However, no one has made the connection to the concept of light energy for them. When light is directed toward a transparent material, the light is able to pass all the way through the material.

Translucent materials such as frosted glass windows, some plastics, fog or thin paper allow some light to pass through it. Light does not pass directly through the materials. It changes direction many times and is scattered as it passes through. This scattering of the light makes objects on the other side of a translucent object appear fuzzy and unclear.

Students do not think of opaque materials such as: walls, desks, apples, pencils, thick paper, wood, stone, metals etc… as needing or interacting with light. However, without light, we would not see the object or the color of the object. Opaque materials allow absolutely NO light to travel through. All light is either reflected by the object, refracted by the object, and/or absorbed and converted to heat. In the lesson, Conservation of Light Energy, students will begin to understand the importance of light interactions with opaque materials.

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REFLECTION

www.science.howstuffworks.com/light.htm

Introduction

We see things every day, from the moment we get up in the morning until we go to sleep at night. We look at everything around us using light. We appreciate kids' crayon drawings, fine oil paintings, swirling computer graphics, gorgeous sunsets, a blue sky, shooting stars and rainbows. We rely on mirrors to make ourselves presentable and sparkling gemstones to show affection. But did you ever stop to think that when we see any of these things, we are not directly connected to it? We are, in fact, seeing light -- light that somehow left objects far or near and reached our eyes. Light is all our eyes can really see. The other way that we encounter light is in devices that *produce* light -- incandescent bulbs, fluorescent bulbs, lasers, lightning bugs, and the sun. Each one uses a different technique to generate photons.

What is Light?

Light is a part of the electromagnetic spectrum that is called visible light. Light is believed to travel in rays. So, it is sometimes referred to as a ray model.

A second look at what is light: The classical description says light is an electro-magnetic wave. This means that it is a varying electric and magnetic field, which spreads out or propagates from one place to another. It is not a physical substance. The modern quantum mechanical description says that light can also be considered to be particles called photons. These carry energy and momentum but have no mass. In both descriptions, the light energy is carried by a very real and observable mechanism. But I would not call it a physical substance.

Why is it that a beam of light radiates outward? What is really going on? To understand light waves, it helps to start by discussing a more familiar kind of wave -- the one we see in the water. One key point to keep in mind about the water wave is that it is not made up of water: The wave is made up of energy traveling through the water. If a wave moves across a pool from left to right, this does not mean that the water on the left side of the pool is moving to the right side of the pool. The water has actually stayed about where it was. It is the wave that has moved. When you move your hand through a filled bathtub, you make a wave, because you are putting your energy into the water. The energy travels through the water in the form of the wave.

All waves are traveling energy, and they are usually moving through some medium, such as water. A water wave consists of water molecules that vibrate up and down at right angles to the direction of motion of the wave. This type of wave is called a transverse wave.

Light waves are a little more complicated, and they do not need a medium to travel through. They can travel through a vacuum. A light wave consists of energy in the form of electric and magnetic fields. The fields vibrate at right angles to the direction of movement of the wave, and at right angles to each other. Because light has both electric and magnetic fields, it is also referred to as electromagnetic radiation.

The wavelengths of the light we can *see* range from 400 to 700 billionths of a meter. But the full range of wavelengths included in the definition of electromagnetic radiation extends from one billionth of a meter, as in gamma rays, to centimeters and meters, as in radio waves. Light is one

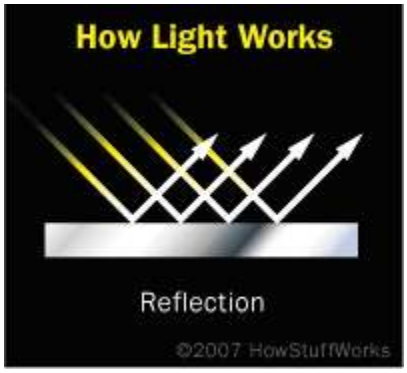
small part of the spectrum. The website www.science.howstuffworks.com/light.htm has some excellent pictures that are moving and can show several areas of this.

When Light Hits an Object

When a light wave hits an object, what happens to it depends on the energy of the light wave, the natural frequency at which electrons vibrate in the material and the strength with which the atoms in the material hold on to their electrons. Based on these three factors, four different things can happen when light hits an object: 1) The waves can be **reflected** or **scattered** off the object; (2) The waves can be absorbed by the object; 3) The waves can be refracted through the object; 4) The waves can pass through the object with no effect. More than one of these possibilities can happen at once.

When light is reflected?

The atoms in some materials hold on to their electrons loosely. In other words, the materials contain many free electrons that can jump readily from one atom to another within the material. When the electrons in this type of material absorb energy from an incoming light wave, they do not pass that energy on to other atoms. The energized electrons merely vibrate and then send the energy back out of the object as a light wave with the same frequency as the incoming wave. The overall effect is that the light wave does not penetrate deeply into the material.



In most metals, electrons are held loosely, and are free to move around, so these metals reflect visible light and appear to be shiny. The electrons in glass have some freedom, though not as much as in metals. To a lesser degree, glass reflects light and appears to be shiny, as well.

A **reflected wave** always comes off the surface of a material at an angle equal to the angle at which the incoming wave hit the surface.

You can see for yourself that reflected light has the same frequency as the incoming wave. Just look at yourself in a mirror. The colors you see in the mirror's image are the same as those you see when you look down at yourself. The colors of your shirt and hair are the same as reflected in the mirror as they are on you. If this were not true, we would have to rely entirely on other people to tell us what we look like!

When light is scattered?

Scattering is merely reflection off a rough surface. Incoming light waves get reflected at all sorts of angles, because the surface is uneven. The surface of paper is a good example. You can see just how rough it is if you look at it under a microscope. When light hits paper, the waves are reflected in all directions. This is what makes paper so incredibly useful -- you can read the words on a printed page regardless of the angle at which your eyes view the surface.

Another interesting rough surface is Earth's atmosphere. You probably don't think of the atmosphere as a surface, but the atmosphere is "rough" to incoming white light. The atmosphere contains molecules of many different sizes, including nitrogen,

oxygen, water vapor and various pollutants. This assortment scatters the higher energy light waves, the ones we see as blue light. This is why the sky looks blue.

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REFRACTION

Light is a form of energy that is visible to the human eye and is common in our everyday lives. Light can be treated as if it travels in a straight line through transparent materials such as air, water, glass, or clear plastic. A ray of light will continue until it interacts with an object. At that time, the ray of light will be absorbed, reflected or refracted. A narrow beam of light aimed at a mirrored surface will provide examples of reflection. An object such as a pencil or straw in a clear glass of water will provide evidence of refraction. When the light passes through the glass, the light changes speed. The light changes speed again when it enters the water. Therefore, the eye assumes no refraction has taken place only a change in the placement of the object. In addition, a rainbow provides evidence of refraction. Light passes through a prism (a collection of raindrops can be a prism) and white light is bent/separated to reveal the visible colors of the spectrum. The visible spectrum is white light and includes red, orange, yellow, green, cyan and violet. ROYGBIV is no longer used as a mnemonic device to remember the colors of the rainbow because indigo is no longer included. In the 1700's, what we call blue was called indigo. So, real colors of the rainbow are red, orange, yellow, green, cyan and violet. Cyan has replaced the "old" blue/indigo.

Additional resources:
The websites below provide videos and additional information.
http://www.teachersdomain.org/resource/lsps07.sci.phys.energy.lighttravel
http://www.promotega.org/hgr07009/index.htm (site created by 5th graders)
http://www.exploratorium.edu/snacks/blue_sky/index.html

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CONSERVATION OF ENERGY: ABSORPTION

All waves are traveling energy. Energy comes in different forms such as: light energy, sound energy, and heat energy. The law of conservation of energy states that the total amount of energy remains constant in an isolated system. Therefore, energy is not created or destroyed. The law of light energy would indicate the total amount of light energy entering a system will be equal to the amount of light that is reflected refracted and/or absorbed. Energy in an isolated system can change form, for instance light energy from the sun in that isolated system changes to heat energy when it reaches our skin. This is why our skin feels warm when directly exposed to sunlight.

The sun is our major source of light. The sun emits waves through the empty space and enters Earth's atmosphere to reach everything on Earth. As a result, the waves from the sun light up our day; change to heat energy to warm our air and water; and are stored as energy in green plants.

Light waves are energy in the form of electric and magnetic fields. In most cases, light expands on a spherical wave front and does not need a medium to travel through. Light travels in waves. If we are far enough away from the light source, the wave front appears "flat" and we can use the "ray model" to demonstrate light traveling in straight lines. Light from the sun travels in waves, but the light wave behaves as if it travels in a straight line. This model can be used to describe how light reacts to different types of matter. But, it does not explain why it reacts in this manner.

Waves travel in a series of frequencies. In absorption the frequency of the incidental (incoming) light wave is near the amount of energy needed to move the electrons in the material to the next orbital energy level. Matter comes in four forms: solids, liquids, gases and plasma. In solids, the molecules are packed very tightly; in liquids, molecules are packed less tightly; in gases, molecules move more freely; and in plasma atoms have so much energy and are moving so much, their outsides come off! This is important to the absorption of light because when light hits a material where the frequency of the incoming light is near the energy level of the electrons in the material, the electrons of that material take in the energy from the light wave and are able to move to the next energy level.

When the electrons are held tightly, they pass the energy on to the nuclei of the atoms. This speeds up the atoms which cause them to hit other atoms in the material. The energy from the vibrations is transferred to heat energy. The material may then feel warm to the touch or may transfer that heat energy to other materials behind it. This why wearing dark clothing is not a good option in the summer months when the sunlight reaches us more directly.