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DISCOVERY MUSEUM

Light & Lasers

Teacher Resource Guide

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Light & Lasers

Light is a form of energy. All different kinds of light – electric light, sunlight, firefly light, and laser light – have this in common. It helps to remember this when thinking about the different things that light can do, from illuminating rooms, to making heat, to switching things on and off, to cutting through metal.

Laser light is just one of many forms of light. It exists in high and low energy forms, which helps to account for the many different applications for which lasers are used. In order to understand laser light, it is useful to compare it to ordinary light such as sunlight or electric light.

Because people are more familiar with ordinary light, it is helpful to begin by describing its properties.

Flashlight Demonstrations

Materials

flashlight
mirror
prism

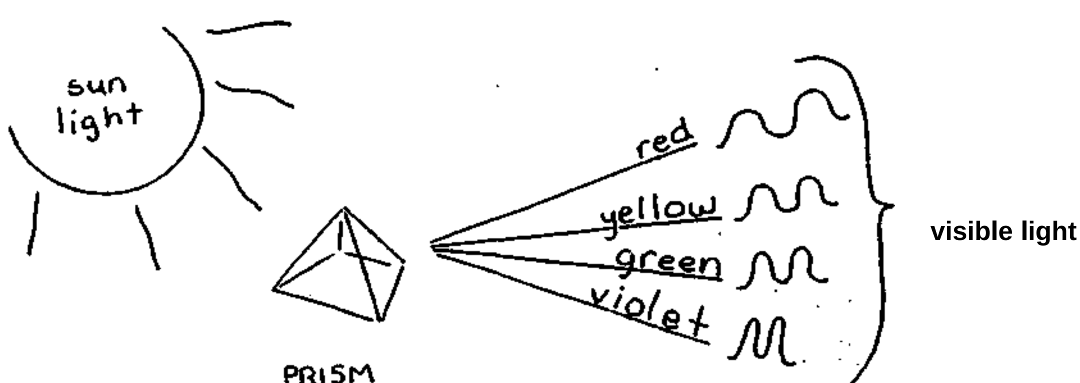
Procedure

Ask your students if they could see a beam of light from a flashlight if it were pointed straight up outdoors on a sunny day. Why or why not? They will probably say no, because the brightness drowns out the light. Ask them what parts of their body they see with, and when they say their eyes, ask how a beam of light pointed away from their eyes could possibly get back to their eyes? While you ask this, point a flashlight away from them into a mirror so the light is reflected back to them. Ordinary light must be reflected in order to be seen. You can reflect light from the flashlight off the walls, ceiling, clock, etc., but it needs to reflect off something to be seen. Even in dark movie theaters, the beam of light from the projector is visible because it is reflecting off dust particles in the air.

Next, turn on the flashlight and point it at the ceiling. Ask what color it is. All color responses will be correct. Anyone who answered white will have said the scientific term for this kind of light. Actually, "white" light is a misnomer. With the room lights off, shine the flashlight through the prism at the ceiling to show that "white" light is simply a mixture of all the colors in the rainbow. In fact, rainbows form when light shines through drops of water in the sky that refract the different colors of light into different places.

Finally, shine a beam of light onto the chalkboard from a short distance away. Ask a student to circle the illuminated area on the board. Ask the class what will happen to the circle when you back up. Back up ten steps and circle the illuminated area. It will be significantly larger.

These are all properties of "white" light: it needs to be reflected in order to be seen, it can be broken into all the colors of the rainbow when shone through a prism, and it spreads out quite rapidly.



Laser Demonstrations

Materials
laser
spray bottle
prism

Procedure
Set up the laser so it is pointed at a white wall or projection screen. Turn it on and ask what differences can be seen between laser light and flashlight light, or "white" light. Most classroom lasers are helium-neon lasers and appear red. If someone answers that the laser looks red and the flashlight looked white, ask what they think will happen when the laser is shone through a prism? Put the prism in front of the laser, and they will see that it does not break up into colors; it remains red. This is because laser light is made up of one, and only one, wavelength of light. All different colors of light are light waves that travel at different wavelengths.

Orient the laser so it is pointed across the front of the room and ask if your students can see the beam of light coming from the laser. They will be able to see the dot where the light hits the wall, but unable to see the beam extending from the laser to the dot. Ask why not? Your students should say that it is not reflecting off of anything. Take a spray bottle and spray a mist of water along the length of the beam (or clap out some chalk dust from erasers into the beam). The beam should become visible. Ask what they believe is happening to allow them to see the light. They see it now because the light can reflect, or bounce off, the water or chalk particles and travel to their eyes.

Finally, repeat the experiment of circling a beam of light shone on the chalkboard using the laser. You will find that the laser beam does not spread out appreciably. This is because laser light is just one color and therefore one wavelength. The different colors of white light are caused by different-sized wavelengths, which interfere with each other and cause the light to spread. Imagine a group of people with very different strides trying to walk in a group in the same direction. They would get in each other's way if they didn’t spread apart. Laser light is like a group of soldiers marching with exactly the same stride so they can stay in a tight formation. Most helium-neon lasers in classrooms will spread out about 6 feet over the course of one mile. Some lasers are so finely made that a beam of light can shine to the moon, where scientists have placed several mirrors less than a mile apart, which then reflect the light back to earth, allowing scientists to measure the exact distance to the moon!

These are the differences between white light and laser light: both need to be reflected in order to be seen, and white light is a mixture of all the wavelengths of light and spreads out rapidly, whereas laser light is made up of only one wavelength of light and does not spread out much at all.

Applications of Lasers

Ask your class what uses they know of for lasers, either real or in movies. As they mention applications, try to help them see which properties of laser light make it appropriate for that application. They will find that the property of not spreading out is useful in both large and small applications.

For instance, using laser light to blow things up and cut through metal works because lasers are concentrated beams. If the beam were to spread out too far, the cut would be sloppy. There are many examples, such as greeting cards, where a laser has etched intricate patterns. The reason that small classroom lasers do not cut through your hand while some lasers can cut through metal is that the energy coming out of a classroom laser is less than that of one AA battery. High energy, metal-cutting lasers are useful because there is no contact with a blade, less chance for slipping or sloppiness, and no blades need be sharpened.

When I ask whether people can think of small applications for lasers, I usually ask how many people have lasers in their home. Usually, at least half the people in any class don't know they have lasers at home. CD players, DVD players, and laser printers all contain lasers. CDs are smaller than records, yet they hold more music. Therefore, the laser beam that reads the musical information on a CD by bouncing light off of it and reading it back must be smaller than the needle on a phonograph that reads musical information by riding along the crests and troughs etched into the grooves of a vinyl record. It must not spread out if it is to read the musical information accurately. A laser printer scans text with a small laser beam, which reflects off the white space between letters but does not bounce off the letters. Because the beam is so small, it enables type and graphics to be printed more accurately than dot printers.

Laser surgery needs beams that are small and accurate. Laser surgery also reduces the possibility of infection because there is no scalpel to sterilize and less chance for germs to spread. Checkout scanners in supermarkets are a very common everyday laser application. Like laser printers, they scan along the bar codes on product labels and reflect off the white lines. Each pattern is different and the laser must not spread out if it is to distinguish between two similar patterns.

There are many other uses for lasers. A good assignment would be to identify and research some of them.

How Lasers Work

Lasers consist of a vacuum tube, similar to the tube in fluorescent light bulbs, which have mirrors on both ends, and particular gases inside. One mirror has a tiny hole in the center. When electricity flows through the gas inside the vacuum tube, the gas will glow, just like electricity makes the gas in fluorescent light bulbs glow. It does this by energizing an electron, which orbits around the nucleus of one of the gas molecules. Electrons orbit around nuclei, a bit like planets around the sun. When the electrons are energized, they jump out to an orbit that is more distant from the nucleus. This is an unstable, high-energy arrangement for the molecule, and eventually the electron will fall back into its normal orbit. When it does, it releases some of the energy that it had in the higher energy orbit in the form of light. This light will be at a particular wavelength, and the light given off from that electron will bounce back and forth between the mirrors of the vacuum tube until it finds the hole in one of the mirrors. The wavelength of light emitted is specific to the gas used in the laser. This is how lasers can emit very fine beams of light that are all the same wavelength.

Laser Light Shows

One application of lasers is entertainment. Many students may have seen laser light shows and there are similar components to each kind of light show. The most basic component is the laser. Lasers can be red (helium-neon gas), blue (argon gas), green (krypton gas), or other colors, depending on the gas mixture inside the laser tube. Another component is one or more mirrors. You can make fairly interesting laser patterns simply by waving the laser around. The laser only forms a dot on a wall when still. When the laser is moved rapidly, your eyes cannot follow the dot quickly enough so it looks like a two-dimensional pattern. To make precise patterns, you have to move the laser precisely. For this, you need a computer. It is easier to hook up a computer to control the position of the mirrors than it is to change the position of the laser.

In our laser show, people will control the spinning speed of two mirrors, instead of a computer. We will use hand generators that are wired to small motors fastened to the mirrors. You will be able see the effect of changing speed, as the image formed will also change.

Try to think of other methods of creating laser patterns, i.e., shine a beam up through the surface of a glass of water while you jiggle it. Have fun, but remember not to look directly into the laser beam. This could harm your eyes.

Making a Laser Spirograph

Materials

laser
plywood base 6" x 4" x 1/2"
2 1.5-3 volt motors from Radio Shack
2 mirrors 1.5" x 1.5" (preferably front surface mirrors)
2 volume control knobs from Radio Shack with flat ends
2 1" pieces of dowels that fit into the volume control knobs
4 small "L" brackets with screws
clamp for drilling
electric drill with bits the size of the motor and the size of the motor's shaft
2-ton epoxy
2 pieces of plywood 2" x 3 " x 1/2"
2 Genecon hand generators from Arbor Scientific or two power supplies with clips

Procedure

Epoxy the front of the knobs to the center of the back of the mirrors. Allow to dry 24 hours. Drill a hole the size of the motor's shaft into the center of one end of each dowel. Epoxy the other end of the dowel into the back of the volume control knobs. Drill a hole the size of the motors in the centers of the 2 small pieces of plywood. Epoxy the motors into the holes so the back of the motors are flush with the plywood. Allow to dry 24 hours. Carefully epoxy the dowels to the shafts of the motors and allow to dry, propping them up level so no epoxy adheres the shaft to the motor. This would prevent it from spinning. Allow to dry 24 hours. Mount the mirror and motor units onto the top hole of two "L" brackets halfway up the width of the small piece of plywood on either side. Mount each of the mirror-motor units to the plywood base facing each other with screws through the base of the "L" brackets into the plywood. Mount your laser so it reflects from one mirror to the other, then onto the wall or screen. Adjust the position of the laser and the angles of the mirrors until you can spin each mirror and get fully circular patterns on the wall.

Clip the leads of your hand generator or power supply to the motors and spin them simultaneously to get laser spirograph patterns. Try changing the speed and direction of spinning to get different patterns. A variety of patterns result from the circles being slightly offset (unless you mounted and glued everything absolutely centered) and from the different angles of the mirrors as they spin.

Resources

<u>Print Resources</u>

- *Light Action! Amazing Experiments with Optics*, Vicki Cobb, SPIE Publications, 2005
- *How Lasers Work*, Ryan Jacobson, The Child's World Inc., 2011
- *The Way Things Work Now*, David Macaulay, HMH Books for Young Readers, 2016
- *Light: Shadows, Mirrors, and Rainbows*, Natalie Rosinsky, Picture Window Books, 2002
- *Light is All Around Us*, Wendy Pfeffer, HarperCollins, 2015
- *Fun Experiments with Light: Periscopes, Kaleidoscopes, and More*, Rob Ives, Hungry Tomato, 2017

<u>Online Resources</u>

- Optics4Kids, a site with information about lasers and optics, including activities, resources, and information.
  - https://www.optics4kids.org/
- What is a Laser? via NASA SpacePlace
  - https://spaceplace.nasa.gov/laser/en/