Uncovering the Secrets of Light

Hands-on experiments and demonstrations to see the surprising ways we use light in our lives. Students will also learn how engineers and scientists are exploring new ways in which the colorful world of light can impact our health, happiness and safety while saving energy and protecting the environment.

Activities (Have each activity checked off by an ERC student when you have completed it.)

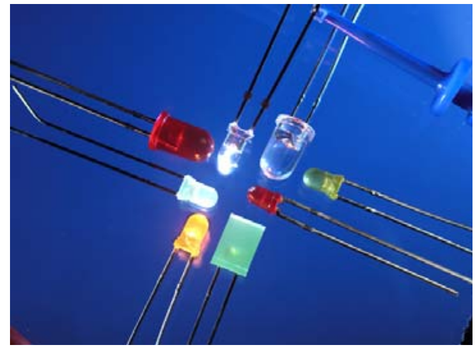
1. Turning on an LED by connecting it correctly to a battery.
2. Optical Communication – Using LED flashes to remotely control electronic components such as televisions and to give music a ride on a light beam.
3. Observing the colors produced by different sources of light.
4. Light Saber – A discharge lamp that shows us that we are conductors just like wires and that can magically turn on a special kind of lamp without touching it.
5. USB Microscope – Using light to see small things, especially how displays work.
6. Pulse Width Modulation – Controlling light by turning it on and off. Bright light comes from having it on more than off.
7. Theremin – A musical instrument that is played without touching it.
8. Flat Panel Displays – What is polarized light and how do we use it to make TV and computer displays?
9. Magnetic Levitation – Using a light beam and a magnet to make a ball float in space
10. Coin Flipper – One magnet makes another magnet with the opposite pole so they can rapidly repel one another.

For all activities, there is some secret of light or how we use lighting marked with this image. You should answer the question about the secret.

Your Name: ________________________________

Today's Date: _______________________________

Activity #1



LED Circuit: Making Light with Electronics

Components:

LED (Light Emitting Diode)
Resistor
Wires
Battery

- We will now make a solid state light
- Such a light could be used to send flashing signals
- This is what traffic lights (red, yellow, green) are made from these days

The Light Emitting Diode is an electrical component. To operate it requires electricity to power it. For our experiment, we will get this electricity from a 9Volt battery

For this activity, you have a bag of parts and a protoboard. Remove the parts from the bag. The board has lines of holes marked with red, blue, black and green markers. First, we will build a simple configuration that lights up an LED.

1. Connect the red battery wire to a red hole in the protoboard and connect the black battery wire to a black hole
2. Insert the LED wires into the board. The shorter wire goes into a red hole and the longer wire into a green hole.
3. Insert one end of the resistor wire into a black hole and the other end into a green hole.
4. Have your circuit checked. If it is OK, connect the battery to the battery wires. Your LED should light up.

If your LED does not light up, remove it and insert it in the other direction. Also, you can add a second LED to your circuit. Do they both light up?

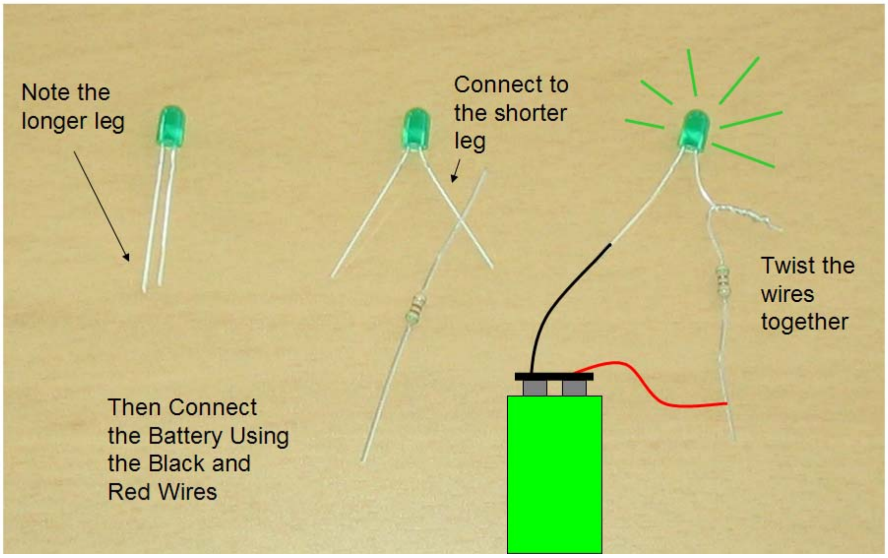
We will now modify the circuit slightly.

5. Remove the end of the resistor from the green hole and place it in a blue hole.
6. With the help of an ERC student, insert the blue potentiometer with the small white knob into the three holes, one blue, one green and one red. There are three wires from the bottom of the potentiometer.

Your LED should light up again. If not, turn the knob and it should. This configuration shows us one way to control the intensity of the light from the LED. Unfortunately, it is not a very efficient way of doing this, just simple and inexpensive.

Note: The parts in the bag are yours to keep. We need the protoboard returned to us, but you will still be able to make the LED light up at home by following the instructions found below.

First, connect the LED and the resistor, by twisting the wires together.



To light the LED, touch the metal ends of the black and red wires to the resistor and diode. This should cause the light to turn on. Again, if the LED does not turn on, try connecting the wires in the other direction.

True or False: An LED will only work with the battery connected one way. A standard incandescent light can be connected either way.

Question: Did both of your LEDs light up together? What colors are your LEDs?

Make a List of Some of the Things You Could Do or Make With LEDs:

1. **Flashing On-Off Light that reminds us that some electrical device is on and working.**

2.

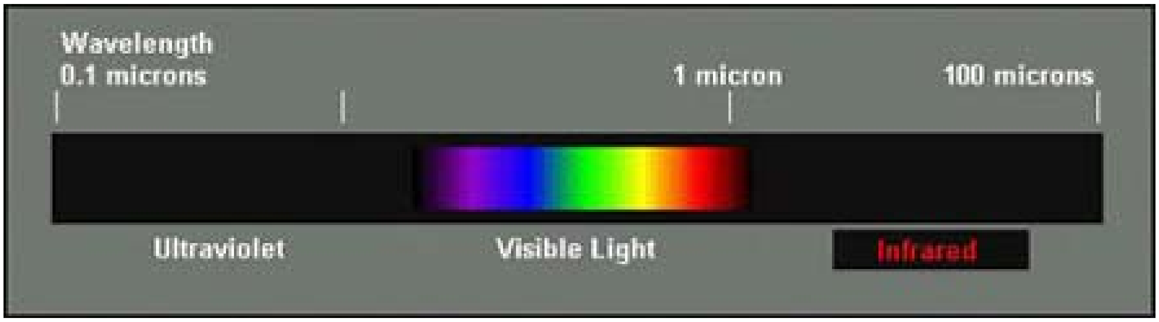
3.

4.

5. **Traffic Light**

Activity #2

Optical Signals: Using light to control the operation of televisions, etc. and to send music through the air.



Infrared Light – What is Infrared Light? It is light beyond red that is not visible to us. IR is given off by hot things. There is also ultraviolet light that is beyond blue. UV light gives us sun tans.

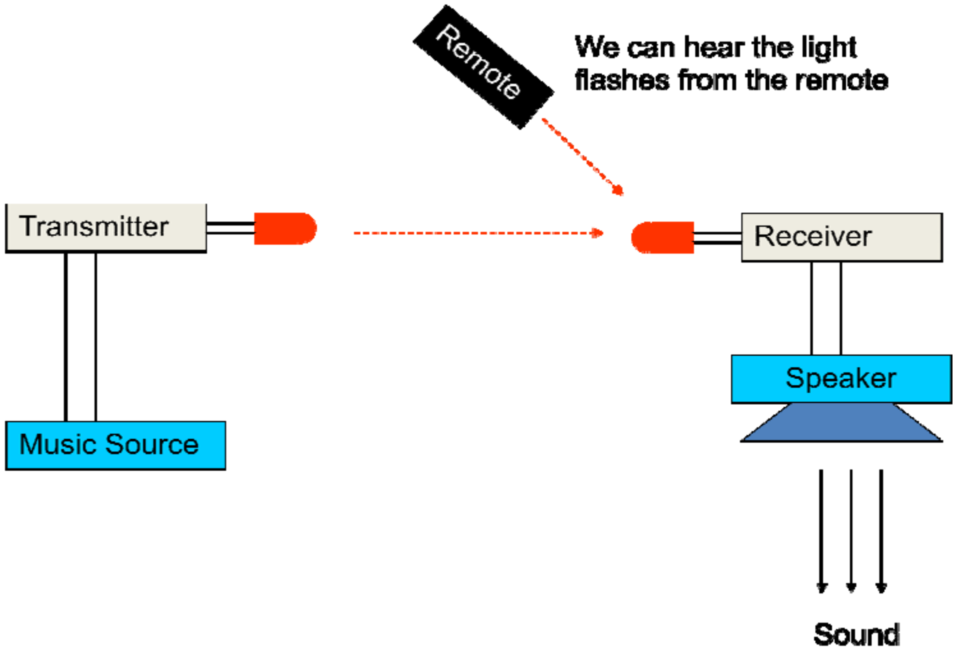
- Cannot be seen by humans
- Can be seen by digital camera
- Remote control sends IR light flashes to TV or any other device it is to control

Pushing a button on a remote control causes a particular sequence of light flashes to be sent to the TV or other device that is being controlled. The flashes are like a secret code that only the TV can understand and that we cannot see.

1. Using any available remote control device and a video camera, aim the remote at the camera and observe the light flashes. Can you tell the difference between the flashes sent by different buttons? (No – only the main flash can be seen. The individual flashes occur too fast to be seen by humans but the TV can tell the difference.)

2. Using the same remote control device, aim the remote at the receiver circuit for the audio transmitter and receiver combination (diagram on the next page). The device that receives the IR signal is a photo diode (it looks like an LED). You should be able to hear the pulses of light given off by the remote. Can you describe what they sound like?

Question: Which 'language' spoken by a remote did you like the best? (Name the brand of the remote control.)



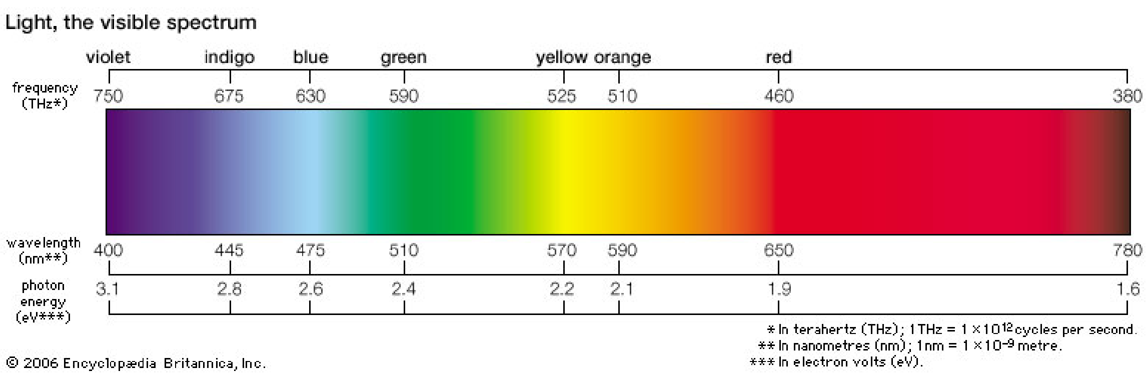
3. In the last step, you have tested the receiver. If you detected the sound produced by the remote, your receiver is working. Now you are to set up the music source and transmitter. Using a music source like an iPod, connect the input cable for the transmitter to the iPod. Making sure that the LED on the transmitter is pointing directly at the photo diode receiver (looks like an LED) on the receiver, turn on the music signal from the iPod. You should be able to hear the music from the speaker connected to the receiver.
    a. Block the light from the transmitter to the receiver. The sound from the speaker should stop.
    b. Move the transmitter and receiver apart. The sound should become weaker.
    c. Aim the transmitter so it does not send a signal to the receiver. The sound should go away.
    d. Use the optical fiber to direct the light from the transmitter to the receiver. That is, place one end of the fiber by the transmitter LED and the other end by the photodetector. You should be able to hear the music again.
    e. Re-align the transmitter and receiver and cover the entire experiment (transmitter and receiver) with some kind of material that blocks the background light from the room or turn the room lights off. The sound should become stronger. This is because the photo diode senses the increase in light due to the signal from the transmitter. If the room is too bright, it has a hard time seeing the light.

Question: What kind of light can a digital camera see that we cannot?

Activity #3

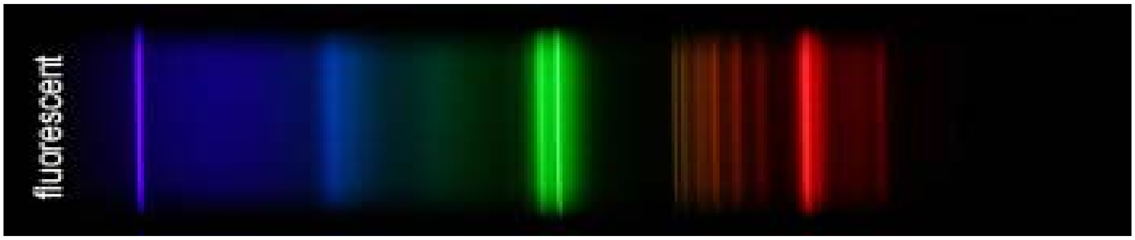
Other Sources of Light: Observing the colors that make up light

Light is made up of all the colors of the rainbow from blue to red. To be able to see the individual colors that make up sunlight, for example, we can use a simple device called a spectroscope. In the picture below, the spectroscope looks like a very small telescope. However, unlike a telescope, it has a small slit at one end that separates the colors into a display that looks like the visible spectrum below.

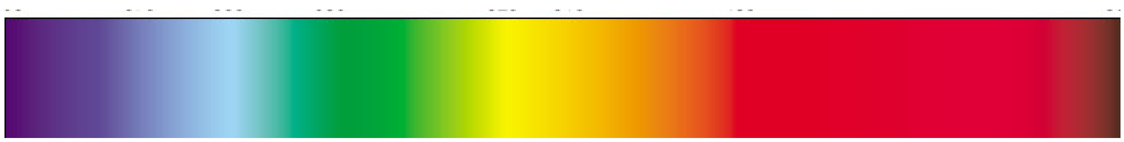


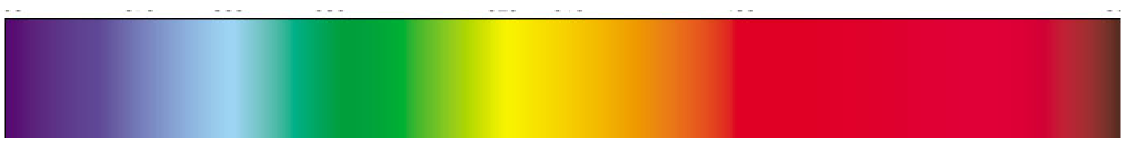
1. Before we use the spectroscope to look at the kind of light sources made by humans, we should first look at the light from the sun. Go to the nearest window and look out the window through the spectroscope. You should observe something like the picture above (just the colors, without all of the numbers).

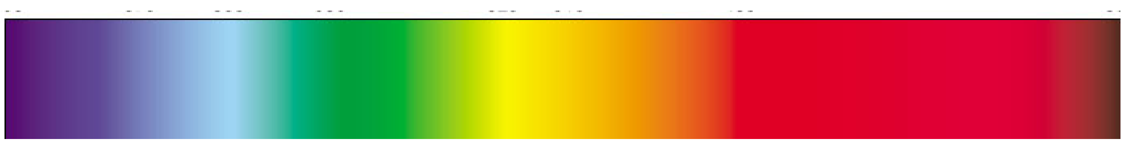
2. Next, observe several artificial light sources – fluorescent lamps, the light from a computer monitor. Note that the light you observe will look different than sunlight because there are bright lines that stand out in the spectrum. An example is shown below, where a type of fluorescent lamp is seen to have many bright lines. The lamps in the classroom will probably not produce this same pattern.

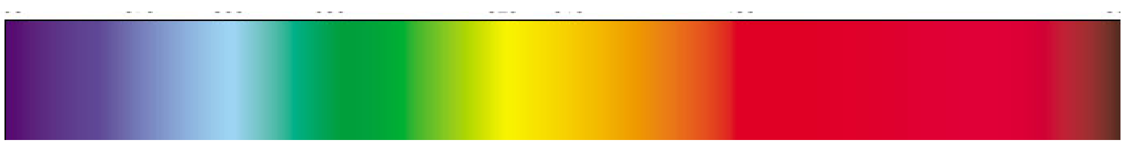


Observe at least two different light sources in the classroom and then (if you have time) show where you observe the brightest lines by sketching them on the spectra below. If possible, it is a good idea to turn off most other light sources in the room and to have all members of your group observe the light pattern before you sketch it.









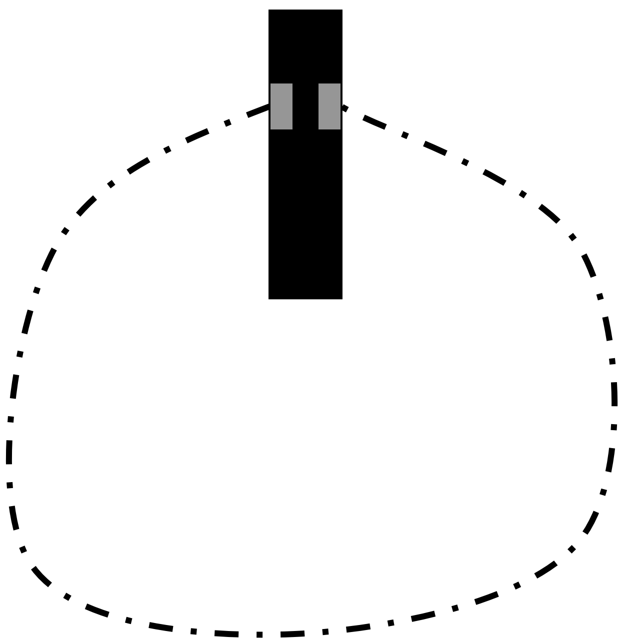
Question: Do all lamps produce the same kind of white light?

<u>Activity #4:</u>

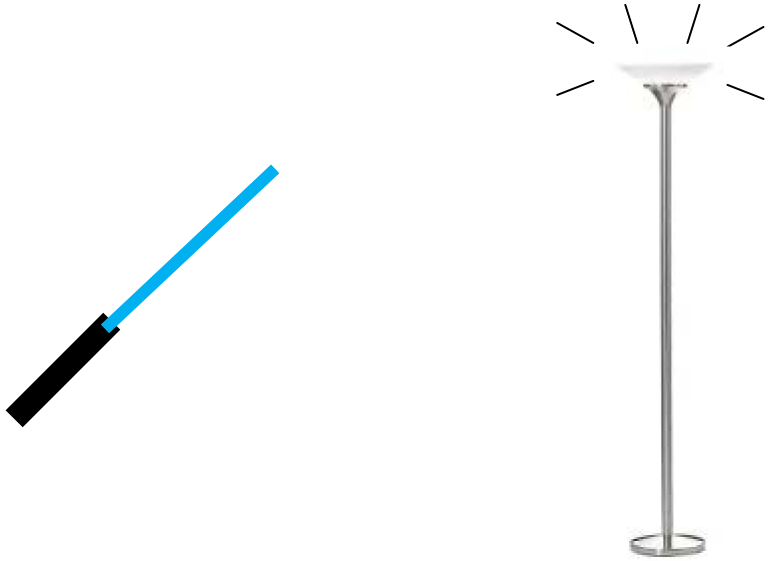
Light Saber – A discharge lamp that looks like the light saber from Star Wars

In this device, a light beam is caused to move up a glass tube when the person holding the handle connects the two metal contacts with their thumb or finger

To make this more interesting, and to show that we are all good electrical conductors, we will all hold hands and form a circle with the people at the end each making contact with one of the metal contacts. The length of the light beam is determined by how good the contact is, so having many people in the loop will probably make the beam rather short.



Each student should, thus, try to turn the beam on by themselves and then see if it is longer or shorter. The red beam is neon and the blue beam is argon. Once the beam is as bright as possible, it can be observed through the spectroscope.

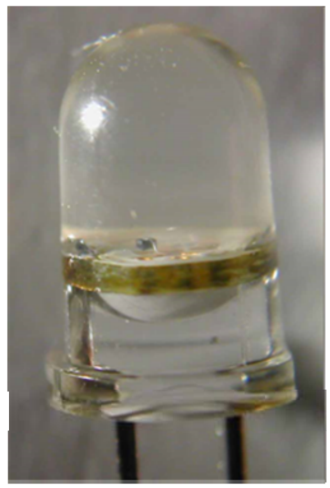


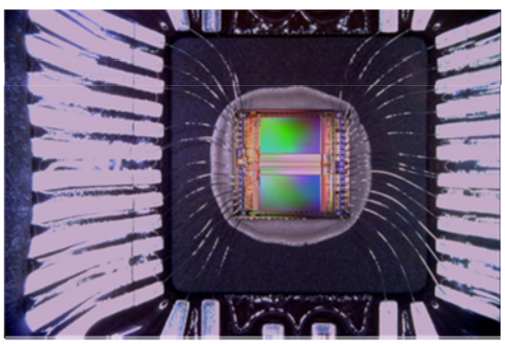
Bring the light saber close to the floor lamp without touching it. About one meter of separation is good. Turn on the light saber and you should also see the floor lamp turn on. This happens because the lamp is electrically very noisy and the floor lamp is a touch lamp. Touch lamps turn on when you touch them because you are acting like an antenna and you pick up electrical noise from the air. To act like an antenna, you much be a conductor, but we have already shown that we are conductors by holding hands and turning the light saber on.

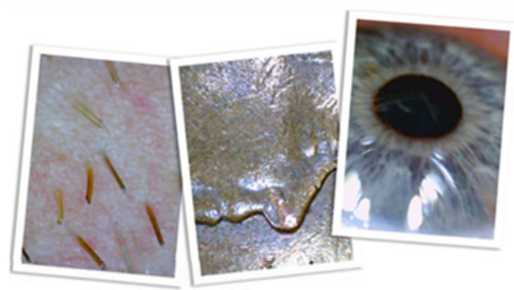
Question: Can you conduct electricity like a wire?

Activity #5

USB Microscope – Using a smart lighting, computer-based microscope to see small things.





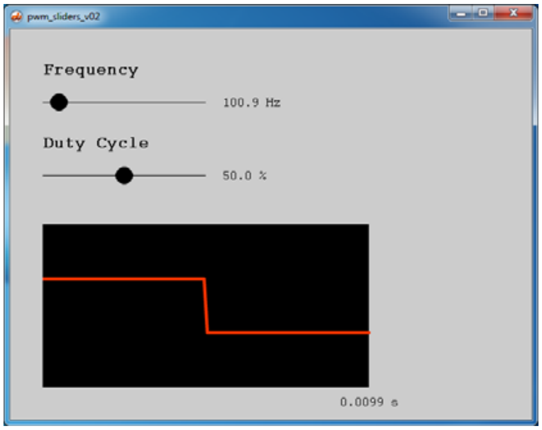


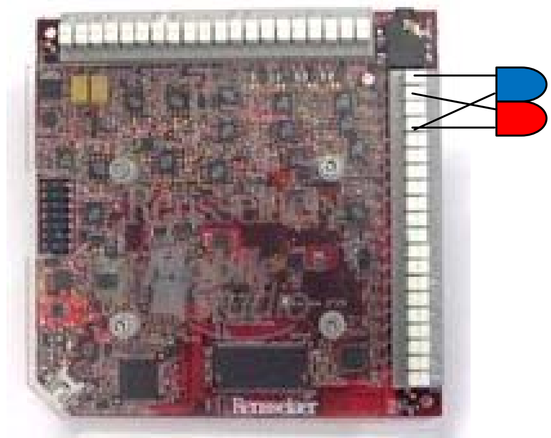
Question: Can you find the second picture of Lincoln on the US penny?

Question: How does a computer display make different colors out or red, green and blue light?

Activity #6

Pulse Width Modulation – How we fool our eyes into seeing different brightness while turning an LED on with exactly the same intensity. Also, how to mix colors to make a new color.





In this activity we see how we can flash an LED on and off to make it look bright and dim. The light is pulsed. The longer the on pulse and the shorter the off pulse, the brighter the light. Try different pulse widths to see this effect.

Also, if the light flashes more than 30 times per second (30Hz) we cannot see the light flash. Our eyes do not respond fast enough. To see the light flash, slow it down to 10Hz or less (1Hz is best) and you will see the light does indeed flash. Also, you will see that the two LEDs flash alternately so that when one gets brighter the other gets dimmer.

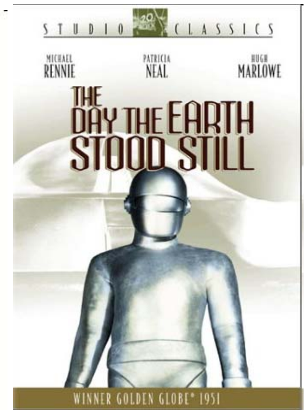
Movies and television images appear to move smoothly because they flash faster than we can see.

Question: What is the fastest rate of light flashing that you can see?

Question: What color do you get when you mix blue and red light from LEDs?

<u>Activity #7</u>

The Theremin – Maybe the strangest musical instrument ever made



In this activity we learn how sensors, like airport metal detectors, can sense that we are nearby. You can control the volume and pitch of this musical instrument by bringing your hands close to two metal electrodes. When you do this, you become part of the electrical circuit (a capacitor, actually), which changes the way it operates. In an airport metal detector, any metallic object you have will change the inductance of the circuit, but otherwise the effect is the same.

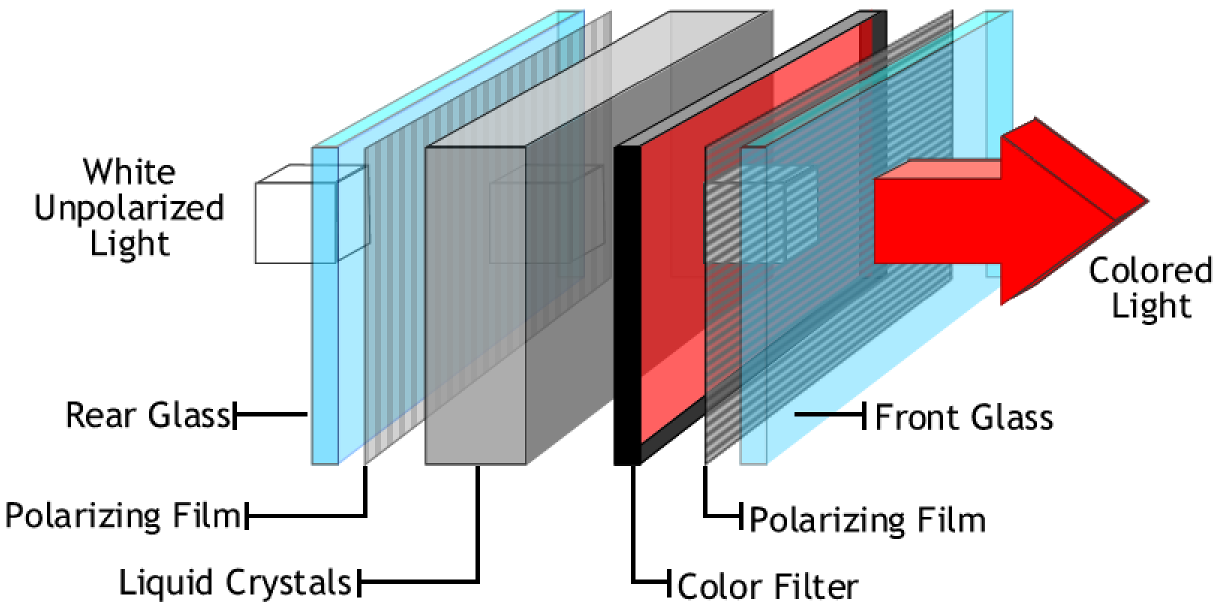
This instrument works by creating a beat frequency between two pitches that are too high for us to hear. The difference in pitch is very small, so we can easily hear it.

Instruments similar to this are used by many music groups. It is also used in science fiction movies to make weird and scary noises.

Question: What is the weirdest noise you can make with a Theremin? Can you make it play a song of some kind (Mary had a little lamb?)

Activity #8

Flat Panel Displays – How polarized light allows us to make Liquid Crystal Displays Work.

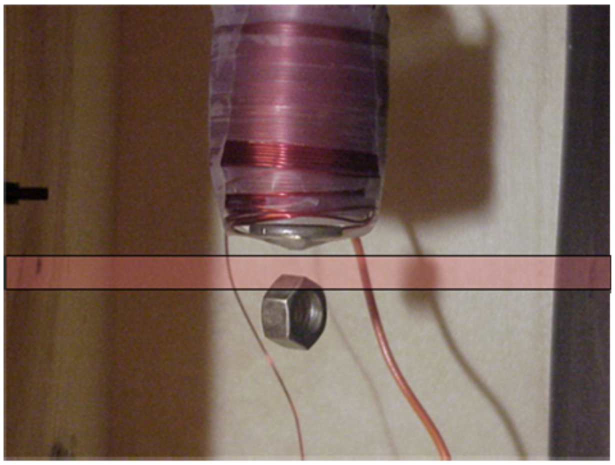


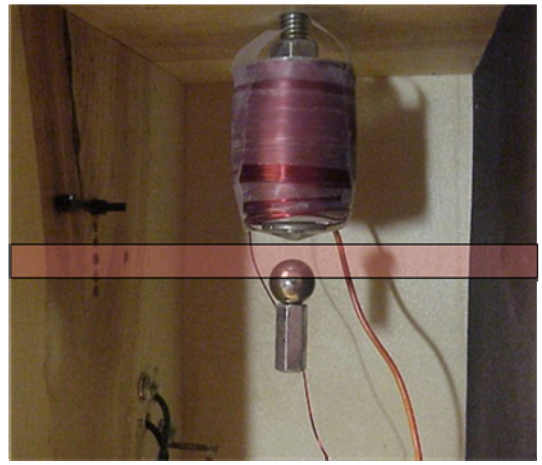
LCD displays use light polarizers like the ones we use for sunglasses and 3D displays to turn small dots of colored light on and off. To see that there is a polarizer in such a display, place a polarizing filter over a flat panel display and rotate it until the image goes away. Also use two filters to see the same effect.

Question: Can you describe what happens when you rotate a polarizing filter in front of an LCD display? What do you see?

Activity#9

Magnetic Levitation – Using a light beam and magnet to make a ball float in space





- Close up photos showing levitation of washer and ball bearing with magnet attached. Some preferred orientation is necessary for stability.

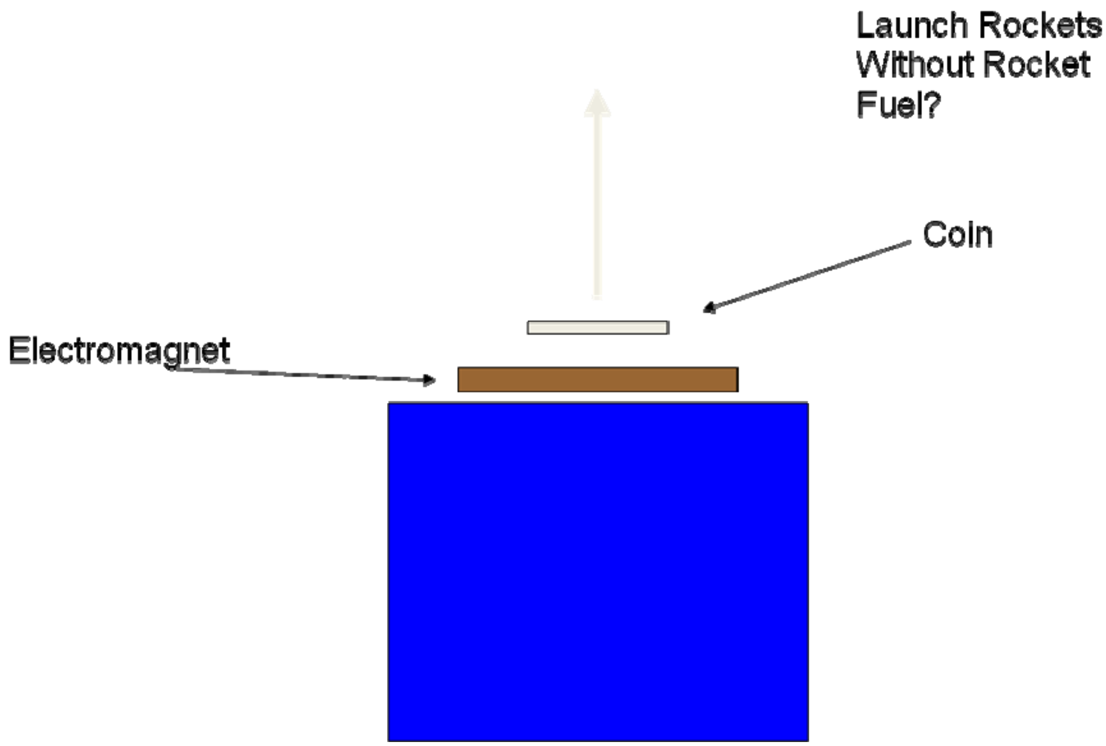
An invisible (IR) light beam 'sees' where the object is and tells the magnet how powerful it has to be to hold it in place.

In this activity, you should try to get the magnet to levitate the ball. Remember that you have to keep your fingers out of the beam of light, otherwise you will block the light sensor and the system cannot work. This is an example of a smart system that can do a job for us without us doing anything, at least once the ball in floating. The light beam is IR so we cannot see it, but we can definitely feel the magnet once the light beam tells it to turn on.

Questions: Can you identify where the beam comes from in the maglev support? Can you feel the magnet once you have the ball in the beam? Do you believe there is a light beam even though you cannot see it?

Activity #10

Coin Flipper – Using one electromagnet to repel another



In the maglev activity, we saw that a magnet can put a force on a ball that pulls the two objects together. There is a second kind of magnetic force that pushes things apart. The second force happens when one electromagnetic makes currents flow in another conductor (called eddy currents). The current in the second object also forms an electromagnet, but with its poles pointed in the opposite direction. Since north poles repel north poles and south poles repel south poles, the two magnets will repel one another. There is sufficient force produced to launch objects at high speed. In this case, we launch coins and similar disk shaped objects. Also required for this force is that the disk be a very good conductor but not magnetic. If it is magnetic, it will be both attracted and repelled and little will happen.

We can measure the speed of the coin using light, but that is not yet included in this activity.

Questions: What coin went the greatest distance? What coin went the least distance?