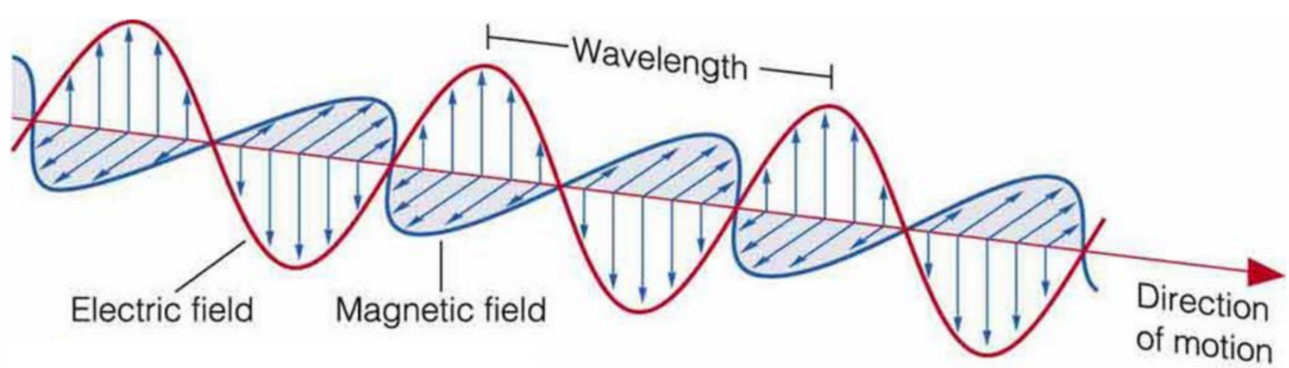
What is Light?

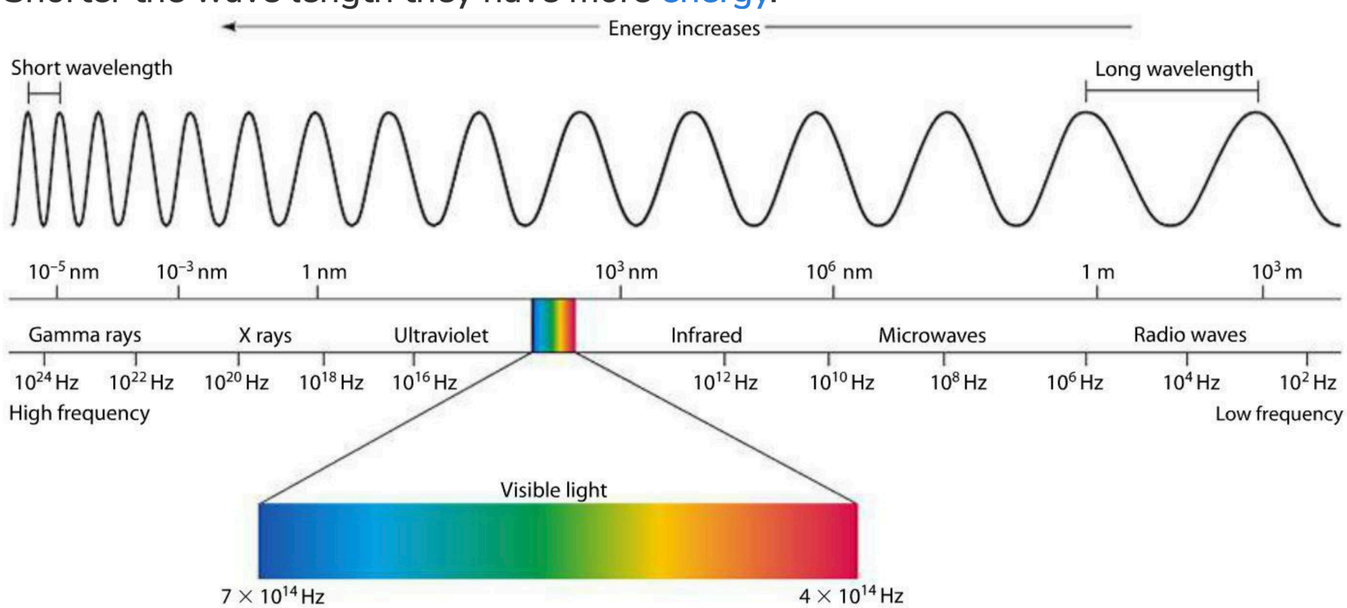
All sources of light have atoms that can absorb some form of energy, such as heat or electricity, and then emit energy in some form of **electromagnetic radiation** (**EMR**), such as visible light. Because electromagnetic radiation carries energy through space, it is also known as *radiant energy*. All types of EMR travel through a vacuum at the speed of light (186,000 miles per second), and have wavelike characteristics similar to those of waves that move through water. These characteristics include waves that have peaks and troughs with a consistent wavelength, and a fixed number of waves that pass a given point each second, which is known as the frequency of the wave. All EMR radiation has an electric field wave that is perpendicular to a magnetic field wave, as shown in the diagram below.



Electromagnetic Radiation (EMR)

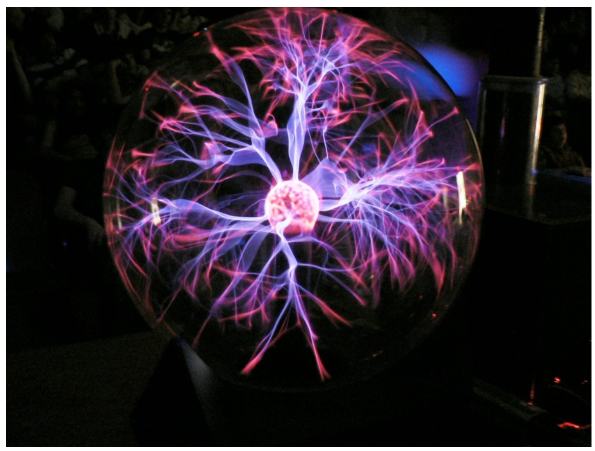
Since all forms of EMR travel through space at the same speed, the wavelength and the frequency have an inverse relationship. The longer the wavelength of the EMR, the lower the frequency and vice-versa. Also, as the wavelength becomes shorter, the frequency of the waves increases and a greater amount of energy is transmitted through space. A chart showing the ranges of the wavelengths and frequencies of various forms of EMR is below. Notice that the colors of visible light that we can see is only a very small portion of this spectrum of EMR radiation.

Shorter the wave length they have more energy.



Energy Changes in Atoms

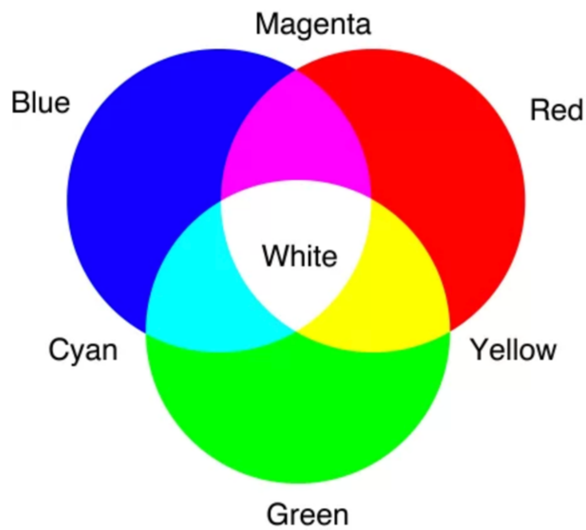
When atoms are heated or exposed to an electric current, the electrons absorb specific amounts of energy and jump to a higher level that is farther from the nucleus. These **"excited atoms" quickly lose this excess energy as a form of EMR when the electrons drop back down to lower energy levels**. Examine the poster to see how fireworks get their colors from added metallic substances.



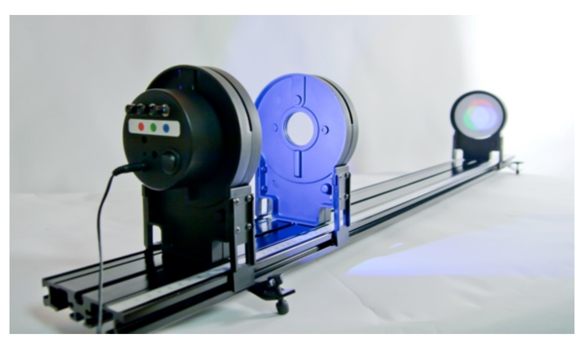
A **plasma globe** has a coil of wires inside that have a very high frequency current going through them. This shakes the atoms around the wires so hard that their electrons start to fall off and *a plasma made of electrons and ions is formed!* Inside the glass globe is a partial vacuum. Some of the air inside the ball has been sucked out to create a partial vacuum, which *makes electric sparks that can be seen*. If you dare, touch the globe so that the electrons can get to ground through you!!! Does the path of the sparks change if you touch the globe on top or on the sides? Try it to find out!

The Nature of Color

The normal human eye is able to see light that has wavelengths within the range of **red, green** or **blue** colors (RGB). When these colors of light are combined, they are **additive primary colors**, which create a lighter *color that is closer to white*. Examples of additive color sources include computers and televisions.



Combining one of these additive primary colors with equal amounts of another one results in the **additive secondary colors** of **cyan, magenta** and **yellow**. Combining all three additive primary colors in equal amounts will produce the color white. When mixed in varying proportions, the human eye can distinguish more than 100 shades of color.

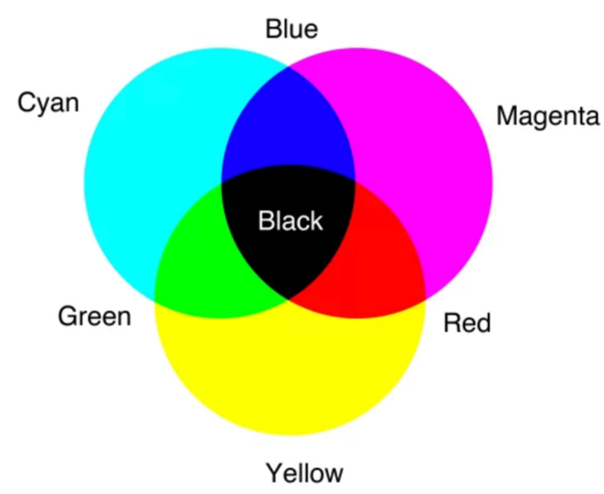


Additive color mixing can be demonstrated using the Vernier track and Color Mixer Kit. ***Turn on the light source and adjust the intensity of the LEDs in order to produce the additive colors*** *shown above and many others.*

Subtractive Color Mixing

Photographs, magazines and other objects of nature, such as a red apple, ***create color by subtracting or absorbing certain wavelengths of color while reflecting other wavelengths*** back to the viewer. This phenomenon is called **subtractive color**.

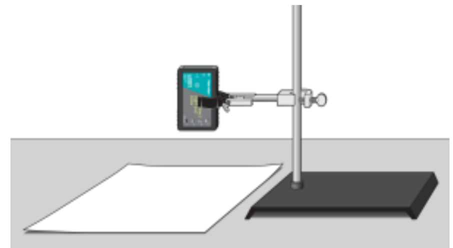
Subtractive colors refer to the **CMYK** or secondary colors of **cyan, magenta, yellow, and black**. In subtractive colors the light hits the surface of the objects, like photographs, and some or all of the colors of the light are absorbed (or subtracted) and the rest is reflected. When you combine all three CMY colors, *you produce a black color*.



Subtractive color starts with an object that reflects light and uses colorants (such as **pigments or dyes)** to subtract portions of the white light illuminating the object to produce other colors. It is the subtractive process that allows everyday objects around us to show color, such as the poster with colored glass.

Measuring the Components of Light

Using a Light & Color Sensor attached to a ring stand, measure the components of light that are reflected and absorbed by different colored pieces of paper.

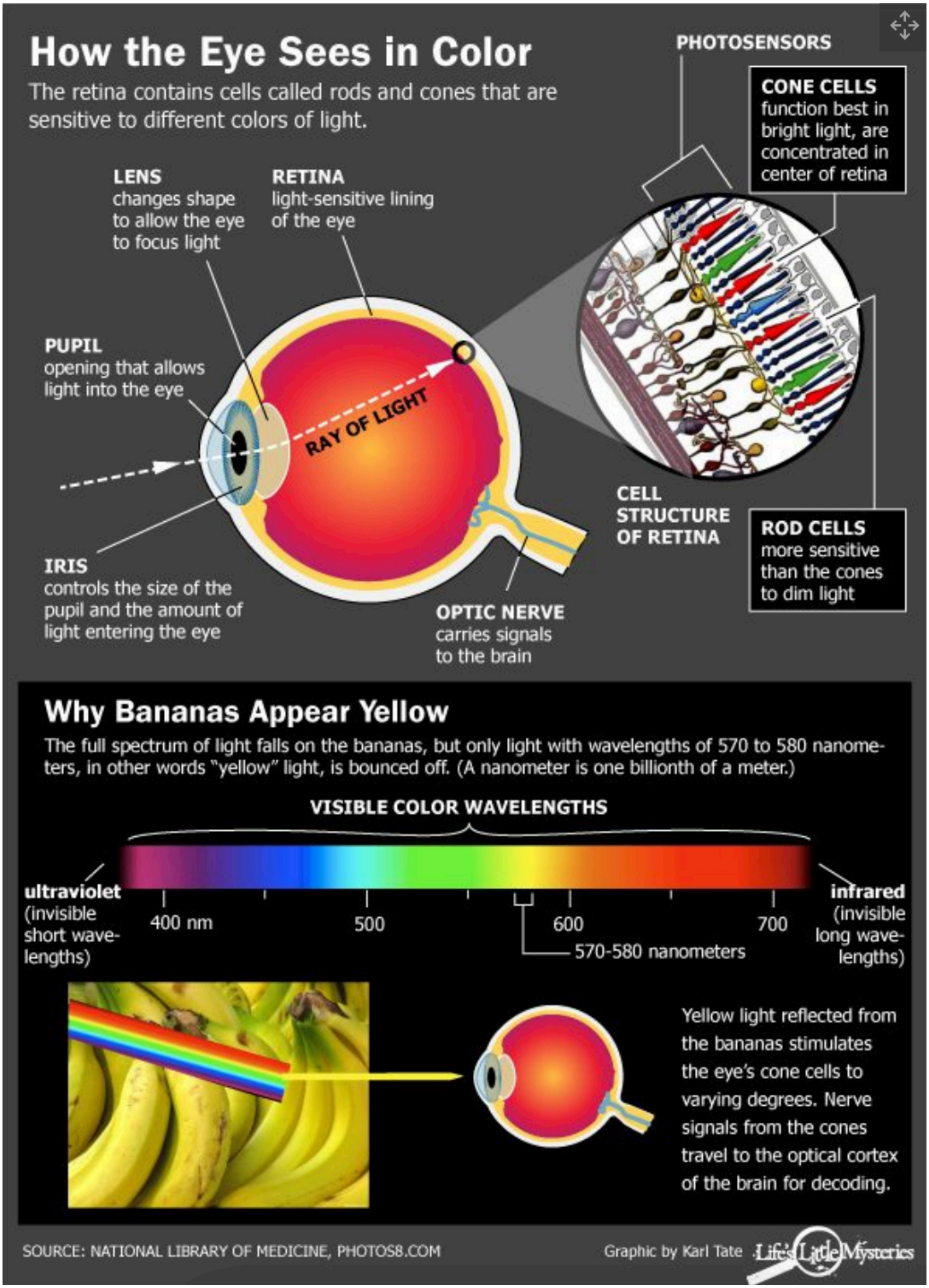


Begin with the sensor being positioned 5 cm above a piece of white paper as shown above. The sensor is set to & ***measure light brightness*** (lux = lumens/m^2) and ***amount of reflected red, green blue light*** (0 to 255)

1. With the sensor's LED light turned on, place a mirror on the paper directly under the light sensor. Record the values for the light intensity and the portion of each RGB color in your data table.
2. Remove the mirror and record these values for the white paper.
3. Calculate the reflectivity of the white paper using the relationship shown below:

   %reflectivity = (lux value for paper/lux value for mirror) x 100

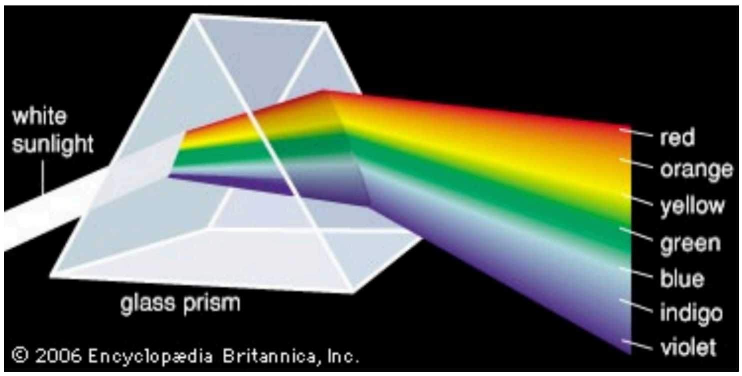
4. Which RGB colors were absorbed the most by the white paper? Record your observations.
5. Repeat this process using black paper, then various colored paper or colored filters. Record the results.



Originally published on Live Science by Stephanie Pappas.

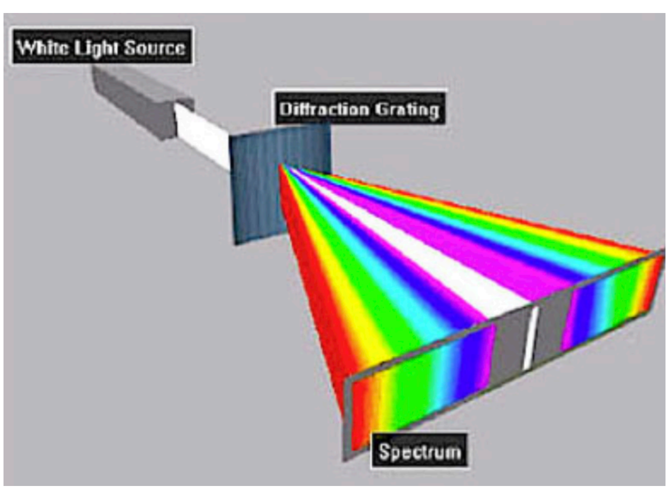
Separating White Light Into Its Colors

Isaac Newton discovered that *white light could be split into the colors of the rainbow when passed through a triangular-shaped glass prism*, as shown in the diagram below.



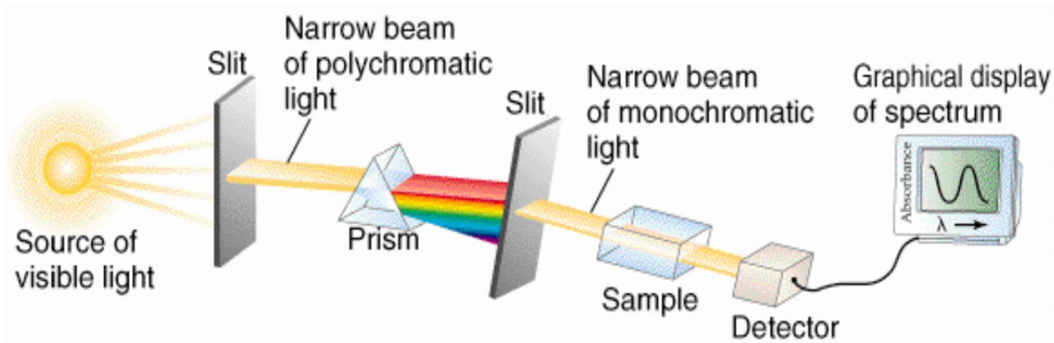
It was later discovered that a diffraction grating, which has equidistant parallel lines scratched onto a transparent material will create a similar effect in separating white light into its colors.

Try on the GloFX glasses to see how this works.



Analyzing Colored Solutions

A typical **Spectrophotometer** has a white light source that passes through a movable prism or diffraction grating to change the wavelength of the emitted color. This light will then pass through a solution and strikes a photocell or detector, which measures the *absorbance* or *percent transmittance* of the light.



Most sports drinks contain FD&C food dyes to color them. The type of dye present can be determined based on the absorbance pattern of known dyes when compared to those found in the drink.

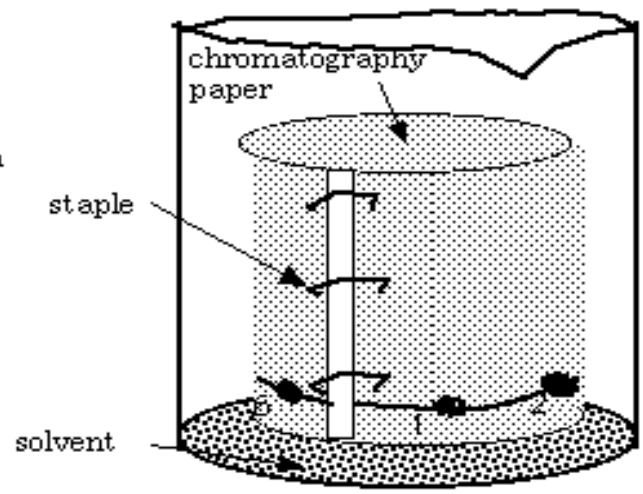
Directions: **Use a spectrophotometer connected to a computer running the Spectral Analysis App to record the absorbance plot for the dye(s) found in a sports drink**. Do this by filling a cuvette with the drink and placing it in the chamber so the light passes through the clear sides. Save this file. Then test the known dyes to find matching absorbance plots.

Paper Chromatography

Chromatography is a technique used to separate a mixture into its various colored components based on differences in the degree of attractive forces. The mixture is carried by the mobile phase (some type of solvent) across a stationary phase, such as porous paper, and the components stop moving at a point where the attractive forces for the stationary phase becomes greater than the attractive forces for the mobile phase.

On a 10cm x 20cm piece of chromatography paper make pencil dots about 1cm above the long edge and at equal distances apart and label them with numbers. Use dyes or markers to make a large dot at the appropriate spot on the line.

Roll the paper into a cylinder having the dots on the outside, and staple the edges of the paper together without overlapping the paper. Put a few milliliters of the best solvent in the bottom of a large beaker, then slide the paper down into the solvent, with the dotted end first. The ink dots should be *above* the level of the selected solvent! Cover the beaker with a watch glass to prevent evaporation of the solvent. Let the solvent move to the top of the paper before removing it from the beaker.



Compare the results from the known dyes/pens to the chromatograph from the drink/pen that needs to be identified. A retention factor, R_f value, can be determined for each dye spot by dividing the distance from the center of the spot to its starting point by the distance the solvent traveled. This gives a quantitative comparison.

Speed Chromatography

Paper chromatography typically takes more than 10 minutes to allow for the separation of the colors. In order to speed up this process, an artist's painting wheel can be used to spin the paper in a circle and use centrifugal force to push the water to the outer edges.

Use pens, markers or dyes to make dots or lines in a pattern on a piece of round filter paper.

Secure the colored filter paper to the platform of the artist's painting wheel.

Obtain a pipet or eye dropper filled with a few milliliters of water.

Turn on the wheel to start spinning the paper and begin to add water to the center of the paper, one drop at a time. Slowly work towards the outer edge until the colors have spread out across the paper.

Stop the wheel and admire your work. If necessary, spin the paper again and add more water.

Shaving Cream Marbling

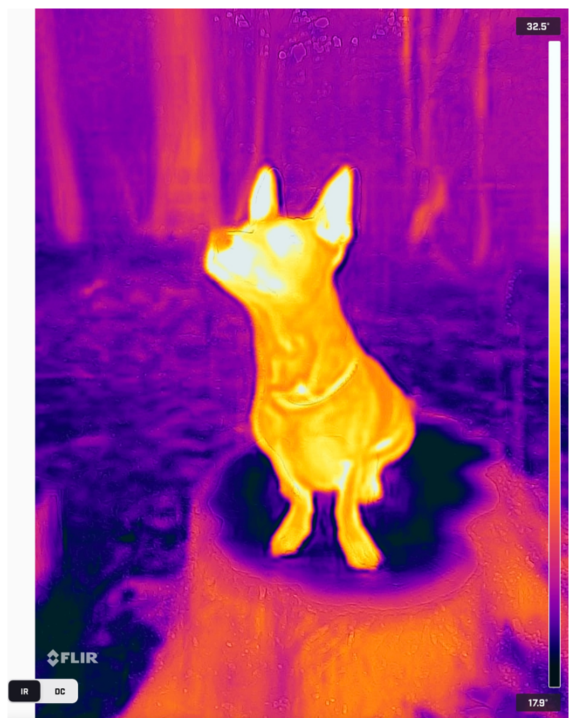
INSTRUCTIONS

1. **Spray shaving cream** onto your pan or tray, then smooth the surface a bit with a spatula(cardboard, etc).
2. Use a dropper to **transfer the watercolor paint or food coloring to the surface of the shaving cream**.
3. Use a craft stick or stirrer to *swirl the colors together on the surface of the shaving cream to create a marbled effect.*
4. *Lay a piece of paper on the surface of the 'painted' shaving cream and gently push down* to make contact across the entire side of the paper.
5. Lift the paper off of the shaving cream and scrape off the excess shaving cream right away with a craft stick, piece of cardboard or a ruler.
6. Set paper on wax paper or in a plastic bag. Keep a wet washcloth or bowl of water handy for washing hands.
7. Repeat with more prints! You can make several prints each time you add paint to the shaving cream, and you can add more color to existing colored shaving cream. When you're ready for a clean slate, add a new layer of shaving cream on top of the existing layer or start fresh.
8. When finished, wash trays and tools with warm water.

Infrared Radiation

Infrared waves, or infrared light, are **part of the electromagnetic spectrum**. People encounter infrared waves every day; A remote control uses light waves just beyond the visible spectrum of light (infrared waves) to change channels on your TV. The human eye cannot see it, but humans can detect it as heat.

Infrared cameras can detect this heat energy and convert it into images that show the transfer of heat from one object to another.



Stand in front of the Flir One infrared camera that is attached to the iPad to view yourself as a heat source.

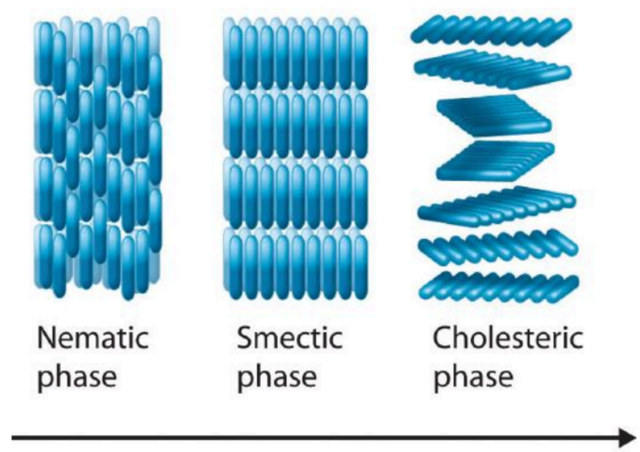
Where is most of the heat energy concentrated in your body? Could you use friction to warm your hands on a cold day by quickly rubbing them together? Try it and see if it works. What type of material can you block your infrared image?

Color Changing Liquid Crystals

Place your hand on the sheet of liquid crystals for 30 seconds. Then remove your hand.

Why do liquid crystals change color?

Liquid crystals are typically long, rigid molecules that can interact strongly with one another, which exhibit different properties when viewed from different directions.

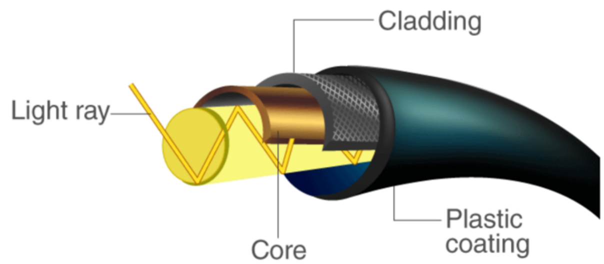


In the *nematic phase*, only the long axes of the molecules are aligned, whereas in the *smectic phase*, the long axes of the molecules are parallel and the molecules are arranged in planes. In the *cholesteric phase*, the molecules are arranged in planes, but each layer is rotated by a certain amount with respect to those above and below it, giving a helical structure.

At cold temperatures, red light is reflected back. At higher temperatures the molecules move faster and the layers twist more, reflecting blue light. Each liquid crystal has only a few degrees of temperature where the organization is such that light is reflected back. *On either side of this temperature range, all light is absorbed and the* ***liquid crystal appears black****.*

Fiber Optics Cable Transmits Light

Fiber optics cables are used to transmit light over long distances. They are made of long, thin strands of glass about the diameter of a human hair, which are wrapped in a reflective cladding. This cladding acts as a mirror by bouncing light off the walls of the cable repeatedly as the light beam travels down the glass **core** of the cable.



The Vernier SpectroVis Plus has been fitted with a fiber optics cable, which can be pointed at various types of light sources to view the spectrum of visible light that is transmitted.

Aim the fiber optics cable at the color-changing light bulb. Watch how the transmitted colors of EMR compare to the color perceived by your eyes. Which transmitted colors of light are needed to produce a yellow colored light that you see with your eyes?

Aim the fiber at other light sources, such as the neon cathode ray tube, which is similar to those used to make neon signs. You can also check it out with your GloFX glasses.