Can you see beyond the rainbow?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

We all know about the rainbow, the spectrum of electromagnetic radiation that your eyes can see. But what lies beyond the rainbow, in the range of wavelengths that we don't normally see?

Theory

Electromagnetic radiation spans a very wide spectrum of wavelengths, from AM radio waves that are longer than a football field to gamma rays which are smaller than an atom.

But the most important "slice" of the spectrum is the segment from about 400 to 700 nm (nanometers, or billionths of a meter) which is visible light. This band is the familiar rainbow of colors that the eye can sense. The blue end of the rainbow is 400 nm; beyond this is the ultraviolet. The red end of the spectrum is about 700 nm; beyond this is the infrared.

Necessary materials:

- IR goggles
- Colorful question page
- Infrared ink
- Cyan, magenta, and yellow gel filters

You can't just buy these IR goggles; you need to create them. We purchased inexpensive welding goggles and modified them by sliding off the front of the goggles and replacing the lens with plastic that transmits only infrared, not visible light. The IR-transmitting plastic is ACRYLITE GP, Color # 1146-0. It transmits light of wavelengths greater than 750nm. The plastic can be obtained from a plastic supplier; check your local directory.

Welding goggles can be had from http://store.weldingdepot.com

Gel filters can be found at Stage Spot: www.stagespot.com

This photo was taken on a sunny day through a pair of IR goggles. Notice how the trees appear light and the sky appears dark.

There are two types of infrared: Near infrared, just beyond the range that your eyes can see, and far infrared, which is also called thermal radiation. Night vision scopes use near infrared; the thermal images you may have seen that show the temperature of objects are showing far infrared.

These goggles let through near infrared. This isn't thermal radiation; it's just a slice of the spectrum that's a lot like light, just a bit beyond the end of the rainbow. This is also a part of the spectrum that you can see, if the pesky visible light is removed. Take this away, and your eyes can sense wavelenghts out to at least 800 nm—beyond the rainbow!

Doing the Experiment

The view beyond the rainbow is very eerie; familiar objects look very different. Everything looks red, because it is the red color sensors in your eyes that pick up the infrared. But notice the brightness; which things appear bright, which appear dim?

This is an open-ended exploration, and it takes time to get used to the infrared world. Before you begin, let students know about these safety precautions:

> **SAFETY NOTE 1: As students explore with the IR goggles, warn them to never look at the sun! The sun gives off a good deal of IR, but the eyes are only weakly sensitive to it, meaning there is a lot of energy present with no blink reflex to tell you to shut or avert your eyes. Unless you have special glasses designed for solar viewing, which these are not, DO NOT LOOK AT THE SUN!!!**
>
> **SAFETY NOTE 2: When you are wearing the IR goggles, it may be hard to see where you are walking, making it easy to stumble or fall. Do this activity in a wide-open area where students are free to move around without bumping into anything. Use the goggles outside during daylight, or if you work inside where there is less illumination, have students work with a partner without goggles who can serve as a guide.**

Here are some things you can explore:

- Take a look at the colored sheet accompanying this exercise. What colors can you see with the goggles on? What colors have disappeared? Is there a secret message you didn't notice in visible light, but you can read in infrared?
- Now, look around you as you are outside. This is how the world looks in infrared! Plants are light; they reflect infrared. Clouds are also light, as is snow. The sky is dark; very little infrared is scattered. (This makes sense; it's the short wavelengths at the blue end of the spectrum that are scattered the most. That's why the sky is blue!)
- Look at the people around you and check out their clothing. Do the patterns become more pronounced or disappear on any items? Some fabrics that are dark in visible light are light in the infrared; some materials that are light in visible light are dark in the infrared. And some items are actually transparent to the infrared. . .
- Take off your goggles, while others are wearing them and try to see their eyes. Now, put on your goggles and look again. Why can you see their eyes when you too, are wearing goggles?
- Stack a cyan, magenta, and yellow gel filter on top of each other. Take off your goggles and try to look through all three filters. Now, put on your goggles and look through all three filters again. Why do you think you can see through them with the goggles on?

Summing Up

This is an important experiment to give your students more experience with the spectrum of electromagnetic waves. Students are familiar with visible light, but they don't really know about the other forms they cannot see. It's important that you give them a chance to explore these other parts of the spectrum before you talk about them, otherwise your discussion will be too abstract for your students to be able to comprehend.

Besides, it's cool. Seeing beyond the rainbow is a lot of fun.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu