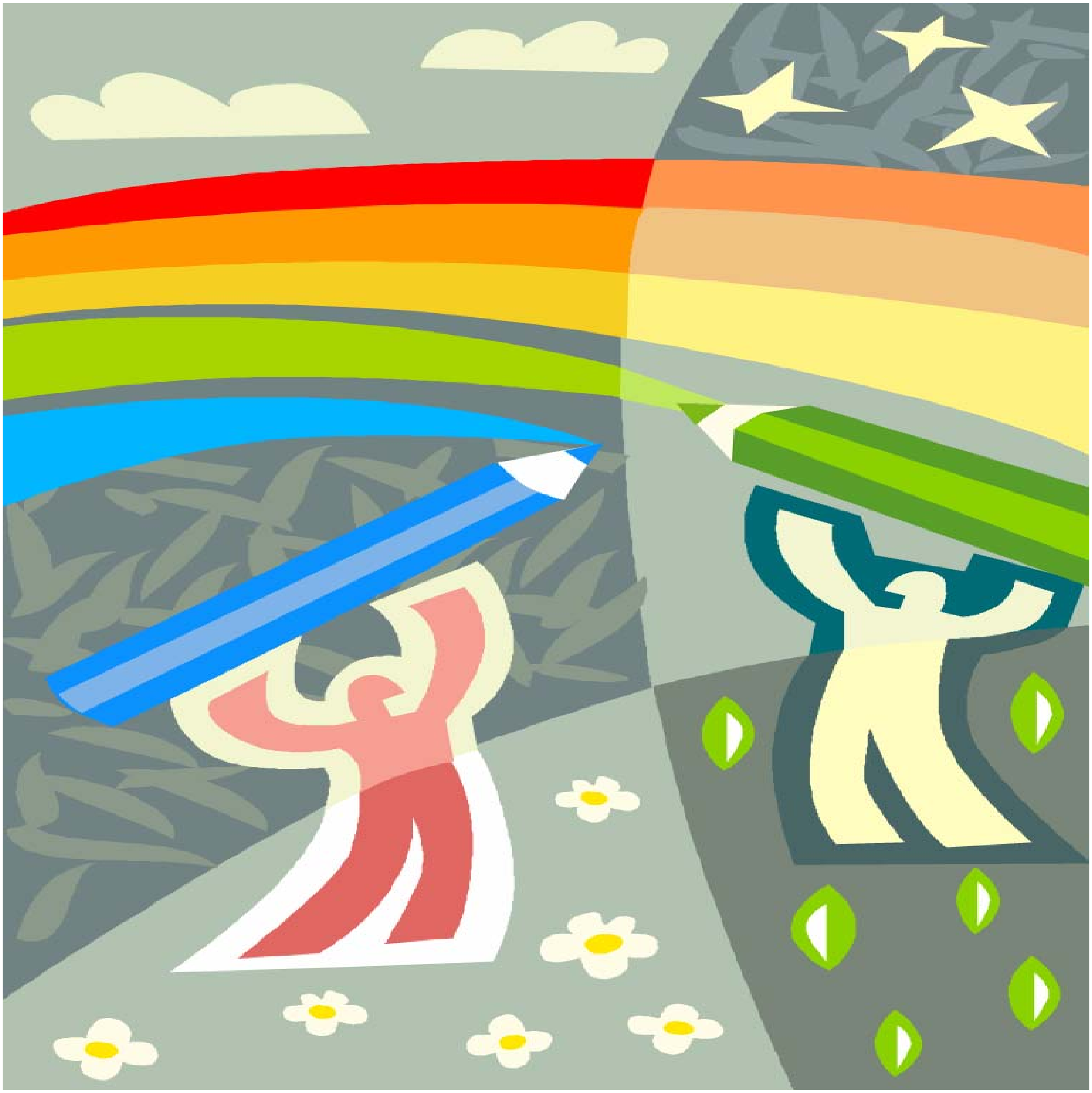
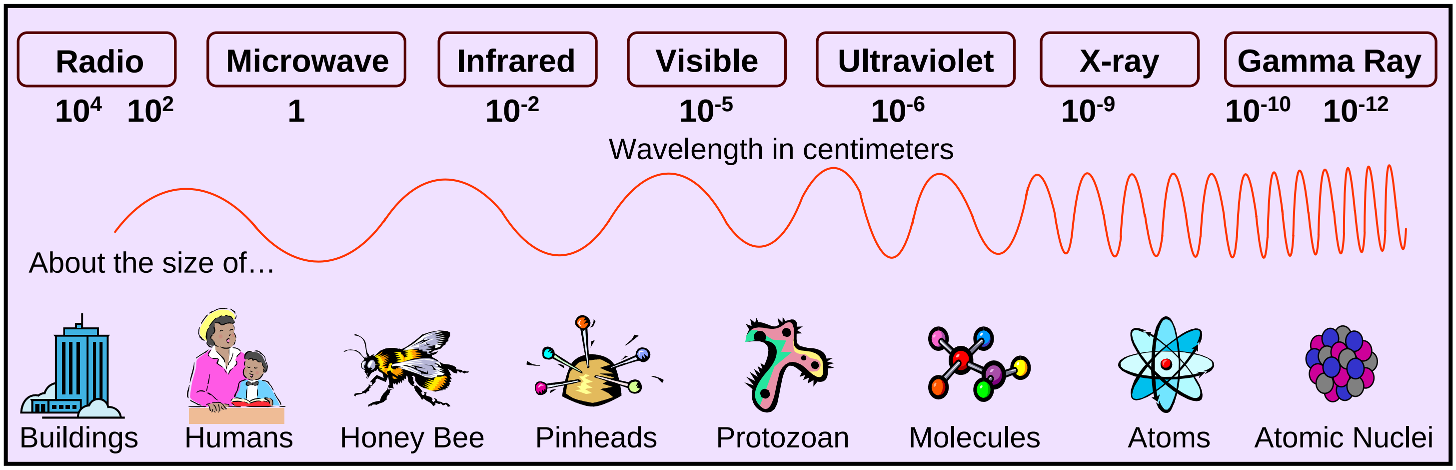
LEARNING about the Electromagnetic Spectrum



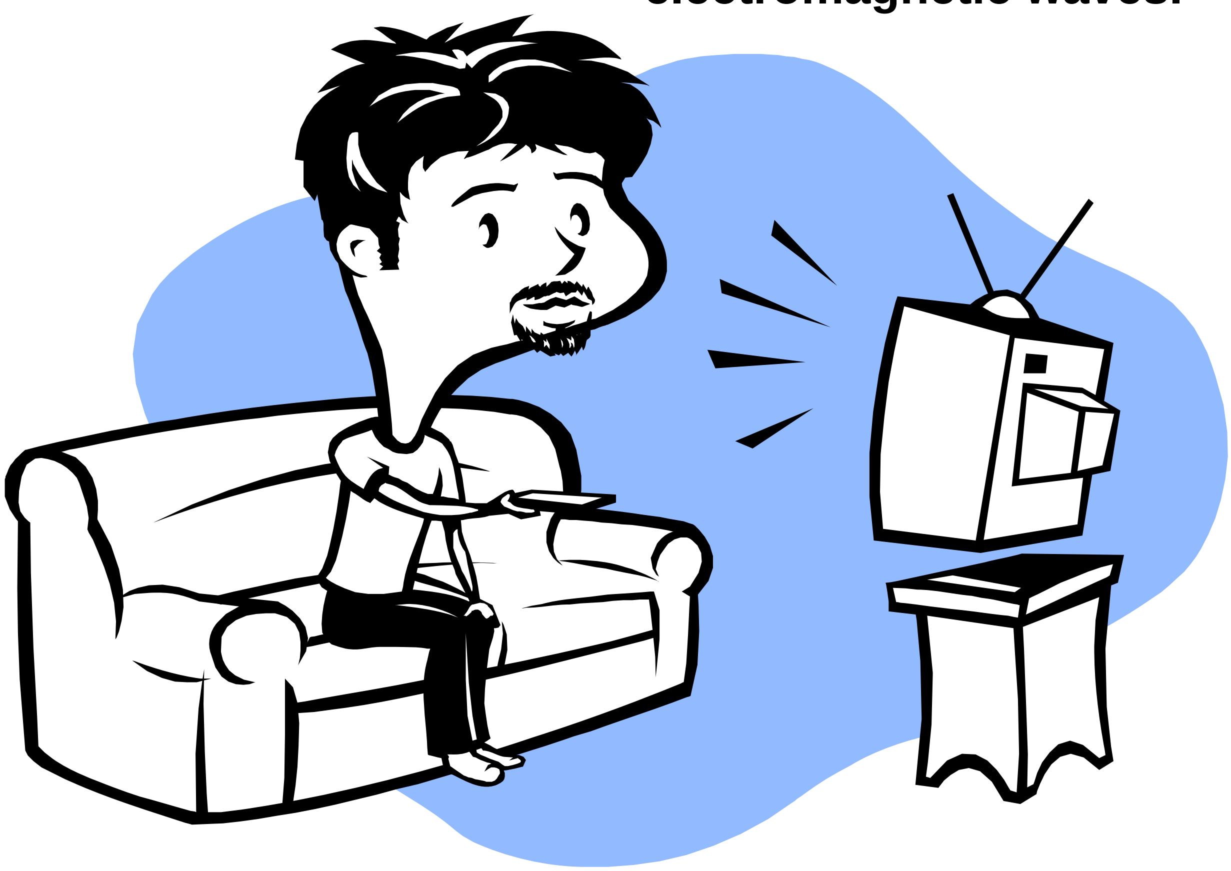
NOAA's National Climatic Data Center
Veach-Baley Federal Building
151 Patton Avenue
Asheville, NC 28801-5001

Electromagnetic Waves



Radio waves, television waves, and microwaves are all types of electromagnetic waves. They only differ from each other in wavelength. Wavelength is the distance between one wave crest to the next.

When you listen to the radio, watch TV, or cook dinner in a microwave oven, you are using electromagnetic waves.



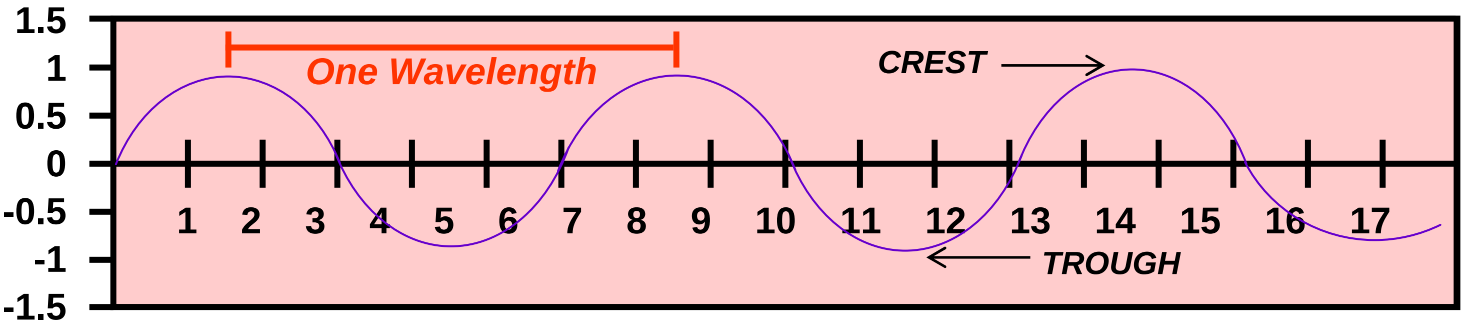
What is Light?

A Spectrum of Colors

The rainbow is a familiar example of a spectrum. Raindrops separate the white light from the sun into the rainbow colors. The colors are always in the same order: red, orange, yellow, green, blue, indigo, and violet, the range of colors that our eyes can see.

Light Consists of Electromagnetic Waves

When light with a single wavelength enters our eyes, we see it as a distinct color. White light is a mixture of all the colors and their corresponding wavelengths. You can think of this like the surface of the sea or a lake with wind because there is a mixture of different length water waves. Our eyes see this mixture of light waves as white. At this point you don't need to completely know what electromagnetic waves are. Just remember that different wavelengths make different colors.



Wavelengths are measured from peak to peak of a wave. In this figure, one wavelength is about 6 units long.

The VISIBLE spectrum

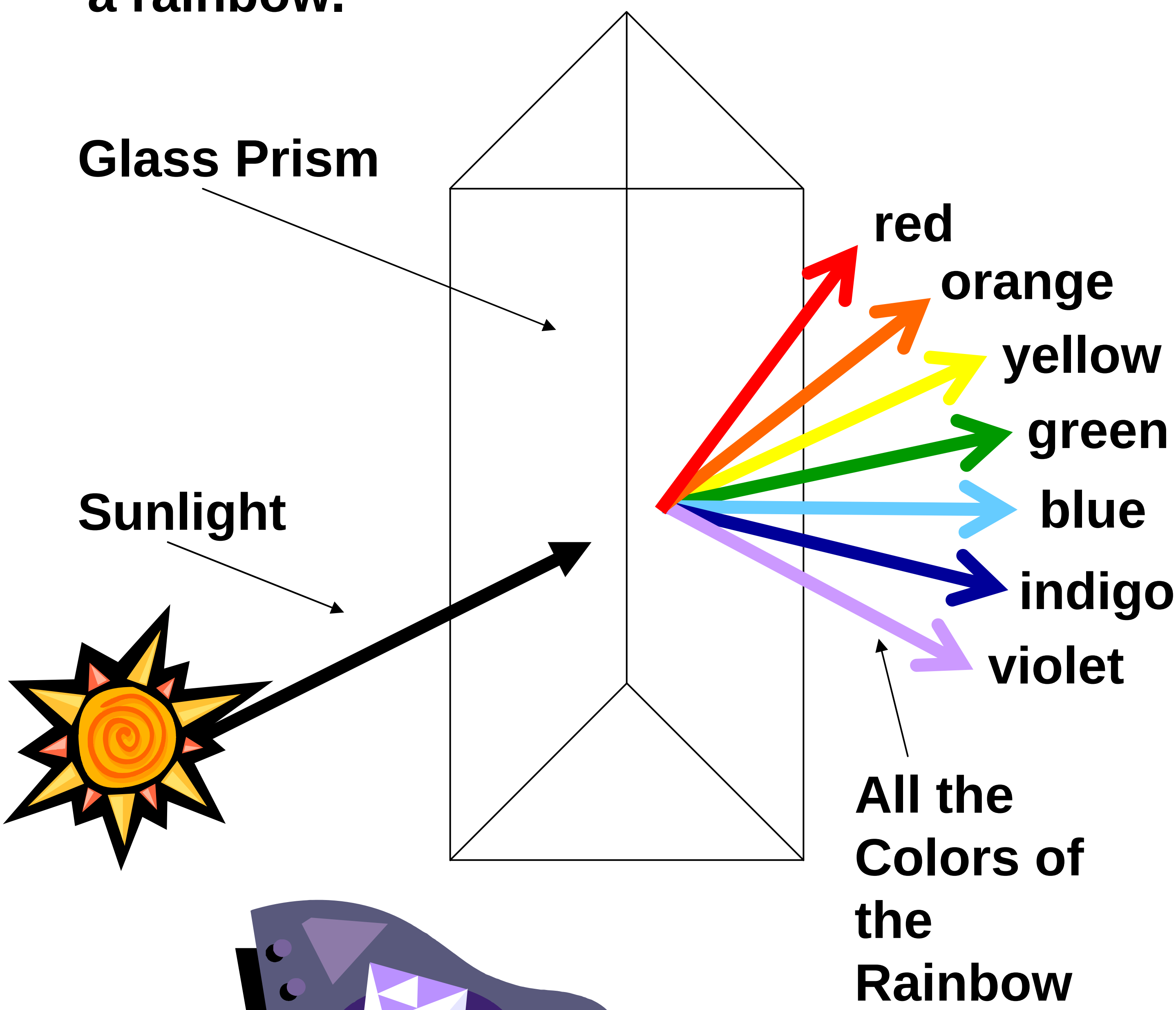
Sir Isaac Newton in his early experiments decided the colors of the rainbow were Red, Orange, Yellow, Green, Blue, Indigo and Violet. Are there only seven colors in a rainbow? Actually, the colors of a rainbow merge gradually into one another. Our eyes sort them out into groupings. How many colors are actually in a rainbow? As many as several thousand are possible!

The **color order of a rainbow** starts with red at the outer edge and moves through the colors to violet. The brightness and the width of the bands and colors can vary greatly in an instant while you watch a rainbow and are related to the size of the drops that form the bow. The colors at the base of a rainbow are different than those at the top.

The rainbow's colors are just like people. **No two are exactly alike.** To really understand the colors of the rainbow study them carefully when they appear and you will see the many differences.

What makes the colors in the rainbow?

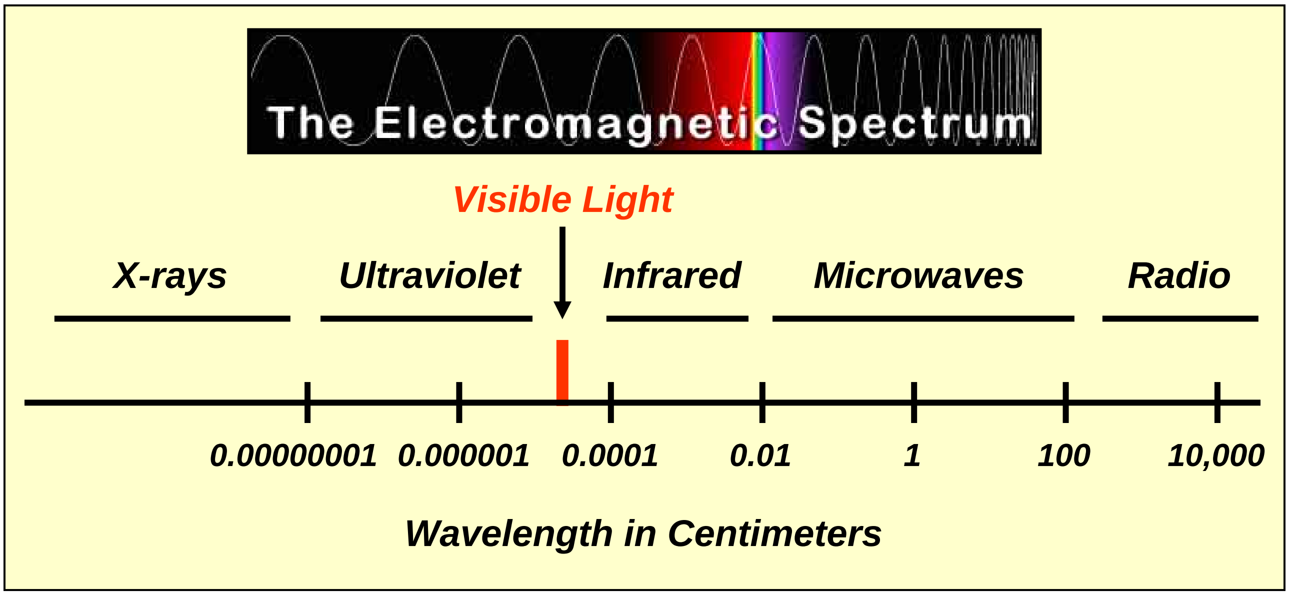
When sunlight passes through a glass prism (or raindrops), it separates the ordinary light into all the colors you see in a rainbow.



The **rainbow** is a familiar example of a **spectrum** (range of colors). Raindrops separate the white light from the sun into the rainbow colors. **The colors are always in the same order**: red, orange, yellow, green, blue, and violet. This is the range of colors that our eyes are able to see.

The INVISIBLE spectrum

The rainbow colors violet through red correspond to increasing **wavelengths**. Could there be wavelengths shorter than violet or longer than red light? The answer is yes. This figure shows a range of wavelengths that we give various names.

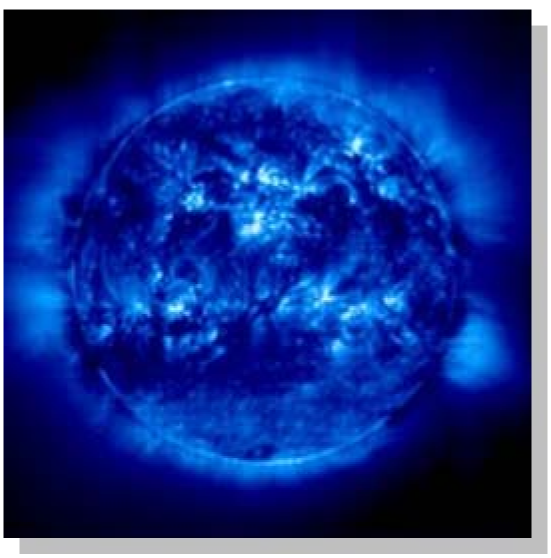


Look at the figure. Wavelengths are short on the left and longer on the right. **Visible light occupies only a small part of it**. On either side of "visible light" there are infrared (IR) and ultraviolet (UV). Waves a little shorter than violet are called ultraviolet; still shorter ones are X-rays. Our eyes don't see these, but we get a sunburn from ultraviolet, while X-rays pass through us without our feeling them. Waves longer than red are infrared; still longer ones are radio waves of various kinds. Our eyes don't see these either, but we can feel infrared as heat on our skin. Electromagnetic radiation of all wavelengths travels with the same speed. This is called the speed of light, denoted by the letter *c*. The speed is 300,000 kilometers per second or 186,000 miles per second. We can measure some of these invisible waves with instruments or other devices. For instance, photographic film for X-rays, a radio or TV receiver for radio waves.

Ultraviolet Light

What is an Angstrom?

Radiation travels in waves. Scientists use the length of the wave (the distance between peaks) to define the energy of the radiation. Astronomers measure this length in "angstroms," a unit of measure equal to 1 hundred-millionth of a centimeter. It's a convenient shorthand way to avoid writing lots of zeroes when talking about the wavelengths of light. In everyday terms, a sheet of paper is approximately 1,000,000 angstroms thick. The ultraviolet portion of the spectrum being studied by Astro-2 covers the portion of the spectrum from about 900 angstroms to about 3,000 angstroms. Visible light, on the other hand, covers the range from 4,000 to 8,000 angstroms.



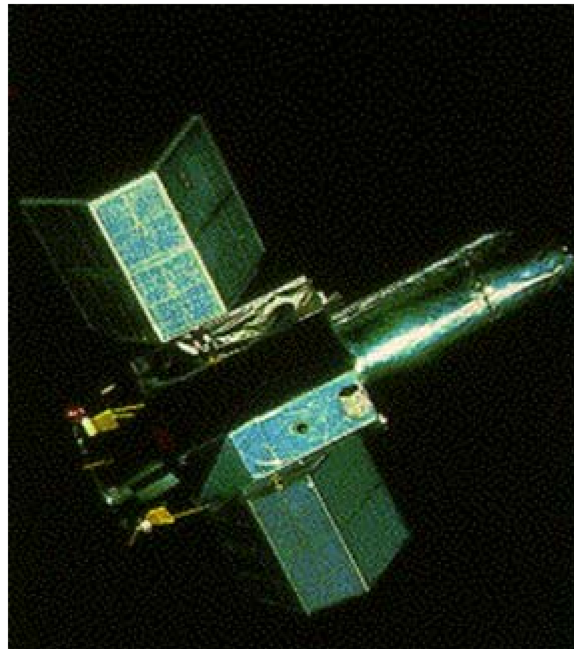
Our Sun emits light at all the different wavelengths in electromagnetic spectrum, but it is ultraviolet waves that are responsible for causing our sunburns. To the left is an image of the Sun taken at an Extreme Ultraviolet wavelength - 171 Angstroms to be exact. (An Angstrom is a unit length equal to 10^{-10} meters.) This image was taken by a satellite named SOHO and it shows what the Sun looked like on April 24, 2000.

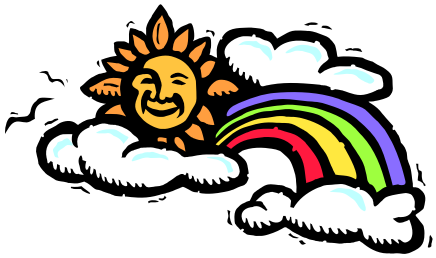
Some ultraviolet waves from the Sun penetrate Earth's atmosphere but most of them are blocked from entering by various gases like Ozone. Scientists have developed a UV index to help people protect themselves from these harmful ultraviolet waves.

How do we "see" using ultraviolet light?

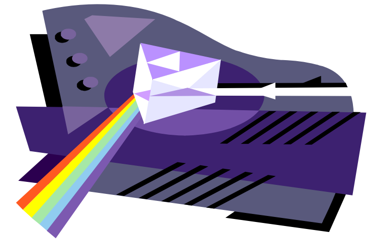
It is good for humans that we are protected from getting too much ultraviolet radiation, but it is bad for scientists! Astronomers have to put ultraviolet telescopes on satellites to measure the ultraviolet light from stars and galaxies or even closer things like the Sun!

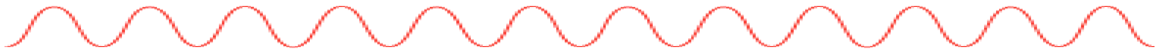
There are many different satellites that help us study ultraviolet astronomy. Many of them only detect a small portion of UV light. For example, the Hubble Space Telescope observes stars and galaxies mostly in near ultraviolet light. NASA's Extreme Ultraviolet Explorer satellite is currently exploring the extreme ultraviolet universe. For over 17 years The International Ultraviolet Explorer (IUE) satellite has observed objects in the far and near ultraviolet regions.





Activity



A 

B 

C 

1.) How many wavelengths does each wave have?

A.________ B.________ C.________

2.) Which wave has the largest value for crest and through?

a.) A b.) B c.) C

3.) Wave A most likely represents ____ wave.

a.) Radio b.) Microwave c.) Ultraviolet

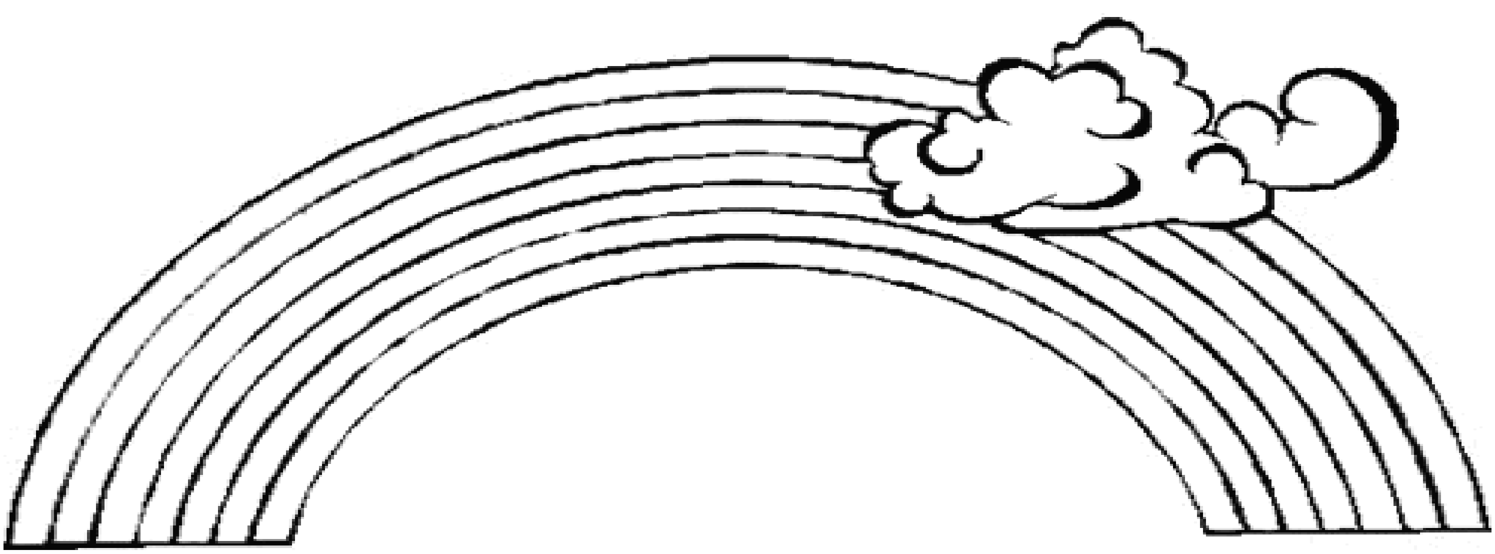
4.) Wave B most likely represents ____ wave.

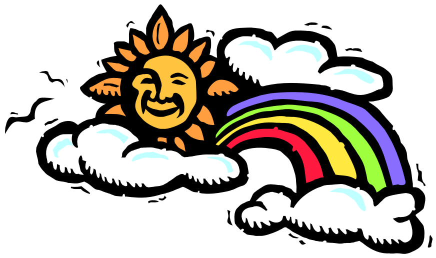
a.) Gamma b.) Radio c.) Visible

5.) Wave C most likely represents ____ wave.

a.) X-Ray b.) Radio c.) Gamma

6.) Color the Rainbow in the correct order.





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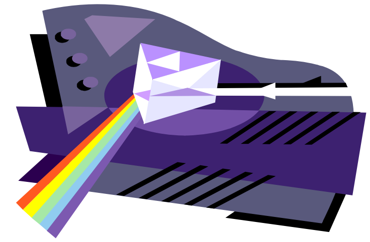
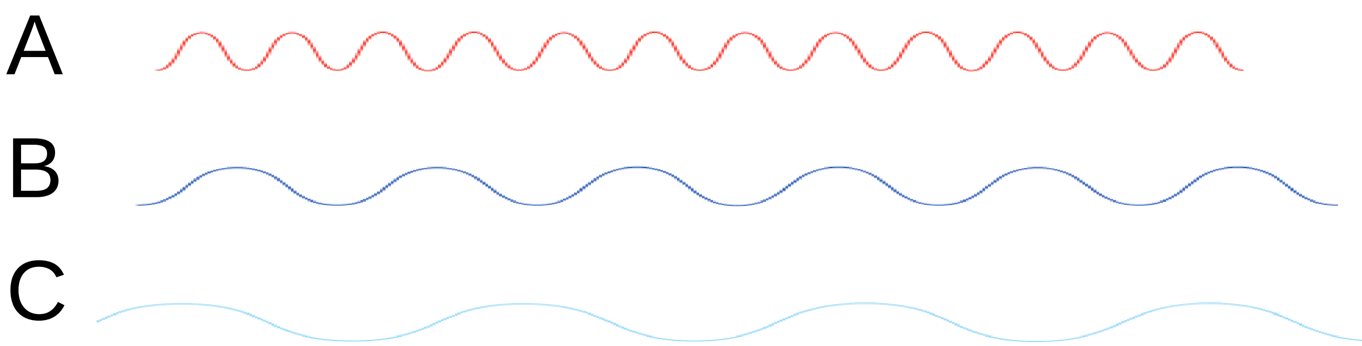


(ANSWERS)



1.) How many wavelengths does each wave have?

A. **11** B. **5** C. **3**

2.) Which wave has the largest value for crest and through?

a.) A b.) B c.) C

3.) Wave A most likely represents ____ wave.

a.) Radio b.) Microwave c.) Ultraviolet

4.) Wave B most likely represents ____ wave.

a.) Gamma b.) Radio c.) Visible

5.) Wave C most likely represents ____ wave.

a.) X-Ray b.) Radio c.) Gamma

6.) Color the Rainbow in the correct order.

Making Your Own Rainbow

- **Materials:**
  - Prism
  - Light Ray Box
  - White paper

- **Directions:**

  1.) Position the prism in front of the light ray box so that the light will shine through it.

  2.) Adjust the position of the prism, turning it slowly, moving it closer to or further from the light source, until a rainbow is visible in the light shining through the prism.

  3.) Hold the white paper near the prism. The rainbow will be seen more easily on a white background.