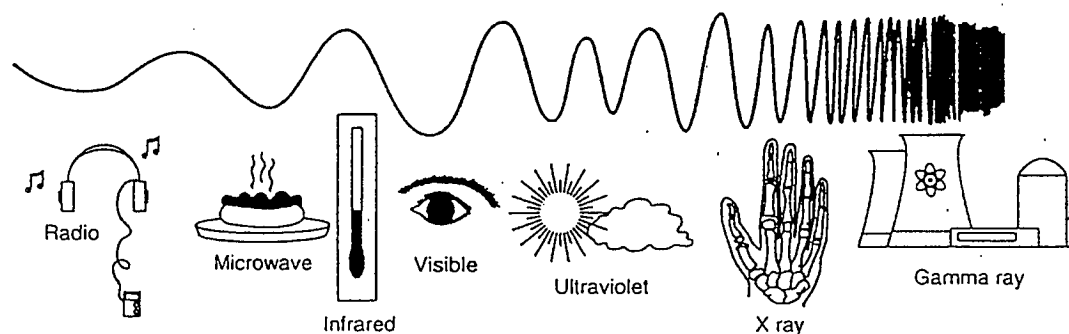


Teacher Background Information: Energy From the Sun

Part I: Introduction: In the case of the Earth, except for the relatively small amounts of energy provided to Earth's surface as a consequence of its internal composition and internal heating, all the energy that drives the biological, geophysical and geochemical processes comes from the Sun. This radiation can be sensed in various ways: some as visible radiation, some as heat radiation, some as radio waves and so forth. The basic mechanism involved in the absorption or emission of radiation is the same: it reflects the transition of an atom or molecule between a higher and a lower energy state. As a molecule gains energy, its electrons jump to higher (excited) energy states. As a molecule loses energy, that energy is emitted radiation. This energy comprises the spectrum of energy from radio waves on one end to gamma rays on the other end. It is called the **electromagnetic spectrum** because this radiation is associated with both electric and magnetic fields that transfer energy as they travel through space. Because humans can see it, the most familiar part of the spectrum it is called **visible light**- red, orange, yellow, green, blue and violet.

Electromagnetic radiation has characteristics of both waves and particles. What we detect depends on the method we use to study it. The rainbow colors that appear in soap film or the dispersion of light from a diamond are described as waves. The light that strikes a solar cell to produce an electric current is best described as a particle. Individual particles or "packets" of light are called **photons**. The amount of energy in a photon depends on its wavelength. Radiation with a long wavelength has very little energy; radiation with a short wavelength contains a large amount of energy. The different regions of the electromagnetic spectrum are named according to their wavelengths. Radio waves have the longest wavelengths; gamma rays have the shortest. Visible light is somewhere in the middle in a very narrow band of radiation.

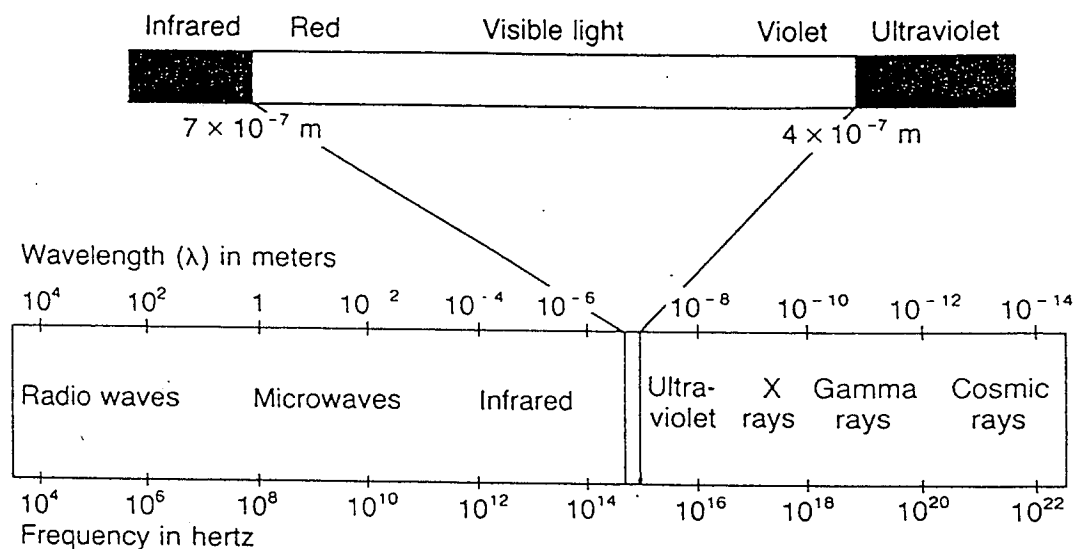
(Notes: The wavelengths of gamma and X- rays are so tiny that an alternate unit of measurement is used to describe them-- the electron volt. One electron volt has a wavelength of about 0.0001cm. X-rays range from 100 electron volts (eV) to thousands of electron volts. Gamma rays range from thousands of electron volts to billions of electron volts.



Like expanding ripples in a pond after a pebble has been tossed in, electromagnetic radiation travels across space in the form of **waves**. These waves travel at the **speed of light**- 300,000 km/sec (186,000 m/sec). These **wavelengths**, the distance from wavecrest to wave crest, vary from thousands of kilometers across, in the case of the longest radiowaves, to smaller than the diameter of an atom, in the case of the smallest X-rays and gamma rays.

Part II: The Regions of the Electromagnetic Spectrum: Scientists name the different regions of the electromagnetic spectrum according to their wavelengths. (See illustration attached.) **Radio waves** have the longest wavelengths, ranging from a few centimeters from crest to crest to thousands of kilometers. **Microwaves** range from a few centimeters to about 0.1cm. **Infrared radiation** falls between 700 nanometer and 0.1 cm. **Visible light** is a very narrow band of radiation ranging from 400 to 700 nanometers. For comparison, the thickness of a sheet of household plastic wrap could contain about 50 visible light waves arranged end to end. Below visible light is the slightly broader band of **ultraviolet light** that lies between 10 and 300 nanometers. **X-rays** follow ultraviolet light and diminish into the hundred-billionth of a meter range. **Gamma rays** fall in the trillionth of a meter range. (Note: Nano means one billionth. So 700 nanometers is a distance equal to 700 billionths or 7×10^{-7} meter).

The Electromagnetic Spectrum



Part III: Using the Electromagnetic Spectrum: All objects in space are very distant and difficult for humans to visit. Only the moon has been visited so far. Instead of actually visiting stars and planets, astronomers collect electromagnetic radiation from them using a variety of tools. **Radio dishes** capture radio signals from space. **Large telescopes** on Earth gather both visible and infrared light. **Interplanetary spacecraft** have traveled to all the planets in our solar system except Pluto and have landed on two. No spacecraft has ever brought back planetary material for study. All their information is sent back by radiowaves.

Virtually everything that we know about the Universe beyond our planet depends on information contained in the electromagnetic radiation that has traveled to Earth. For example, when a star explodes as a supernova, it emits energy in all wavelengths of the electromagnetic spectrum. The most famous supernova to date is the stellar explosion that was visible in 1054 CE and produced the Crab Nebula. Electromagnetic radiation from radio waves to gamma rays has been detected from this object; each section of the spectrum that is represented tells a different story:

- **Visible light observation** - gives us information about the density, temperature and constituents distribution as well as the motions of stars.
- **Radio waves**- give us information about the gases of the Milky Way, and details about magnetic fields in space.
- **Infrared studies** -tell us about molecules in space (e.g. formaldehyde clouds in outer space)
- **Ultraviolet light**- help scientists to map the regions of hot gases around the Sun;
- **X-rays and gamma rays**- help in studies of matter at very high densities and temperatures in the presence of electric and magnetic fields;

Each region of the spectrum provides a piece of a puzzle. Using more than one region of the puzzle at a time gives scientists a more complete picture. The two main techniques for analyzing the light from space are spectroscopy and photometry. *Spectroscopy* spreads the light out into a spectrum for study. *Photometry* measures the quantity of light in specific wave lengths or by combining all wavelengths. *Filters* help to analyze specific parts of the spectrum. For example, a red filter blocks out all visible light, except light which falls around 600 nanometers (nm). The atmosphere of the Earth acts as a filter and unfortunately allows only small portions of the spectrum to reach the surface of the planet. Quality research can be made at high altitudes on mountain tops, or using instruments in high altitude balloons or planes. However, the best observatory is still outer space.

(Note: Astronomers still use a relatively old unit of measurement for the wavelengths of electromagnetic radiation. This unit is the Angstrom, or A. One nanometer is equal to 10 angstroms. Green light for example, has a wavelength of about 5000 A, 500 nanometers or 5×10^{-7} m.)

Part IV: Important Terms: Radiation, electromagnetic, energy, radio waves, gamma rays, visible light, waves, speed of light, wavelength, solar cell, photon, electron, volt, supernova, density, magnetic field, molecule, temperature, spectroscopy, photometry, filter, nanometer;

Part V: Teaching Strategies:

1. Because of the complex apparatus required to study some of the wavelengths of the spectrum, feel free to only concentrate on the visible light spectrum.
2. Choose the method(s) that you feel will work for your students. Do not feel pressured to present all of the activities.
3. Some of the activities may involve sunlight; feel free to use spotlights or floodlights.