## Teaching Activity: The Electromagnetic Spectrum: Visible and Invisible Light

**Background:** Have you ever wondered what similarities might exist between: a) X-rays, b) solar radiation, c) a radio signal, d) a microwave oven and e) an infrared lamp? Although these might appear to be completely unrelated phenomena at first glance, they are actually all the same -- electromagnetic energy. Electromagnetic energy is a wave-like propagation of an electric and magnetic field. Electromagnetic waves differ from sound waves or waves on the surface of the ocean in that they do not need to travel in a substance, like water or air; they can travel through a vacuum. The term "electromagnetic radiation" is commonly used to refer to the same types of waves. In order to avoid confusion with the term "radioactivity", which refers to reactions involving the atomic nucleus, the term "electromagnetic energy" is used consistently.

Although identical in nature, electromagnetic waves differ from each other in their length and energy levels. The length of the wave is the distance between two subsequent wave crests. Energy levels are inversely proportional to the wavelengths; that is the shorter the wavelength, the higher the energy. The arrangement of the electromagnetic waves according to their wavelengths or energy levels is known as the electromagnetic spectrum (EMS). The range of electromagnetic waves is subdivided into different categories, depending upon the level of energy. In decreasing order of energy, or increasing wavelength, they were named: gamma rays, X-rays, ultra-violet rays, visible light, infrared rays, microwaves and TV and radio waves.

Visible light represents the only portion of the entire EMS which we can perceive with our eyes. These waves are just the right length to stimulate special cells in the retina (comes and rods) of our eyes which cause neural impulses to be sent to the brain. Electromagnetic waves with lengths either above or below the visible light cannot be perceived by unaided human eyes. This phenomenon is analogous to the higher sound frequencies which are inaudible to the human ear, but which can be heard by animals like dogs and bats. For this reason, electromagnetic waves, or energy, outside the visible portion are known as "invisible light". Within the visible portion, different wavelengths stimulate different sensations of color in our eyes.

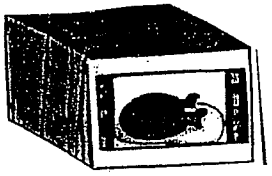
Although not perceived by the human eye, the invisible portions of the EMS have very familiar effects, such as:

- **Gamma rays: highest in energy; used in medical treatment to kill cancerous cells;**

- **X-rays: used to check for dental and bone problems and to detect metals in unopened packages; are able to pass through many materials that stop visible light; the density of the material affects the absorption of X-rays;**

- **Ultraviolet (UV) rays: have enough energy to damage or kill living cells; Hospitals use them to kill bacteria and sterilize equipment; UV rays also enable our skin to produce vitamin D, but frequent exposure can cause cataracts, skin cancer and immune system problem;**

- **Infrared (IR) rays: can stimulate the sensation of warmth on our skin; certain animals (rattlesnakes) can detect the IR emitted by other warm blooded creatures; an incandescent light bulb emits all visible wavelengths in addition to IR wavelengths;**



- **Microwaves: just the right length to cause water molecules in food to vibrate so rapidly that they cause the food to get hot and cook, a phenomenon employed in microwave ovens; their name makes them sound very small, but in fact their wavelength is larger than the ranges just mentioned above;**


- **Radio and TV waves: are the longest wavelengths, with the least amount of energy;**

## Objectives:

- To help students understand the concept of energy;
- To develop a working knowledge of the electromagnetic spectrum;
- To be able to provide real-life example or different types of electromagnetic energy;

**Materials:** Overhead transparency of the EMS, paper copies for each student, colored chalk or overhead markers, materials that students can relate to: X-ray picture, a "black light" lamp (source of UV), sun screen with UV protectant, a flashlight, a hot plate or burner, a heat lamp, a microwave oven, a radio with antenna, a large Slinky, prisms and light sources)

## Preparation:

1. Get all available materials.

2. Experiment with the prism so that you can better guide students in obtaining an intense spectrum of visible light.
   - You will probably need to project the spectrum onto a white sheet of paper.
3. Prepare the overhead of the EMS.

## Procedure:

1. Display the materials you gathered on a demonstration table.

2. Have student write down briefly what they know about each individual object.
   - Also have them write what they think are some possible commonalities among them.

3. Sample student responses.
    - It is unlikely that the idea of electromagnetic waves or energy will come up at this stage.

4. Introduce the topic by telling the class that they will be studying a phenomenon related to all the artifacts: electromagnetic energy.

5. Demonstrate and assist students in obtaining a spectrum of light by having a beam of white light pass through a prism and shine onto a white surface.

6. Discuss observations, leading students to suggest that white light is composed of different colors, ranging from red to violet; the colors of the rainbow".
    - Explain the notion that light is a type of energy that travels as waves called "electromagnetic waves".

7. Using a slinky, briefly demonstrate the concepts of waves, wavelength, and electromagnetic wave.
    - Point out the inverse relationship between wavelength and energy level.

8. Explain to the class that our eyes can differentiate wavelengths or levels of energy through the sensation of color: different colors are associated with different energy levels, or wavelengths.
    - Energy increase towards the violet end (as the wavelength decreases) and decreases toward the red end of the spectrum (as the wavelength increases ).

9. Using colored chalk or markers, draw on the blackboard or overhead, the visible spectrum (See attached diagram).

10. Introduce and develop the idea that what we see is not the entire continuum.
    - You may wish to direct students in feeling the infrared energy given off by the hot plate or an infrared lamp.
    - Introduce the notion that the sensation of warmth is caused by infrared light, another form of electromagnetic energy. Human eyes cannot see it, but we feel it as heat.
    - Point out that some animals are more sensitive to IR energy than humans.
    - Refer students to the sources of infrared light that you have gathered. Ask for ore examples (e.g., certain restaurants use IR lamps to keep the food warm, the heating lamp in bathrooms of some homes and hotels, the sun, etc.,)

11. Reiterate that visible light and IR light are both forms of the same type of energy-electromagnetic energy, visible and invisible. ]
    - We can only see electromagnetic energy of certain wavelengths, while others have different, familiar effects.
    - Analogously, human beings are "deaf" to certain sounds that dog and bats can hear easily.

12. In the same way, introduce and develop the concept of ultraviolet light and refer students to the items on display.
    - Ask for more examples: welding metals, the Sun, etc.

13. Using the drawing, help students locate the logical place for IU and UV light on the EMS by explaining the meaning of the Latin prefixes: ultra = beyond and infra = below.

14. In the same way, introduce the remaining ranges of the EMS.
    - Constantly refer to the items on display.
    - Try to be systematic so that it is easier for students to internalize the idea of energy increasing in the same direction that the wavelength decreases.
    - Use your drawing to illustrate the full range of energies.

15. Put up the overhead of the EMS.
    - Indicate that this is just a visual representation of the EM waves ordered by level of energy or wavelength.
    - Reinforce the notion that the visible part of the spectrum, which lies somewhat in the middle of the continuum, represents a very narrow range of wavelengths when compared to all the possible ones.

16. At this point you might want to introduce the "microwave oven" as a rather perplexing example of the way EM waves interact with different substances.
    - Although it emits longer waves than either IR or UV, with less energy, it causes food to heat up much quicker than a light bulb or hot burner would. This happens because microwaves ovens emit just the right wavelength to cause water molecules in foods to vibrate so rapidly that the food gets hot and cooks.
    - In other words, the effect of EM waves on a substance is not only determined by the energy level of the wave, but also by the substance's special properties.

18. Scramble all the display items.
    - Ask students to, working in their groups, discuss what commonalities and differences between the items that were presented during class.
    - You may also wish to have the groups list all the items with their corresponding type of electromagnetic wave, in ascending order of energy, or descending wavelength. Sample responses.

19. A final brief activity is very important to help insure that students have appropriate conceptions about the different items used in describing the EMS or referring to its individual components.
    - Write the following terms on the board: UV energy, UV light, UV radiation, UV rays and UV waves.
    - Ask the following question of the class: Do these terms all have the same meaning (or refer to the same thing) or do they have different meanings?
    - Repeat the same questions for the term infrared (IR) to make sure that the students are clear that they all mean the same thing.

****Assessment Item: Have students write a short story about how the different types of wavelengths of EM energy play a part in their lives.

NOTE: THE ELECTROMAGNETIC SPECTRUM