Electromagnetic Spectrum

Student Objective
The student:
- will know that the Sun's energy is transferred to Earth by electromagnetic waves
- will understand that there are eight main types of electromagnetic waves that are classified on the electromagnetic spectrum by their wavelengths
- will be able to explain how each of the types of electromagnetic radiation is used or found in our everyday lives.

Materials:
- electromagnetic spectrum chart (1 per student)
- internet access
- reference books
- overhead projector, computer with LCD projector or other presentation equipment
- chart paper, construction paper and other materials for creating presentation visuals

Key Words:
compressional waves
electromagnetic spectrum
frequency
gamma rays
hertz
infrared waves
microwaves
photon
radio waves
speed of light
transverse waves
visible light
ultraviolet light
x-rays

Time:
1 class period for research
Homework
1 class period for presentations

Background Information

Electromagnetic radiation can be described in terms of a stream of massless particles, each traveling in a wave-like pattern and moving at the speed of light. Each massless particle contains a certain amount (or bundle) of energy. Each bundle of energy is called a photon, and all electromagnetic radiation consists of these photons. The only difference between the various types of electromagnetic radiation is the amount of energy found in the photons. Radio waves have photons with low energies, microwaves have a little more energy than radio waves, infrared has still more, then visible, ultraviolet, x-rays, and the most energetic of all, gamma rays.

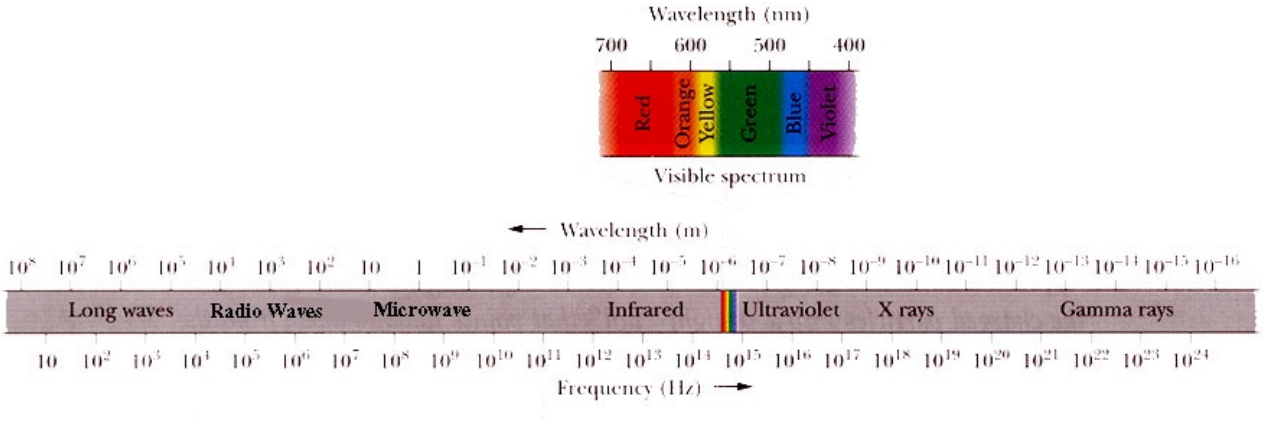
Electromagnetic radiation from space is unable to reach the surface of the Earth except at a very few wavelengths, such as the visible spectrum and radio frequencies. Astronomers can get above enough of the Earth's atmosphere on mountain tops or by flying their telescopes in an

spacecraft, to observe some infrared wavelengths.

The small portion of the electromagnetic spectrum that we can detect with our eyes is called the optical spectrum. This spectrum ranges in color from reads and oranges up through blues and purples. Each of these colors actually correspond to a different energy of light and make up only a small portion of the electromagnetic spectrum–visible light. Of all the colors in the visible spectrum, red light is the least energetic and blue is the most. Beyond the red end of the visible part of the spectrum lie infrared and radio light, both of which have lower energy than visible light. Above the blue end of the visible spectrum lies the higher energies of ultraviolet light, x-rays and gamma rays.

Light can be described not only in terms of its energy, but also its wavelength, or its frequency. There is a one-to-one correspondence between each of these representations. X-rays and gamma-rays are usually described in terms of energy, optical and infrared light in terms of wavelength, and radio in terms of frequency. This is a scientific convention that allows the use of the units that are the most convenient for describing whatever energy of light is being observed.

Wavelength is the distance between two peaks of a wave, and it can be measured with a base unit of meters. Frequency is the number of cycles of a wave to pass some point in a second. The basic unit of frequency is cycles per second, or Hertz. In astronomy, gamma rays are often measured in electron volts, or eV.



Procedure (research and presentation preparation)

1. Lead a classroom discussion on transverse waves, electromagnetic radiation, and the electromagnetic spectrum. Some points to cover are:
   - transverse waves can travel through a vacuum such as space (compressional waves such as radio waves have to travel through a medium)
   - only a few frequencies of radiation are able to penetrate our atmosphere from space, mostly the visible spectrum and the radio frequencies
   - electromagnetic radiation is a wave of massless particles (photons) of energy that travel at the speed of light
   - the amount of energy in the photons varies with the different wavelengths (frequencies); conversely, all types of electromagnetic radiation are basically the same except for their frequency (wavelength) and therefore the amount of energy

in the photons
- the longer wavelengths have photons with less energy, the shorter wavelengths have photons of greater energy
- the small part of the electromagnetic spectrum that we can detect with our eyes is the optical spectrum
- the frequency of a wave is the number of wave crests that pass a point during one second.

2. Divide the students into eight groups.
3. Explain that they will be researching one of the eight types of electromagnetic energy in the spectrum and reporting their findings to the class. Tell the students that their presentations will be rated by the rest of the class on these criteria:
   - content knowledge (Do they know what their electromagnetic energy is about?)
   - creativity & originality (Did they present their knowledge in an interesting and original way?)
   - interest level (Was the presentation interesting to watch?)
4. Assign each group a type of electromagnetic energy:
   - radio waves
   - microwaves
   - infrared waves
   - visible light
   - ultraviolet light
   - x rays
   - gamma rays
   - cosmic waves
5. Give the class time to research and prepare their presentations. They should begin by answering the questions in their Science Journal, then use that information as the content knowledge for their presentation.
6. Assist as necessary.

Procedure (presentation day)

1. Hand out copies of the rating sheet and have each student 'x' out the presentation that they are doing (they can not assess their own presentation!)
2. Have them rate the other seven presentations on a scale of 1 - 10 (with 10 being the highest) for each of the three criteria
3. After the presentations, announce the group with the highest score, lead a classroom discussion of what they did to make an effective presentation.

Key Words & Definitions

- **compressional waves** - waves such as sound waves that require a medium to transfer energy.
- **electromagnetic spectrum** - The full range of frequencies, from radio waves to gamma rays, that characterizes light.
- **electromagnetic waves** - waves that transfer radiation. These waves are created by electrically charged particles that move; since they are transverse waves they can travel

through a vacuum such as space.

- **frequency** - A property of a wave that describes how many wave patterns or cycles pass by in a period of time. Frequency is often measured in Hertz (Hz), where a wave with a frequency of 1 Hz will pass by at 1 cycle per second.
- **gamma rays** - The highest energy, shortest wavelength electromagnetic radiations. Usually, they are thought of as any photons having energies greater than about 100 keV.
- **hertz** - The derived SI (international standard) unit of frequency, defined as a frequency of 1 cycle per second.
- **infrared waves** - Electromagnetic radiation at wavelengths longer than the red end of visible light and shorter than microwaves (roughly between 1 and 100 microns). Almost none of the infrared portion of the electromagnetic spectrum can reach the surface of the Earth, although some portions can be observed by high-altitude aircraft or telescopes on high mountaintops.
- **microwaves** - Electromagnetic radiation which has a longer wavelength (between 1 mm and 30 cm) than visible light, but shorter than radio waves. Microwaves can be used to study the Universe, communicate with satellites in Earth orbit, and cook popcorn.
- **photon** - a tiny particle or bundle of radiant energy
- **radio waves** - Electromagnetic radiation which has the lowest frequency, the longest wavelength, and is produced by charged particles moving back and forth. The atmosphere of the Earth is transparent to radio waves with wavelengths from a few millimeters to about twenty meters. Radio waves are used to broadcast radio and television as well as being emitted by stars and gases in space.
- **speed of light** - 186,000 miles per second
- **transverse waves** - waves such as light waves that can transfer energy in a vacuum without a medium.
- **visible light** - Electromagnetic radiation at wavelengths which the human eye can see. We perceive this radiation as colors ranging from red (longer wavelengths; ~ 700 nanometers) to violet (shorter wavelengths; ~400 nanometers.).
- **ultraviolet light** - Electromagnetic radiation at wavelengths shorter than the violet end of visible light. The atmosphere of the Earth effectively blocks the transmission of most ultraviolet light.
- **x-rays** - Electromagnetic radiation of very short wavelength and very high-energy. X-rays have shorter wavelengths than ultraviolet light but longer wavelengths than gamma rays.

Related Research

1. Should the federal government be allowed to control the frequency bandwidths for communication? Support your argument.
2. How are thermograms (infrared photographs) used to help in energy efficient building design?
3. Defend the importance of gamma rays in treating cancer, even though many patients suffer serious side effects to such treatment.
4. If radio waves are not compressional waves like sound waves, explain what their role is in enabling us to hear music from a radio station.

5. How is the depletion of the ozone layer related to increased ultraviolet radiation? What measures can we take to stop the depletion of the ozone layer? What can we do to prevent exposure to ultraviolet radiation?
6. Keep an 'electromagnetic journal' for a week. Record each time you observe or come in contact with electromagnetic radiation. Record the date, time, what type of radiation you observe and a brief explanation of the incident.

Related Reading

- ***This Strange Quantum World & You*** by Patricia Topp (Blue Dolphin Publishing, 1999) Patricia Topp explains in clear, developmentally appropriate language how the world can seem solid yet is really light and energy, and how this is relevant in the world of kids and leading-edge physicists alike.

Internet Sites

http://school.discoveryeducation.com/lessonplans/interact/electromagneticspectrum.html
Discovery Education's interactive electromagnetic spectrum tutorial, including what areas of the spectrum are found in the natural world and how areas are used in science, space exploration, communications, and medicine.

http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
NASA's Imagine the Universe site. Information on the electromagnetic spectrum and the different frequencies of waves on it.

http://spaceplace.nasa.gov/en/kids/chandra.shtml
NASA's The Space Place website featuring The Land of The Magic Windows. Students can 'see' the different parts of the electromagnetic spectrum through NASA photos of the universe.

http://www.sciencejoywagon.com/explrsci/media/prism.htm
Science Joy Wagon's virtual prism. Select the wavelength of the light and see how it affects the angle that the light bends as it passes through the prism

http://missionscience.nasa.gov/ems/emsVideo_01intro.html
NASA's Mission: Science video on the electromagnetic spectrum. This video is broken down into segments for the different sections of the spectrum.

Electromagnetic Spectrum

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 6														
Earth Systems & Patterns	# 7	SC.6.E.7	**X**											
Forces & Changes in Motion	# 13	SC.6.P.13	**X**											
Grade 7														
Forms of Energy	# 10	SC.7.P.10	**X**		**X**									
Grade 8														
Earth in Space & Time	# 5	SC.8.E.5											**X**	
Language Arts Standards	**Sixth Grade:** LAFS.6.SL.1.1, LAFS.6.SL.2.4 **Seventh Grade:** LAFS.7.SL.1.1, LAFS.7.SL.2.4 **Eighth Grade:** LAFS.8.SL.1.1, LAFS.8.SL.2.4													

Sixth Grade Benchmarks

Science–Big Idea 7: Earth Systems and Patterns

- SC.6.E.7.1 - Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through Earth's system.

Science–Big Idea 13: Forces and Changes in Motion

- SC.6.E.13.1 - Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic and gravitational.

Language Arts–Standards for Speaking & Listening

- LAFS.6.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- LAFS.6.SL.2.4 - Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

Seventh Grade Benchmarks

Science–Big Idea 10: Forms of Energy

- SC.7.E.10.1 - Illustrate that the sun's energy arrives as radiation with a wide range of wavelengths, including infrared, visible, and ultraviolet, and that white light is made up of a spectrum of many different colors.

- SC.7.E.10.3 - Recognize that light waves, sound waves, and other waves move at different speeds in different materials.

Language Arts–Standards for Speaking & Listening

- LAFS.7.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- LAFS.7.SL.2.4 - Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

Eighth Grade Benchmarks

Science–Big Idea 5: Earth in Space and Time

- SC.8.E.5.11 - Identify and compare characteristics of the electromagnetic spectrum such as wavelength, frequency, use, and hazards and recognize its application to an understanding of planetary images and satellite photographs.

Language Arts–Standards for Speaking & Listening

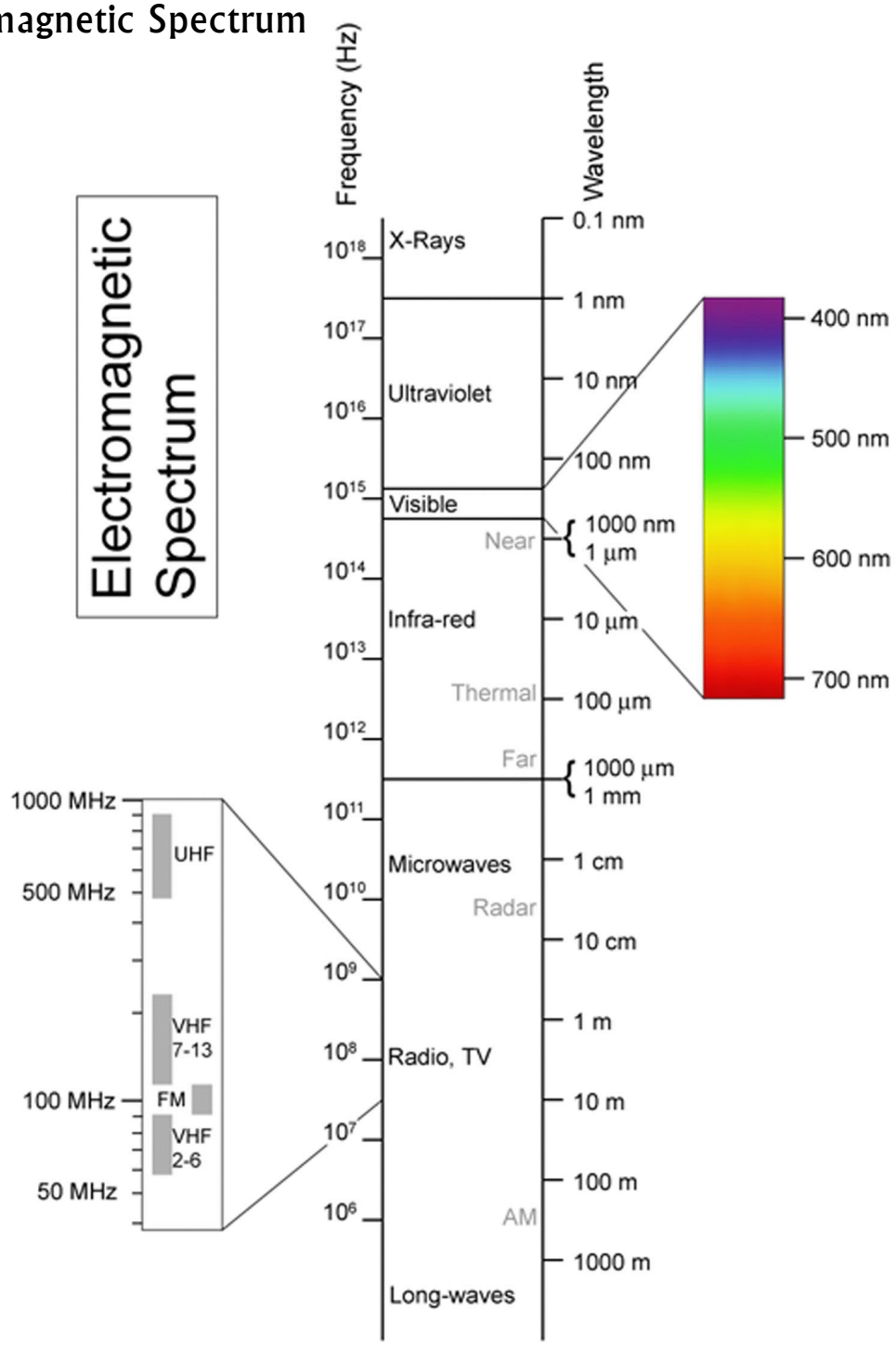
- LAFS.8.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- LAFS.8.SL.2.4 - Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Electromagnetic Spectrum

Rate each group on a 1 - 10 scale (with 10 being the highest) for each of the three categories. Total each groups score across.

	Content Knowledge	Creativity & Originality	Interesting?	Total Score
Radio Waves				
Microwaves				
Infrared Waves				
Visible Light				
Ultraviolet Light				
X Rays				
Gamma Rays				
Cosmic Rays				

Electromagnetic Spectrum



Reprinted from: Louis E. Keiner, Coastal Carolina University

With your group, answer the questions below. Use this information to form the basis of your presentation.

Type of radiation assigned for research _____

1. What are the characteristics of this type of radiation (i.e. wavelength, frequency, key facts)?

2. Where is this type of radiation found on the electromagnetic spectrum, and what types of radiation are found on either side of it on the spectrum?

3. What properties of the wave define why it is found within this area of the spectrum?

4. How is it used or found in our everyday lives or in certain industries? Identify and explain at least four uses.