EclipseMob

LESSON TITLE: THE ELECTROMAGNETIC SPECTRUM AND RADIO WAVES

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LESSON GOALS AND OBJECTIVES:

Students will be able to:

1. Explain what a wave is.
2. Define wavelength and wave frequency and demonstrate changes in frequency with a physical model.
3. Describe the relationship between wavelength and energy.
4. Explain what the electromagnetic radiation and the electromagnetic spectrum are.
5. Name the different parts of the electromagnetic spectrum and explain where radio waves fall on the spectrum.

BROAD GOALS:

1. Students will understand that energy has many forms and that energy can travel.
2. Students can explain what a spectrum is and what the electromagnetic spectrum is and what electromagnetic radiation is. They can relate the different energies of electromagnetic radiation to their daily lives.
3. Students can model and understand waves and wavelength and apply this knowledge to an understanding of the electromagnetic spectrum.

NGSS STANDARDS:

HS-PS4-1. Use mathematical representations to support a claim regarding relations among the frequency, wavelength, and speed of waves traveling in various media.

HS-PS4-2. Evaluate questions about the advantage of using a digital transmission and storage of information.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

MATERIALS REQUIRED:

For each student or team of students:

1. One meter stick or at least one ruler showing metric.
2. A prism (one per team or one for the teacher to demo)
3. Textbook or websites about the electromagnetic spectrum
4. Student data chart seen below (the chart below is also part of the Student Worksheet included in this lesson; information for radio waves are filled in as an example)

BACKGROUND INFORMATION:

EclipseMob is focused on the unique way radio waves emitted by the sun travel through the ionosphere, which is a part of the outer layer of Earth's atmosphere. For detailed lesson plans about how radio waves behave in Earth's atmosphere, see Lesson Two: Radio Waves and Earth's Atmosphere. These lessons also are helpful for teaching about Earth's atmosphere in general, including what happens to the sun's energy once it reaches Earth's atmosphere.

LESSON PLAN OUTLINE:

Part I: Introduction to Energy

The following activity can be done as a demonstration with discussion; or a teacher can set up stations and let students ask themselves and each other questions.

1. Find out what students already know about energy. Brainstorm ideas with the students. Ask them to share definitions of energy and examples of energy. Write down their phrases and ideas on the board. Most likely, all of their ideas will be examples of energy. Help students understand that energy exists in many forms.
2. Now begin to discuss specific forms of energy and the fact that energy travels as waves. This concept will help students begin to think of energy as something that travels. There are several ways to communicate this idea:

a) Show a picture of ocean waves. A good image is here (also visible below): http://earthobservatory.nasa.gov/IOTD/view.php?id=44567

The following points are possible to emphasize with this image:

a) Ocean waves form because wind blows water. The energy of the wind is transferred into the water.
b) The water is not traveling. The energy is traveling. A boat on the ocean would bob up and down as waves passed under it. The energy is able to travel because it uses the water to move from one place to another.
c) On the picture, if you have it on a Smartboard, you can introduce the concept of wavelength:

CONCEPT: Energy travels as waves (one wavelength is highlighted by the red line).

3. You can also emphasize this idea with a slinky. Again, you can do this as a demo or let a slinky be another station, depending on your students. As a demo in front of the class, ask a student to volunteer to hold one end of the slinky. You hold another. Ask the student to move their end of the slinky up and down. As the class watches, emphasize that the energy of the student moving their arm is being transferred into the slinky and moving through the slinky as waves.

Tie a red string on part of the slinky. Ask the students whether the string is moving forward or up and down. **This should help students understand that the only thing moving forward is the energy.** Ask students to draw and label a picture like the one at left (Source: http://science.hq.nasa.gov/kids/imagers/ems/waves3.html):

Students should then define wavelength. They can do this on the worksheet provided or, if you have students keeping a vocabulary notebook, they can do it there.

> **Wavelength**: For energy, wavelength is the measure of the distance between one peak of a wave and the next, or one trough of a wave and the next. It can be measured in meters and, for very small wavelengths, nanometers (one nanometer is 1 billionth of a meter, or 10^{-9} meters); or Angstroms (1 hundred-millionth of a centimeter).

<u>Part II: Wavelength and Frequency Hands-On Activity</u>

This activity should help students visualize the concept of wavelength further and then be able to apply that understanding to the concept of frequency.

Materials (per team of two students):

Lab tables students can draw on with chalk; chalk; a piece of string about 4 feet long; ruler; one worksheet per student for recording their measurements

1. Ask students to draw a straight line across the top of their desk using the chalk. Their line should measure three feet long.
2. Now ask students to form the string into the shape three waves underneath the line they drew. See the image at right (Source: K.Brody):

3. Ask each team to count how many individual waves they have formed. Then ask students to use the definition of wavelength to measure the wavelength between two of their waves. They should write all this information down under **Scenario I**.

4. Now challenge students to crunch their strings up so that they can fit as many waves as possible into one foot.

5. Students should again count how many individual waves they have formed and then measure and record the wavelength between two of their waves.

6. Now ask students to write down the definition of frequency, both as a sentences and as an equation:

Frequency (for energy): How often something happens during a period of time, OR: the number of waves that pass one point per unit time (smaller wavelengths mean that more waves pass per second than if you have bigger waves). Frequency is measured in cycles per second or Hertz.

Part III: Frequency and the Electromagnetic Spectrum

Students will now use their understanding of wavelength and frequency to understand that electromagnetic radiation exists in a spectrum of energies.

a) Define the electromagnetic spectrum: The range of possible wavelengths of electromagnetic radiation.
b) Define electromagnetic radiation. Here, we will use a very basic definition. For students ready for more challenge, you can teach the history of science leading up to the understanding that electricity and magnetism (electromagnetic) are the same force.

Electromagnetic radiation: This is energy such as light that is composed of photons moving in waves and that travel through empty space. It is the energy we receive from the sun. The “radiation” part does not mean it’s radioactive: it means the energy “radiates” or moves outward from a source (such as a star) through space. All stars, for example, emit electromagnetic radiation in energy levels that span the electromagnetic spectrum.

Photon: A particle or tiny packet of energy. A human cannot see an individual photon. As they travel through space or air or water or anything, the individual photons travel along paths that are wave-shaped (as modeled above). The photons are the energy coming from a star or other source of electromagnetic radiation. A photon in the radio portion of the electromagnetic spectrum contains less energy than a photon in the gamma ray portion.

A way to demo “radiation”: Turn off the classroom lights and shine a flashlight across the room. This is visible light, a form of electromagnetic radiation; It is made up of photons traveling in waves. Then clap your hands. This is sound energy. That energy travels through the air; that energy cannot travel without air (just like the wind energy that needs the ocean water in order to move, or the energy that needed the slinky in order to move). The flashlight beam can travel through air, water or even empty space. That is why the electromagnetic radiation emitted by the sun can travel 93 million miles through space and reach Earth.

Ask students: In the science fiction story Star Wars, when the Death Star blows up, everyone can see it. Why? Can anyone hear it? Explain your answer.

CHALLENGE ACTIVITY: Who first measured the speed of light and how?
Resource: https://www.aps.org/publications/apsnews/201007/physicshistory.cfm

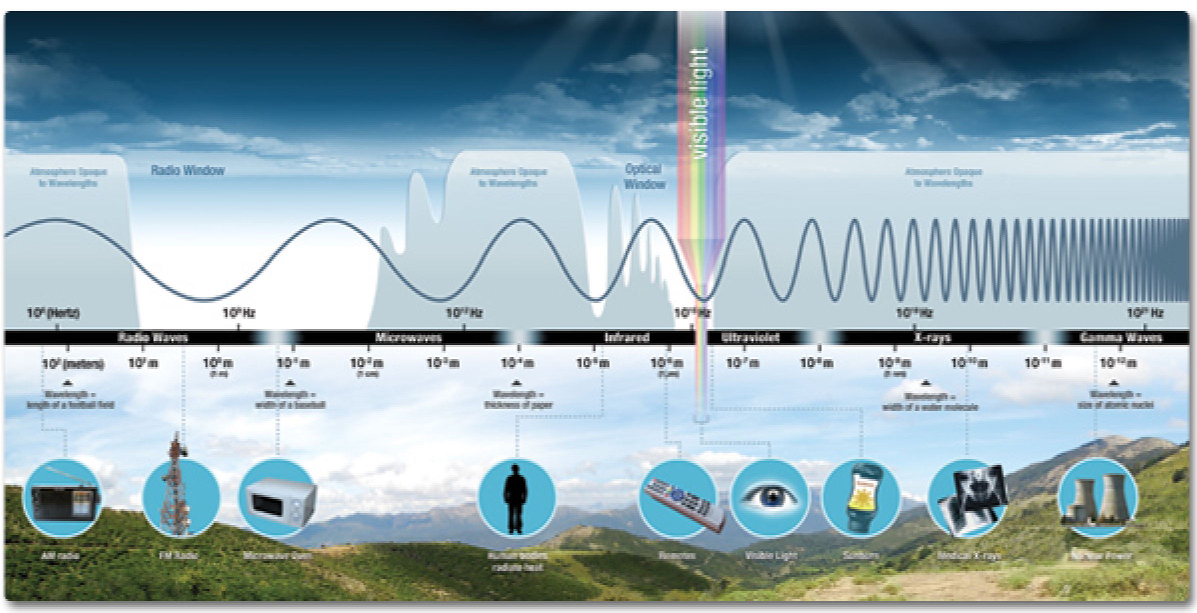
Parti IV: Wavelength and energy activity

Materials: for each student or team of students:

1. One meter stick or at least one ruler showing metric.
2. A prism (one per team or one for the teacher to demo)
3. Textbook or websites about the electromagnetic spectrum
4. Student data chart seen below (the chart below is also part of the Student Worksheet included in this lesson; information for radio waves are filled in as an example):

This is an inquiry exercise and also a guided reading exercise. Students will record information about each type of energy and be able to see that longer wavelength and lower frequency corresponds to lower energy. They should see that radio waves have the lowest energy and longest wavelengths. Teachers provide good reading material or give students access to links to reliable websites.

Students will start at the radio end of spectrum illustration and then move toward the gamma (the illustration below is from http://missionscience.nasa.gov/ems/01_intro.html).



NOTE: You may want to review scientific notation with students before beginning this exercise. Also, some students may have trouble with the ranges: they will be writing wavelength in ranges from large number to small.

You can use an electromagnetic spectrum illustration in a textbook, the one provided above, or see whether any online are helpful: For example, NASA Imagine the Universe:
https://imagine.gsfc.nasa.gov/Images/science/EM_spectrum_full.jpg
https://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

STUDENT DATA CHART (this is also part of the Student Worksheet provided as part of this lesson):

	Type of electromagnetic radiation	Wavelength in meters	This length is about the same as?	Uses in your daily life?
Lowest energy/lowest frequency	RADIO WAVES	As long as 10,000 (10^4) m to as small as 0.1 (10^{-1})	Length between mountain peaks; length of football field	Sending information to your FM or AM radio; talking to satellites; your cell phone
	MICROWAVES			
	INFRARED			
	VISIBLE			
	ULTRAVIOLET (UV)			
	X-RAYS			
Highest energy/highest frequency	GAMMA RAYS			These can be “radioactive” in the way we usually think of the word

Extension: If you have prisms: After students complete their chart, you can have them use the prisms to see how visible light breaks down into the rainbow colors. Then students can record the different wavelengths of visible light. Help them to understand that even as they break down visible light into its parts, they are zooming in for a closer look at just one tiny part of the entire electromagnetic spectrum.

Example of a prism you could order:
https://www.wardsci.com/store/product/8873554/equilateral-glass-prism

Website with energies of visible light:
https://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html#violet

CONCLUSION: For a conclusion, students should write a complete sentence explaining the *trend* or *relationship* between wavelength and energy. They should be able to explain which type of radiation is the lowest energy/longest wavelength and which is the highest energy/shortest wavelength.

CHALLENGE ACTIVITY: How do we "talk to" the satellites roaming the solar system, such as the New Horizons satellite? How do we get pictures and data back from them? Challenge students to understand why radio waves are the best choice for this type of long-distance communication. Students will calculate how long it takes to send a message to Curiosity on Mars and how long it takes to get a response.

Resources for this challenge:
http://www.planetary.org/blogs/emily-lakdawalla/2015/01300800-talking-to-pluto-is-hard.html
http://ieeexplore.ieee.org/document/1458163/ (this link provides an abstract only)

STUDENT HANDOUTS:

In this set of activities, you will learn:

1. Energy has many forms
2. Electromagnetic radiation is energy given off by stars; it travels great distances through empty space.
3. What the electromagnetic spectrum is.
4. Energy travels in waves; wavelength is related to amount of energy
5. Radio waves have a low amount of energy; gamma rays have a high amount of energy

VOCABULARY:

Energy Radiation Wavelength Frequency	Electromagnetic Spectrum Electromagnetic Radiation Radio waves

Part I: Introduction to Energy

1. In the space below, write down three things that are energy:

2. In terms of energy, what are ocean waves:

3. Describe what happens to the red string on the slinky:

4. Draw and label the picture of waves as instructed:

5. Define wavelength:

Part II: Wavelength and frequency hands-on activity

Materials: Lab tables you can draw on with chalk; chalk; a piece of string about 4 feet long; ruler; data table (below) to record your measurements

1. With the chalk, draw a straight line across the top of your desk. Use your ruler to make sure your line is 3 feet long.
1. Form the string into a shape that allows three waves about equal size to be underneath the line.
2. Fill in your data for **Scenario I**. Look at the drawing you made on page one to remind yourself how to measure wavelength.
3. **For Scenario** 2: Crunch up the string so that you have a lot of small waves all fitting within one foot under your line.

Data Chart:

Scenario	Number of waves under the line	Wavelength

Scenario 1		
Scenario 2		

Observations:

6. Which scenario had more waves? ______________________

7. Which scenario had a longer wavelength? _______________________

8. Inference: Which scenario do you think models a higher energy? Why?

9. Write a definition of frequency here:

Part III: Frequency and the Electromagnetic Spectrum

10. Define the electromagnetic spectrum:

11. Define electromagnetic radiation:

Use the reading materials or website supplied by your teacher to finish completing the Data Chart below:

	Type of electromagnetic radiation	Wavelength in meters	This length is about the same as?	Uses in your daily life?

Lowest energy/lowest frequency	RADIO WAVES	As long as 10,000 (10^4) m to as small as 0.1 (10^{-1})	Length between mountain peaks; length of football field	Sending information to your FM or AM radio; talking to satellites; your cell phone
	MICROWAVES			
	INFRARED			
	VISIBLE			
	ULTRAVIOLET (UV)			
	X-RAYS			
Highest energy/highest frequency	GAMMA RAYS			These can be "radioactive" in the way we usually think of the word

12. Conclusion: Explain the relationship you observe between wavelength and energy:

<u>Extension: VISIBLE LIGHT</u>

13. Visible light is the part of the electromagnetic spectrum humans can see with their eyes. Look at your illustration of the electromagnetic spectrum. How much of the spectrum is actually visible light?

Use your prism to break visible light into the colors of the rainbow. Now use the materials provided to understand the different wavelengths and energies of visible light:

Energy	Color	Wavelength (nanometers)
Lowest	R: Red	
	O: Orange	
	Y: Yellow	
	G: Green	
	B: Blue	
	I: Indigo	
Highest	V: Violet	

14. Inference: Why do the hotter stars in the universe appear blue and the “cooler” stars appear red?

ANSWER KEYS:

Available upon request.

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ASSESSMENT:

Coming soon…