

Tactile Electromagnetic Spectrum

Purpose/Overview: Before the measurement of gravitational waves and captured neutrinos from space, electromagnetic (EM) radiation (in the form of EM waves) was the only form of information we were able to detect and analyze. This activity introduces students to the range of EM waves as the EM spectrum, connecting the concepts of frequency and wavelength to the different types of EM waves that constitute the EM spectrum.

Using strings of different thicknesses and materials, seven of the various sections of the EM spectrum will be illustrated tactilely. Each part is on a puzzle piece (or simply an 8X10 piece of foam board). Radio, Microwave, Infrared, Visible, Ultraviolet, X-Ray, Gamma will be represented. The students will get into seven groups, and each group will be responsible for making a piece. After the pieces have been created, students are responsible for putting the puzzle pieces in order, using their knowledge of wavelengths and frequency.

Standards Addressed:

(HS.Waves and Electromagnetic Radiation)

<https://www.nextgenscience.org/sites/default/files/topic-arrangement/HSWER06.21.17WithFooter.pdf>

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

<https://www.nextgenscience.org/pe/hs-ps4-1-waves-and-their-applications-technologies-information-transfer>

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.

<https://www.nextgenscience.org/pe/hs-ps4-3-waves-and-their-applications-technologies-information-transfer>

Focus Questions:

1. What are the defining characteristics of electromagnetic energy that travel to our telescopes?
2. What are the ranges of the defining characteristics that we can detect?

Materials:

1. You will need access to two videos featuring Dr. Dawn Erb
 - a. Bio: <https://www.youtube.com/watch?v=jbnj9exZgz4>
 - b. EM spectrum in her work: <https://www.youtube.com/watch?v=e80r4PhlY0Y>

2. Cut one set of strings for each student group. Each type of string represents a different type of EM wave.

- a. **Gamma rays** - fishing line: 6 crests, 5 troughs; length is 229 cm
- b. **X-rays** - twine (neutral color): 4 crests, 4 troughs; length is 156 cm
- c. **UV** - thin purple yarn: 3 crests, 3 troughs; length is 127 cm
- d. **Visible light** - 3 pipe cleaners (red, green, blue): 2 crests, 2 troughs; length is 88 cm
- e. **Infrared** - red nylon rope: 1 crest, 2 troughs; length is 65 cm
- f. **Micro** - thick blue yarn: 1 crest, 1 trough; length is 50.5 cm
- g. **Radio** - thick purple rope: 1 crest, no trough; length is 29 cm

Larger (longer) wavelengths are represented by the thicker strings which are spread out. These long wavelengths also have the least energy. Smaller (shorter) wavelengths are represented by the thin strings which are packed closer together (Recall: the shorter the wavelength, the more energy it contains)

3. Seven laser-cut black puzzle pieces made from foam board (or just seven 8x10 pieces of foam board). File for Laser-cut pieces [HERE](#)
4. White map pins
5. Velcro Dots for attaching the braille labels of each part of the spectrum.
6. Braille Labels, one label for each of the types of EM radiation. These types of labels usually have sticky backs. Your school's vision specialist can assist with making these.
7. Tone generation app for a phone to demonstrate wavelength and frequency

In advance:

1. Be sure you have access to the Dr. Erb interview and EM Spectrum videos.
2. Install phone app.
3. Separate materials into bags that can be distributed to groups.
4. Cut puzzle pieces

Procedures:

1. Construct EM Puzzle Pieces
 - a. Distribute the puzzle pieces and construction materials.
 - b. Instruct students to create a horizontal line across the middle of the length of the board. This is $y=0$ and represents the undisturbed or rest position of the wave.
 - c. Construct the EM wave that is associated with each piece. Students can use push pins, map pins, or tape to hold the

string and mark the crests and troughs. You can provide them with as much information about which portion of the puzzle they are constructing as you think appropriate. Two possible options:

- i. Label the puzzle pieces in advance and provide the number of troughs and crests that each piece should include. *(see above in the material list for the number of crests and troughs for each part).*
 - ii. Give each group a blank puzzle piece, the correct construction materials, and the number of crests and troughs. Each group will need to decide which part of the EM spectrum they are modeling after the puzzle is put together.
2. Ask each group to research some basic information about their portion of the EM spectrum. You may want to provide specific resources for groups that take a bit longer to complete the puzzle.
 - a. Name
 - b. Range of wavelengths and a comparison size such as “width of a human hair”
 - c. Range of frequencies
 - d. Human uses or places where we encounter this type of EM radiation
 - e. The name of a telescope that captures that type of radiation
 3. After all the pieces are done and discussed, have the students put the pieces in order, from least energy to most energy, or from shortest wavelength to longest wavelength, or even by frequency range order.

Accessibility Considerations:

1. Monitor all puzzle pieces to be sure no pins are exposed.
2. Make sure all students “feel” the difference in materials and the number of crests and troughs of the different pieces.
3. Remind them that this is a model, and models are useful for building concepts in our brains, even if they are not 100% accurate. Ask students to generate ideas about the strengths and weaknesses of this model.

Extensions/Modifications:

1. Can you use a tone generator to extend this model? What does the tone represent? Does this help you visualize the spectrum?
2. Given that each puzzle piece is 25 cm long:
 - a. How many EM waves of the type stated could REALLY fit in that space? Use the middle number of the range of wavelengths for each represented part:
 1. Radio: 100 m
 2. Microwave: 1 cm
 3. Infrared: 10 micrometers = 0.000010 m
 4. Visible: 500 nanometers = 0.000000500 m
 5. Ultraviolet: 100 nanometers = 0.000000100 m
 6. X-rays: 1 nanometer = 0.000000001 m
 7. Gamma rays: 0.0001 nanometers = 0.0000000000001 m
 - b. How fast would something have to vibrate to produce each wave? Use this equation: frequency = speed of light/wavelength, where the speed of light is 3×10^8 m/s.
 - c. Calculate the relative bandwidth that each part of the spectrum really takes up. In this model, the puzzle pieces are all equivalent, but that is obviously not true. Have each group look up the percentage their piece should take up. Report to the others and see if they can come up with a visualization of the spectrum done correctly.

