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.

There are **two** possible ways to this activity::

1. 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.
2. *Use Wikki Stixs on regular sized cardstock. In this case, all waves will be made of the same material and thickness. See below in the "Materials" for more details.*

Standards Addressed:

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

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. [Link to Standard]

***Note: For this standard, stress that electromagnetic radiation is modeled as a wave when it TRAVElS through space. When EM radiation interacts with matter it is modeled as a particle.*

Cross Cutting Concept (element used to write the above performance standards)
Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **(HS-PS4-3)**

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)

   If using Wikki Stixs, follow the same instructions for the number of crests and troughs, but use the whole width of the cardstock for the amplitude (height of crest from the center). You will need 7.5 meters worth of WIkki Stixs (they come in 6 inch, 8 inch, and 3 foot lengths).
3. Seven laser-cut black puzzle pieces made from foam board (or just seven 8.5 inchx11 inch(regular paper size) pieces of foam board or cardstock for the Wikki Stixs). File for Laser-cut pieces HERE
4. White map pins *(not needed for Wikki Stix version)*
5. Velcro Dots or any method 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 relationship.

In advance:

1. Be sure you have access to the Dr. Erb interview and EM Spectrum videos linked above.
2. Install a phone app that produces tones.
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

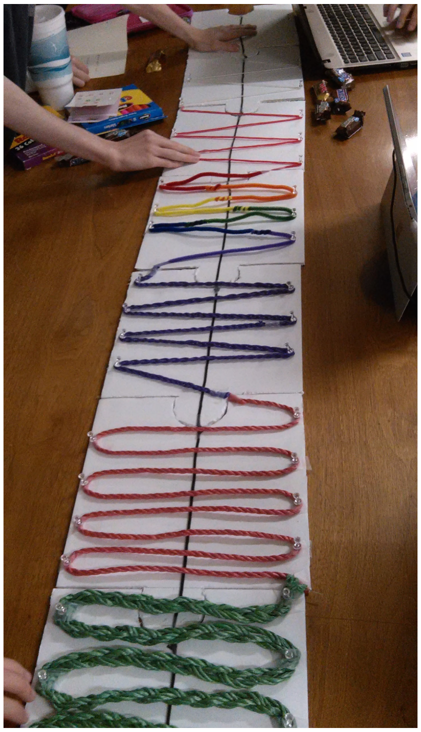
3. After all the pieces are done and discussed, have the students put the pieces in order, from least energy to most energy, or from shortest wavelength to longest wavelength, or even by frequency range order.

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 x 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.



Credits: **Innovators Developing Accessible Tools for Astronomy (IDATA)**, officially known as *Research Supporting Multisensory Engagement by Blind, Visually Impaired,* and *Sighted Students to Advance Integrated Learning of Astronomy and Computer Science,* and the resulting curricular resources, Afterglow Access software, and project research were made possible with support from the U.S. National Science Foundation's STEM+C program (Award 1640131). IDATA institutional collaborators include AUI, GLAS Education, Linder Research & Development Inc., Logos Consulting Group, TERC, University of Nevada – Las Vegas, University of North Carolina at Chapel Hill, and Universidad Diego Portales. Individual consultants on the project include Kathy Gustavson and Alexandra Dean Grossi. IDATA Teacher collaborators in the U.S. include Amanda Allen, Jacqueline Barge, Holly Bensel, Neal Boys, Tim Fahlberg, Kristin Grender, David Lockett, Matthew McCutcheon, Caroline Odden, Michael Prokosch, Kara Rowbotham, Rick Sanchez, and Barbara Stachelski. IDATA Student collaborators in the U.S. include Evan Blad, Naleah Boys, Ellen Butler, Jayden Dimas, Riley Kappell, Joseph Murphy, Logan Ruby, Alex Scerba, Charlize Sentosa, Meg Sorensen, Remy Streichenberger, Trevor Warren, and others. IDATA Undergraduate Mentors include Tia Bertz, Katya Gozman, Chris Mathews, Kendall Mehling, Andrea Salazar, Ben Shafer, Alex Traub, and Sophia Vlahakis. Special thanks to the IDATA external advisors including Nic Bonne, Al Harper, Sue Ann Heatherly, Russ Laher, Luisa Rebull, Ed Summers, and Kathryn Williamson.