Waves and communication in Aerospace Engineering

Goal

These lessons are designed to introduce students to Aerospace Engineering through the lens of understanding the electromagnetic spectrum. Students will explore the nature of waves, examine the electromagnetic spectrum, and learn how aerospace engineers use different parts of the electromagnetic spectrum to communicate with spacecraft.

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| Activity | Location | Duration |
| Lesson 1 –The nature of light and the electromagnetic spectrum | Classroom | Two lesson versions available:  Version A   * for middle school or introductory high school * Two 50-minute lessons   Version B   * For more advanced high school students * One 50-minute lesson |
| Lesson 2 – How NASA communicates with spacecraft | Classroom | 35 minutes |
| Lesson 3 – James Webb and Hubble telescope comparison | Classroom | 50-80 minutes |
| Field trip visit to Northrop Grumman   * Examine different types of spacecraft designed by Northrop Grumman. Learn about the regions of the electromagnetic spectrum each spacecraft detects. * Explore components of a spacecraft and learn about their functions. * Investigate the design of James Webb telescope. * If time permits: Explore satellite data to learn more about the Earth. * Observe the assembly of the James Webb telescope in a Northrop Grumman cleanroom. | Northrop Grumman | 2 hours |
| Lesson 4 - Putting it all together—Space exploration across the electromagnetic spectrum | Classroom | 50 - 120 minutes |

Timeline

Lesson 1 → Lesson 2 → Lesson 3 → Field trip Visit to Northrop Grumman → Lesson 4

**Middle School Standards**

*Next Generation Science Standards*

MS-PS4 Waves and Their Applications in Technologies for Information Transfer

* **MS-PS4-1**. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
  + DCI: A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
* **MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes.]
  + DCI: Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

*California Common Core State Standards Connections: ELA/Literacy –*

* RST.6–8.2Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)
* WHST.6–8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)
* SL.8.5Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2)

**High School Standards**

*Next Generation Science Standards*

MS-PS4 Waves and Their Applications in Technologies for Information Transfer

* **HS-PS4-1**. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
* **HS-PS4-2** Evaluate questions about the advantages of using a digital transmission and storage of information.
  + DCI: Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2), (HS-PS4-5).
* **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.
  + DCI: Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)

*California Common Core State Standards Connections: ELA/Literacy –*

* RST116–12.7Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1),
* WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source. (HS-PS4-4)

**Lesson 1**

Depending on the amount of time you want to dedicate to the electromagnetic spectrum, there are two lesson versions available.

* **Version A**: Explore the nature of waves, frequency, and the electromagnetic spectrum during two classroom lessons. This lesson series is intended for middle school students or high school students for whom this is their first time studying the electromagnetic spectrum.
* **Version B** Review the nature of waves, frequency, and the electromagnetic spectrum in one classroom lesson. This lesson is intended for students who have a greater familiarity with the electromagnetic spectrum and need to review basic concepts.

**Version A: Day 1—The nature of Light**

Duration: 50 minutes

Objectives:

* Students will be able to explain that white light is made up of waves with different frequencies and wavelengths.
* Students will be able to create a model relating wavelength, energy, and frequency of waves.

Vocabulary -

* Visible light—the wavelengths of the electromagnetic spectrum that are visible to most human eyes.
* Photon—tiny packets of energy that make up visible light
* Wave—a disturbance that transmits energy through matter or space. Photons travel in waves.
* Crest—the top portion of a wave
* Trough—the bottom portion of a wave
* Wavelength—the distance between one point on a wave and the corresponding point on an adjacent wave (ex: the distance from crest to crest)
* Frequency—the number of waves that pass a given point in a certain period of time (typically one second)

Focus questions: What is light? Why are there different colors of light?

Activity:

1. Introduce the lesson by asking students what they already know about light. Shine a flashlight across the room and ask students what they observe about the light. (expected answers: Light travels in a straight line. Light travels really fast. Light is white)
2. Demonstrate what happens when white light is passed through a prism. (Alternately show students a picture showing light breaking into different colors as it travels through a prism. <http://facweb.cs.depaul.edu/sgrais/images/ColorTheory/prism8.jpg>)
   1. Ask students why white light separates into colors as it passes through a prism.
   2. Explain that white light is made up of different colors of light as they saw in the demonstration
   3. Direct students to answer #1-3 on the Nature of Light worksheet
3. Using the “Nature of Light” PowerPoint, explain that concepts of photon, wave, wavelength, and frequency. Have students take notes on their worksheet.
4. Activity/demonstration
   1. Group students into pairs—give each pair a piece of string approximately 2 feet long.
      1. Instruct the students to create high frequency and low frequency waves on their desk using the string.
      2. Ask students what they notice about the wavelength of the high frequency waves vs. the wavelength of lower frequency waves.
      3. Direct students to record their observations on the worksheet. Have students explain the relationship between frequency and wavelength.

OR

* 1. Explore the PHET simulation showing waves on a string. <https://phet.colorado.edu/en/simulation/wave-on-a-string>
     1. For best results, choose the “oscillate” and “no end” settings with no damping.
     2. Adjust the frequency using the slider at the bottom of the screen and have students notice differences in the wavelength of the waves produced.
     3. Direct students to record their observations on the worksheet. Have students explain the relationship between frequency and wavelength.

1. Ask students why white light separates into colors as it passes through a prism. Have students complete the conclusion section of the worksheet.

Materials:

* Slideshow “The Nature of Light”
* Worksheet “The Nature of Light”
* Flashlight
* Prism and a bright light source (light from a projector or sunlight through the window work the best)
* Pieces of string (enough for pairs of students) (optional)
* PHET account (register for a free teacher account at phet.colorado.edu)

**Version A: Day 2—The Electromagnetic Spectrum**

Duration: 50 minutes

Objectives:

* Students will be able to identify the regions of the electromagnetic spectrum.
* Students will be able to provide examples showing how each region of the electromagnetic spectrum is used on Earth.
* Students will be able to explain that objects in the Universe give off radiation in different parts of the electromagnetic spectrum.
* Students will be able to explain that, by building spacecraft that detect different wavelengths of energy, astronomers can learn about the Universe.

Vocabulary: (all definitions taken from http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html)

* Electromagnetic Spectrum—the entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and including visible light.
* Radio waves
  + the section of the electromagnetic spectrum that has the longest waves. These waves also have the lowest frequency.
  + Radio waves carry radio and television signal on Earth.
  + Radio waves are also emitted by stars and gases in space.
* Microwaves
  + Located next to radio waves on the electromagnetic spectrum, microwaves have shorter wavelengths and higher frequency than radio waves.
  + Microwave radiation is used in microwave ovens to cook food and in cell phones to communicate.
  + Astronomers use microwaves to learn about the structure of nearby galaxies.
  + Microwaves are used by Doppler radar to study weather patterns on Earth.
* Infrared
  + Located between microwaves and visible light, infrared radiation is often said to show the heat of objects.
  + Night vision goggles work by picking up the infrared light emitted by our skin and other objects with heat.
  + In space, infrared radiation helps us map the dust between stars.
* Visible light
  + This is the light that our eyes detect.
  + Stars emit visible light. Objects within our solar system are visible because of visible light reflected from our Sun.
* Ultraviolet
  + Ultraviolet radiation is emitted by the Sun and is the reason skin tans and burns. These relatively high frequency waves can also damage DNA, possibly leading to the development of cancer.
  + “Hot” objects in space emit ultraviolet radiation.
* X-rays
  + Doctors and dentists use x-rays to image your teeth or bones. Airport security uses x-rays to see through your luggage.
  + Though x-rays have a lower frequency than gamma rays, x-ray radiation can still damage DNA and lead to the development of cancer.
  + Hot gases in the Universe also emit x-rays.
* Gamma rays:
  + These waves have the highest frequency, highest energy, and shortest wavelength of the entire electromagnetic spectrum.
  + Gamma rays are used by doctors to image areas of the body and to treat cancer (radiation therapy)
  + High frequency gamma rays damage DNA and can lead to the development of cancer.
  + The Universe generates gamma rays.

Activity:

1. Review Day 1 activity (white light is made up of different colors of light, each of which has a different wavelength)
2. Explain that visible light is a narrow part of the electromagnetic spectrum and that there are many other types of radiation that we cannot see. Explain that, even though we cannot see these types of radiation, we use them all the time to help us on Earth and to help us explore space.
3. Distribute the “Uses of the Electromagnetic Spectrum” handout. Direct students to cut apart the pictures.
4. Have students conduct research using the website, http://missionscience.nasa.gov/ems/ to determine which region of the electromagnetic spectrum is associated with each image. (If students do not have access to computers, consider projecting the website on a screen and leading students through the activity as a whole-class.)
5. Once students match the image to the correct type of radiation, have them glue the picture in the appropriate space.

Materials:

* Worksheet “The electromagnetic spectrum”
* Worksheet “Uses of the electromagnetic spectrum”
* Scissors
* Glue sticks
* Enough computers for students to work in pairs or one computer and projector for whole-class demonstration.

**Version B: Light, Waves, and the Electromagnetic Spectrum**

Duration: 50 minutes

Objectives:

* Students will be able to explain that visible light is a part of the electromagnetic spectrum.
* Students will be able to explain the relationship between the wavelength and frequency of a wave
* Students will be able to explain that different wavelengths of light provide different images of objects in space.

Vocabulary –

* Visible light—the wavelengths of the electromagnetic spectrum that are visible to most human eyes.
* Photon—tiny packets of energy that make up visible light
* Wave—a disturbance that transmits energy through matter or space. Photons travel in waves.
* Wavelength—the distance between one point on a wave and the corresponding point on an adjacent wave (ex: the distance from crest to crest)
* Frequency—the number of waves that pass a given point in a certain period of time (typically one second)
* Electromagnetic Spectrum—the entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and including visible light.

Activity:

1. Using the PowerPoint, “Light. Waves, and the Electromagnetic Spectrum”, explain the nature of light, the relationship between wavelength and frequency, and the types of radiation found in the electromagnetic spectrum.
2. Explain that different parts of the electromagnetic spectrum can be used for space exploration.
3. Have students complete the worksheet Light, Waves, and the Electromagnetic Spectrum.

Materials:

* Worksheet “The electromagnetic spectrum”
* Worksheet “Uses of the electromagnetic spectrum”

**Lesson 2**

Title: How NASA communicates with Spacecraft

Duration: 35 minutes

Objectives:

* Students will be able to explain that NASA uses the Deep Space Network (DSN) to communicate with spacecraft.
* Students will be able to outline the process used to transmit information between spacecraft and the Earth.

Vocabulary -

* Deep Space Network—a series of three antennas located 120 degrees apart on the surface of the Earth. The DSN receives radio signals from spacecraft that are more than 30,000 miles above the surface of the Earth
* Antenna—a device that transmits or receives radio signals
* Binary—data that is represented as a series of 1s and 0s.
* Transponder—a device on a spacecraft that converts binary data into radio signals.
* Radio signal—the radio wave that is used to transmit data from a spacecraft.
* Receiver—an antenna on Earth that receives signals from a spacecraft
* Decode—the process of converting radio signals into images that humans can see

Activity:

1. Introduce the lesson by showing the Slideshow “How NASA communicates with spacecraft”.
2. Students complete questions on the Worksheet “How NASA communicates with spacecraft”
3. Show the video “How to yell across a solar system” found at <http://spaceplace.nasa.gov/x-ponder/en/>

Materials:

* Slideshow “How NASA communicates with spacecraft”
* Worksheet “How NASA communicates with spacecraft”

**Lesson 3**

Title: James Webb and the Hubble telescope comparison

Duration: 50 - 80 minutes

Objectives:

* Students will be able to explain the need for an infrared space telescope.
* Students will be able to analyze and explain the features of the Webb telescope to understand the design considerations associated with creating an infrared telescope of this size.

**Vocabulary**:

* NASA’s James Webb Space Telescope—The infrared telescope part of the observatory, including the module of scientific instruments, is essentially already built and almost done being tested prior to it being sent to Northrop Grumman to be assembled with the spacecraft element. Northrop Grumman will lead the final observatory assembly step.
* Hubble telescope—a telescope launched into orbit around Earth in 1990. The Hubble provides information about the Universe in the visible, infrared, and ultraviolet ranges of the electromagnetic spectrum.
* Infrared
  + Located between microwaves and visible light, infrared radiation is often said to show the heat of objects.
  + Night vision goggles work by picking up the infrared light emitted by our skin and other objects with heat.
  + In space, infrared radiation helps us map the dust between stars.
* Visible light
  + This is the light that our eyes detect.
  + Stars emit visible light. Objects within our solar system are visible because of visible light reflected from our Sun.
* Red shift—a shift toward longer wavelengths of the spectral lines emitted by objects in space that are moving away from the Earth. The red shift can be observed in light from distant galaxies. The James Webb telescope was designed to detect infrared radiation so that it can capture the red light given off by these distant galaxies.

Activity:

1. Explain to students that they will be comparing the design features of two extremely powerful telescopes that are very different from each other.
2. Distribute the “James Webb and Hubble telescope comparison” worksheet and copies of the “How does the Webb contrast with Hubble?” article.
3. Direct students to read the article and complete the first two columns of the worksheet about the Webb and Hubble telescopes.
4. After 30 minutes, lead students through a discussion related to the third column, the reasons that the Webb telescope needed to be different than the Hubble telescope.
5. OPTIONAL: Distribute “Into the Unknown video study guide” and show Into the Unknown. Into the Unknown is a 38-minute long documentary produced by Northrop Grumman about the design and construction of the Webb Space telescope.

Documentary Name: INTO THE UNKNOWN - 021916   
Web address: <https://vimeo.com/156093791>  
Password to access: JWST20!6

Materials:

* Copies of the worksheet “James Webb and Hubble telescope comparison”
* Copies of the article, “How does the Webb contrast with Hubble?” (available on-line at <http://jwst.nasa.gov/comparison_about.html>)
* Computer with internet connectivity and projector to show “Into the Unknown”, a video about the Webb Space Telescope. (OPTIONAL)

**Lesson 4**

Title: Putting it all Together—Space exploration across the electromagnetic spectrum

Duration: 50 minutes – 2 hours

Objectives:

* Students will be able to explore how various parts of the electromagnetic spectrum provide information about the Universe

**Vocabulary**

* Electromagnetic Spectrum—the entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and including visible light.
* Radio waves
  + the section of the electromagnetic spectrum that has the longest waves. These waves also have the lowest frequency.
  + Radio waves carry radio and television signal on Earth.
  + Radio waves are also emitted by stars and gases in space.
* Microwaves
  + Located next to radio waves on the electromagnetic spectrum, microwaves have shorter wavelengths and higher frequency than radio waves.
  + Microwave radiation is used in microwave ovens to cook food and in cell phones to communicate.
  + Astronomers use microwaves to learn about the structure of nearby galaxies.
  + Microwaves are used by Doppler radar to study weather patterns on Earth.
* Infrared
  + Located between microwaves and visible light, infrared radiation is often said to show the heat of objects.
  + Night vision goggles work by picking up the infrared light emitted by our skin and other objects with heat.
  + In space, infrared radiation helps us map the dust between stars.
* Visible light
  + This is the light that our eyes detect.
  + Stars emit visible light. Objects within our solar system are visible because of visible light reflected from our Sun.
* Ultraviolet
  + Ultraviolet radiation is emitted by the Sun and is the reason skin tans and burns. These relatively high frequency waves can also damage DNA, possibly leading to the development of cancer.
  + “Hot” objects in space emit ultraviolet radiation.
* X-rays
  + Doctors and dentists use x-rays to image your teeth or bones. Airport security uses x-rays to see through your luggage.
  + Though x-rays have a lower frequency than gamma rays, x-ray radiation can still damage DNA and lead to the development of cancer.
  + Hot gases in the Universe also emit x-rays.
* Gamma rays:
  + These waves have the highest frequency, highest energy, and shortest wavelength of the entire electromagnetic spectrum.
  + Gamma rays are used by doctors to image areas of the body and to treat cancer (radiation therapy)
  + High frequency gamma rays damage DNA and can lead to the development of cancer.
  + The Universe generates gamma rays.

Activity:

1. Explain to students that they will be conducting research to learn more about the various types of radiation within the electromagnetic spectrum and how these different types of radiation have helped us learn more about our Universe.
2. Have students select at least one segment of the electromagnetic spectrum to research (either radio, microwave, infrared, visible, ultraviolet, x-ray, or gamma ray).
3. Direct students to create a slide show (or poster if computers are not available) to answer the following questions:
   1. Find one example of a spacecraft that uses this type of radiation to study space. Write the name of the spacecraft on your slide.
   2. Include a picture of the spacecraft.
   3. Explain what information scientists have learned about the Universe using data collected by this spacecraft.
   4. Include an image collected using this spacecraft. Describe what the image shows
4. Present your slide show to others to teach them about your segment of the electromagnetic spectrum.
5. Take notes during all presentations using the handout “Putting it all together—space exploration across the electromagnetic spectrum”

Materials:

* Project handout “Putting it all together—space exploration across the electromagnetic spectrum”
* Access to computers for student research
* If computers are not available, provide students with copies of
  + “Observatories across the electromagnetic spectrum” <http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum_observatories1.html>
  + “Light and telescopes” http://sciencelearn.org.nz/Contexts/Space-Revealed/Science-Ideas-and-Concepts/Light-and-telescopes
  + “It takes more than one kind of telescope to see the light” <https://science.nasa.gov/science-news/science-at-nasa/1999/features/ast20apr99_1/>

Extension:

Have students explore different types of information that can be gathered using the various types of electromagnetic radiation.

* Space observatory game—students are asked to decide which type of telescope (radio, infrared, optical, or ultraviolet) would me most appropriate for visualizing each of six object in space. The game can be found at <http://sciencelearn.org.nz/Contexts/Space-Revealed/Sci-Media/Animations-and-Interactives/Space-observatory>
* Build it yourself satellite game found at <http://jwst.nasa.gov/build.html>. oThe game allows students to choose what object their satellite will study. Students then choose the wavelengths, instruments, and optics they will include on their satellite to help them learn the most about the topic they have chosen. Once students have launched their satellites, they will see a picture of their device and learn what real NASA mission is similar to the one they created. Students will discover a large range of astronomical missions, dating from the 1980s to today.