Electromagnetic Spectrum and Multi-wavelength Astronomy

Learning Plan
Day 3: Beyond the Visible

Targeted Idea: There is invisible light in the electromagnetic spectrum.

Overview of Day 3:

Students examine two photos of a toaster behind a black garbage bag: one taken with a regular camera and one with an infrared (IR) camera. After viewing NASA videos about the electromagnetic spectrum and infrared light, students continue talking about their own mental models of visible and invisible light. Teachers then introduce students to infrared astronomy and observatories, highlighting SOFIA as an example. Students are also introduced to the IR camera and get their first glimpses of themselves and their classroom in the infrared.

Middle School Performance Expectations (PEs) and Disciplinary Core Ideas (DCIs) relevant to Day 3:

PE MS-PS4-2 Waves and their Applications in Technologies for Information Transfer
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.]

DCI MS-PS4.A Wave Properties
A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

DCI MS-PS4.B Electromagnetic Radiation
When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.

Students will build their understanding toward these High School DCIs in Day 3:

PS4.B.1 Electromagnetic Radiation
Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave ~~of changing electric and magnetic fields or as particles called photons~~. The wave model is useful for explaining many features of electromagnetic radiation ~~while the particle model explains other features~~.

PS4.A Wave Properties
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~~.

NASA SMD SciAct AAA

PS4.C Information Technologies and Instrumentation
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Students are building their skills in / understanding of these Science and Engineering Practices (SEPs) in Day 3:

Asking Questions

- Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
- Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.

Developing and Using Models

- Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

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<table>
<tr><th>Instructional Materials</th><th>Resources</th></tr>
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Handouts (one per student unless otherwise indicated)

- Lithograph: SOFIA Mission Overview
- EM Spectrum Review
- Science Case Study: Jupiter First Light

Materials (one per class unless otherwise indicated)

- Black garbage bag
- Small sheet of Plexiglas
- IR camera

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- PowerPoint for Day 3
- Enlarged version of the Classroom Unit Graphic Organizer - either on a white board, bulletin board, or with large sheets of chart paper.
- Ability to project videos:
- "Introduction to the Electromagnetic Spectrum" https://science.nasa.gov/ems/01_intro
- "More Than Your Eyes Can See" https://www.youtube.com/watch?v=2--0q0XlQJ0

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<tr><th>Teacher Role</th><th>Student Role</th></tr>
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- Distribute handouts.
- Encourage students to work independently and also contribute to group efforts, accordingly.
- Reassure that you are only looking for thoughts not "right answer".
- Watch for misconceptions, but do not use this time to instruct.
- Emphasize the importance of multi-wavelength astronomy and the unique role of infrared research. Include importance of high altitude to get above moisture and Earth's atmosphere.
- Provide reading support as needed while going through the Science Case Study. Rephrase and paraphrase as needed. Suggest reading strategies for students.

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- Listen closely to ideas of peers.
- Share own thoughts and reasoning.
- Be aware of own understanding and lack of understanding while reading the Science Case Study.
- Record thoughts and questions about the Case Study on the Reading Organizer and in their own notes.

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Steps to follow:

1. *Engage:* Project the slide in PowerPoint with the questions: "Can special cameras detect light that our eyes cannot see? Could a camera see through this object? Is the object a filter or a block – absorber?"
    - Remind students that in the Fancy Cameras probe, Wei suggested that cameras cannot detect light our eyes cannot see.
    - Hold up the garbage bag and ask for responses to questions 2 and 3 by a show of hands.
    - Repeat questions 2 and 3 holding up a piece of Plexiglas.
    - Project next PowerPoint slide showing both visible and IR images of toaster behind garbage bag.

2. *Explain:* Show the video "Introduction to the Electromagnetic Spectrum." As a focus for viewing, guide the students to note some of the ways the modern world uses the EMS. Also note that the video offers a great deal of content on the EMS, which will be explored on laterdays.
    - After viewing, reiterate that scientists use the wave model to help them understand and predict how light behaves.
    - Show the video "More Than The Eyes Can See."
    - Distribute EM Spectrum Review – Multi-wavelength Milky Way handout.
    - Ask the groups to also think of other technologies that can detect other forms of light (e.g. X-rays), or allow us to see things that we ordinarily could not see; as well as technologies that effects everyday lives. (UV sunscreens, microwave ovens, radio)
    - Ask 2 or 3 groups to share 1 of their technologies.
    - Next, ask students by a show of hands if they agree or disagree with Jared's statement in the Fancy Camera Probe. ("Each image looks different because of the speed of the waves. For example, the radio images looks different because that light travels much slower than visible light, and the infrared light travels the fastest.")

3. Introduce the example of a technology that can detect things that our eyes cannot see - the SOFIA telescope and its science instruments:
    - Airborne observatories such as SOFIA could fly up to altitudes of 45,000 ft to get above most of the moisture in the atmosphere. They did so because almost all the IR light is absorbed by the moisture in the atmosphere.
    - Science instruments on board were engineered to be sensitive to specific wavelengths of light.
    - SOFIA science data were collected on a hard drive during the flight.
    - Research astronomers, in general, use computers to compile data and generate images or curves or plots.
    - SOFIA flew, therefore it could travel to special locations (such as the center of

the Pluto occultation shadow).
- SOFIA observed at visible and near, mid, and far-infrared wavelengths.
- Instruments on SOFIA used filters to restrict the wavelengths that reached the instrument. While significantly more complicated than the filters used in student investigations for Days 1 & 2, the principle is the same: some wavelengths of light pass through (transmitted); some are blocked (absorbed).

4. Distribute SOFIA Mission Overview lithograph and have students review.
   - Ask students to turn to a partner and list a few ways in which the design/engineering of SOFIA made it special? What capabilities did it have that allowed it observe things that other telescopes could not? Share out.

5. *Explore:* Take out IR camera.
   - Explain that it has similar capabilities to SOFIA (or other mentioned multi-wavelength astronomy observatories) as the camera can observe light beyond what our eyes can see.
   - Turn camera on and ask one student to stand up. Show how the camera captures the remaining warmth of their chair, which we cannot see.
   - However, the IR camera cannot observe through certain things that are transparent to our eyes. Hold the Plexiglas in front of the camera lens to demonstrate that to the IR camera; Plexiglas is opaque.
   - Summarize: substances interact with different wavelengths of light in specific ways and can be opaque or transparent (i.e. infrared light is absorbed, transmitted, and even reflected). View reflected infrared light with the IR camera.

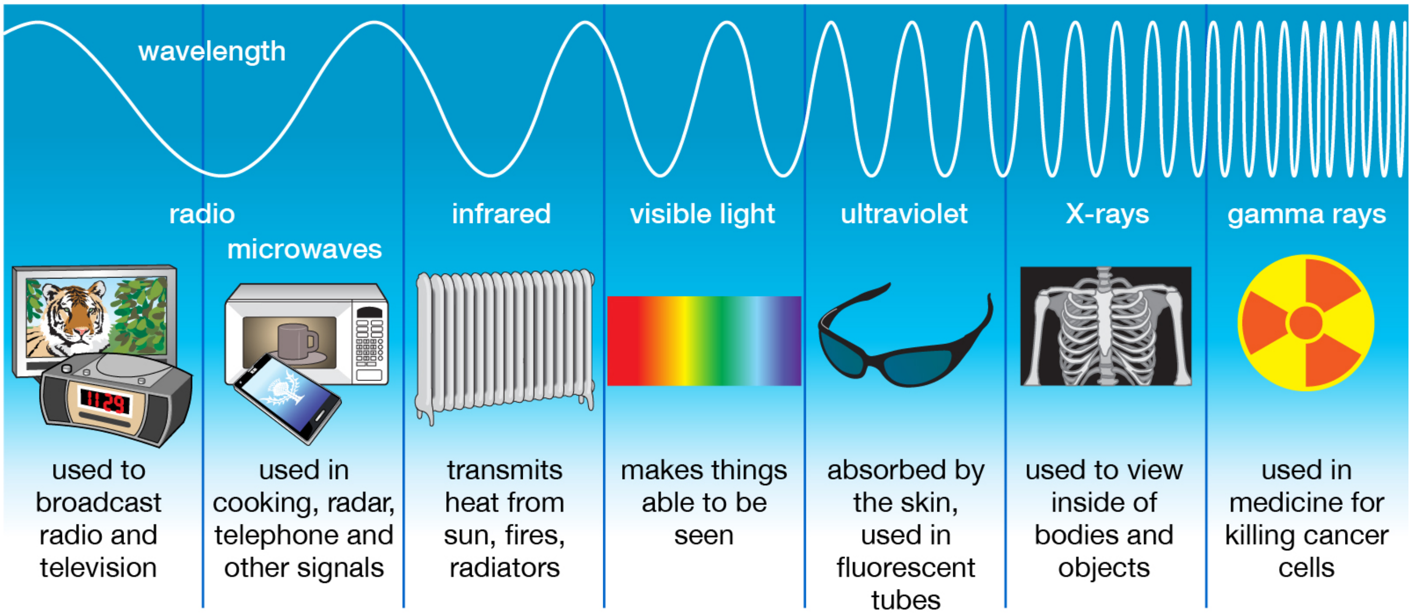
6. Return to the Unit Graphic Organizer and Science Case Study Focus Questions. Remind the students that these sheets will help them think about the unit experiences, as well as the readings.

7. Distribute Science Case Study: Jupiter First Light and look it over together as a class.

8. *Assign Homework:* A) Complete the Science Case Study graphic organizer questions for the Jupiter Case Study and the Unit Graphic Organizer for Day 3, and B) write a short paragraph describing uses of the EM spectrum everyday life.

Electromagnetic Spectrum Review

Types of Electromagnetic Radiation (all types travel at the speed of light)



View of the Milky Way Galaxy's central plane at different wavelengths.