

Kids as Airborne Mission Scientists

Lesson plan overview: What do remote sensors sense?

<u>FRAME</u>	<u>INFORM</u>	<u>EXPLORE</u>	<u>TRY</u>	<u>SUPPORT</u>
Students participate in an invisible light demonstration to learn that energy emitted by a light or the sun contains wavelengths we can and can not detect with our eyes.	Students are divided into groups to examine one of the several forms of EM radiation and then participate in a physical demonstration illustrating the characteristics of each form of EM radiation.	Students participate in the "construction paper investigation" and do a "colors reflected from colored objects" activity to learn more about reflection and absorption of light.	Students apply their understanding of EM radiation to the use of remote sensing instruments to explore the KaAMS mission.	Support materials for the teacher including ideas to promote student reflection, sample answers to the questions, and extension ideas.

Lesson context: Airborne remote sensing typically involves sensing reflected or emitted electromagnetic (EM) radiation. In addressing the overall problem, students will need to have a basic understanding of the EM Spectrum and various types of EM radiation, especially infrared and visible. During this lesson, students learn that there are wavelengths of EM radiation we can and cannot detect with our eyes. Students work in groups to investigate all of the types of EM radiation. They will identify visible and infrared radiation as useful forms of EM radiation to study lava flows. The understanding of EM radiation developed in this lesson, will help students when they analyze the reflected visible and mid-infrared images in the "Analyzing data" lesson to solve the overall problem of locating active lava flows on Kilauea.

Key science concepts:

- Types of EM radiation
- Frequencies and wavelength
- EM spectrum: visible, infrared, and microwave region
- Radiation–absorption and reflection

Links to teacher resources:

- [Fundamentals of Remote Sensing Tutorial](#)
- Electromagnetic spectrum - [NASA's Observatory](#)

Problems addressed in this lesson:

- What are the types of EM radiation?
- What is the difference between the absorption radiation and the reflection radiation?
- What types of EM gradations will be appropriate to study lava flows on Kilauea?

Activity bursts:

- Examining wavelength we can't detect with our eyes - [Invisible Light](#).
- Investigating all forms of EM radiation - [Activity sheet: How Does Remote Sensing Work? \(RSS-2\)](#)
- Reflection radiation - [Activity sheet: Nature of light \(RSS-3\)](#)
- Reflection and absorption radiation - [Colors Reflected From Colored Objects](#)
- Applying EM radiation in the KaAMS mission - [Introduction To The Study of Remote Sensing](#)

Links to other resources:

Lesson	<u>Teacher</u>	<u>Student</u>
FRAME	Invisible light http://imagers.gsfc.nasa.gov/teachersite/UL3_1.html	Invisible light http://imagers.gsfc.nasa.gov/teachersite/UL3_1.html
	Fundamentals of remote sensing http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html	
INFORM	EM spectrum http://imagers.gsfc.nasa.gov/ems/ems.html	EM spectrum http://imagers.gsfc.nasa.gov/EMS/ems.html
	NASA's observatorium http://observe.arc.nasa.gov/nasa/education/reference/emspec/empectrum.html	NASA's observatorium http://observe.arc.nasa.gov/NASA/education/reference/emspec/empectrum.html
	Wavelength http://observe.arc.nasa.gov/NASA/education/reference/emspec/wavelength.html	Wavelength http://observe.arc.nasa.gov/NASA/education/reference/emspec/wavelength.html
	Slinky http://www.physics.umd.edu/deptinfo/facilities/lecdem/g3-24.htm	Slinky http://www.physics.umd.edu/deptinfo/facilities/lecdem/g3-24.htm
EXPLORE	Colors reflected form colored objects http://www.physics.umd.edu/deptinfo/facilities/lecdem/n3-43.htm	Colors reflected form colored objects http://www.physics.umd.edu/deptinfo/facilities/lecdem/n3-43.htm
TRY	Introduction to the study of remote sensing http://geo.arc.nasa.gov/sge/jskiles/top-down/intro_to_rem_sen/intro_to_RS.html	Introduction to the study of remote sensing http://geo.arc.nasa.gov/sge/jskiles/top-down/intro_to_rem_sen/intro_to_RS.html

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What do remote sensors sense?

Related subject area: science

Overall problem: Are there active lava flows on Kilauea volcano?

Relationship of problem in this lesson to overall problem: Airborne remote sensing typically involves sensing reflected or emitted electromagnetic (EM) radiation. In addressing the overall problem, students will need to have a basic understanding of the EM Spectrum and various forms of EM radiation, especially infrared and visible. In the "Analyzing data" lesson, students will be analyzing reflected visible and mid-infrared images as well as emitted mid-infrared images of Kilauea volcano in Hawaii.

Estimated time required: Two to Three class periods.

Student outcomes/objectives:

- The student will identify various types of EM radiation.
- The student will explain that various types of EM radiation have different frequencies, wavelengths, and properties.
- The student will recognize the nature of some of the colored objects they see as particular wavelengths of light that have been reflected from that object as opposed to having been absorbed by that object.
- The student will identify visible and infrared radiation as useful forms of EM radiation with which to study lava flows.

Prerequisite skills or knowledge:

- Basic internet skills
- Basic reading and writing skills

Teacher preparation:

- Print Student Journal / Activity sheets for these activities.
- Bookmark appropriate websites for students.
- Carefully examine internet linked activities to identify and gather necessary materials to complete those lessons.

Student reflection and assessment: [Student reflection activities](#) | [Assessment](#)

Education standards supported by this lesson:

[National Science Education Standards](#) | [Project 2061 Benchmarks](#)

[National Standards for School Mathematics](#) | [National Technology Standards](#) | [National Geography Standards](#)

Cross-curricular connections to National Education Standards for this lesson:

[math](#) | [technology](#) | [geography](#)

Teacher activities

FRAME the lesson by suggesting to the students that one of the questions that they will need to address to resolve the overall KaAMS problem is: How can aircraft and remote sensing be used to locate active lava flows on Kilauea?

Introduce the lesson activities by having the students imagine they are looking out of the window in an airplane flying over Kilauea.

Ask

- What characteristics of a volcano can you see from the airplane?
- What is it that we actually see when we claim to have seen something? Something does enter our eyes.

Explain that what is actually being detected by our eyes is **electromagnetic (EM) radiation**.

Do the [Invisible Light](#) demonstration. It is important to note that technically the term light only refers to those wavelengths of EM radiation that we can detect (see). This particular activity is designed to demonstrate the existence of IR radiation. It also demonstrates:

- White light is composed of EM radiation of many wavelengths.
- Energy emitted by a light bulb or the sun also contains wavelengths we can't detect with our eyes, i.e., that we can't see.

Student activities

Sample student responses:

- Features of the volcano such as lava flows, craters, rocks, surrounding vegetations
- Maybe paths and roads, surrounding buildings
- Light, waves, light waves, colors

Student activity:

- Observe the [Invisible Light](#) demonstration.

Teacher activities

Prompt students to record their observations and write a brief explanation of what they see. See [Activity sheet: Invisible light observation \(RSS-1\)](#) questions 1, 2.

Teacher note: In order to truly appreciate remote sensing, students must gain a basic understanding of EM radiation. Background material for teachers on this topic can be found at the following site:

[Fundamentals of Remote Sensing Tutorial](#) - Focus on sections 1.1, 1.2, and 1.3 by clicking on Start Tutorial.

Student activities

Student activity:

- Record observations on [Activity sheet: Invisible light observation \(RSS-1\)](#) questions 1, 2 and explain observations.
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Teacher activities

INFORM students of important content or activity instructions.

Introduce the concepts of frequency and wavelength as they relate to the EM Spectrum. See [Fundamentals of Remote Sensing Tutorial](#) for more information, section 1.2.

OR

Have students read information on-line about the [EM Spectrum](#).

Divide your students into groups and assign each group one of the following forms of EM radiation: radio, microwave, infrared, visible, ultraviolet, x-rays, and gamma. Brief descriptions of each can be found at [NASA's Observatorium](#). You may want to print them out, cut printout into individual topics, and distribute to students.

Teacher note:

1. When you use the above website in the classroom, make sure students click on [wavelength](#) before reading about the EM types on the page.
2. Have the students complete the [Activity sheet: How does remote sensing work? \(RSS-2\)](#) during this part of the activity.

After students read and become familiar with their assigned form of EM radiation, you may want to have them share with each other the important characteristics of each. Have them focus on information such as whether or not we can see or feel their form of radiation, examples of it from their everyday experience, where it might come from, etc.

Student activities

Optional student activity:

- Review [EM Spectrum](#) web-site.

Student activities:

- Break into groups assigned to one form of EM radiation.
- Read about their assigned form of EM radiation.
- Students complete the [Activity sheet: How does remote sensing work? \(RSS-2\)](#) during this part of the activity.
- Share what you learned with the class or a few classmates.
- Learn the difference between frequency and wavelength and how they help to describe EM radiation.

Teacher activities

Ask for representatives of each assigned form of EM radiation to participate in a physical activity demonstrating the characteristics of their energy form.

- Students line up from lowest to highest frequency.
- Students line up from shortest to longest wavelength.
- In either case they could **role-play** higher frequency by shaking or jumping faster or slower and they could role-play wavelength with objects of varying lengths. (These concepts can also be demonstrated quite effectively with a [slinky](#). A piece of rope is also effective and will not get kinked-up like a slinky sometimes does.)
- **Another option:** Students could be paired and assigned one form of EM Radiation. In the "role play" activity each could be assigned either frequency or wavelength. In this way each student gets to line up.

Ask what do all of these forms of EM radiation have in common, i.e. how are they similar?

Ask how do these forms of EM radiation differ?

Student activities

- Participate in physical demonstration of all of the forms of EM radiation.

Optional student activity:

- Participate in a slinky or rope demonstration of the relationship between frequency and wavelength.

Sample student responses:

- **Similarities:**
 - They are all forms of EM radiation.
 - They all involve waves, frequency, and wavelength.
 - They can travel from source to observer (e.g. across a vacuum, through air, through water) without source and observer actually touching.
- **Differences:**
 - They have different characteristics, i.e., they can do or are used for different purposes.
 - Some we can see or feel, some we can't.
 - The frequencies and wavelengths are different for different types of EM radiation.

High frequency goes with short wavelength and low frequency goes with long wavelength.

Teacher activities

EXPLORE the nature of the light that can be seen by engaging in the following two activities

Activity 1: Construction paper investigation

- Place a piece of colored construction paper on the table and hold a piece of white paper at an angle over the construction paper.
- Look at the underside of the piece of white paper and record your observations. See [Activity sheet: Nature of light \(RSS-3\)](#), question 1.
- Repeat with construction paper of various other colors.

Teacher note: Students should observe a colored hue on the bottom of the white paper that represents colored light that has been reflected by the white paper. Our eyes detect this light. The light originated as white light from the room lights (or sunlight if you have the blinds open). The construction paper has the color you see because it is reflecting that color and absorbing all of the others. See [teacher notes](#) and diagrams below.

Activity 2: Color reflected from colored objects

Do the "[Colors Reflected From Colored Objects](#)" demonstration.

- This activity is designed to show that if the source of light is limited to one wavelength then something that reflects that same wavelength will still reflect it and things that absorb that wavelength will still absorb it.

Student activities

Student activities:

- Conduct colored construction paper activity
- Record observations [Activity sheet: Nature of light \(RSS-3\)](#) question 1.
- Explain observations.

Student activities:

- View the demonstration "[Colors Reflected From Colored Objects](#)."

Teacher activities

- In this demo only a small portion of the EM spectrum is used. The objects have a particular color because they are absorbing all other colors except the one they are reflecting. We are separating out only a small portion by using a filter that only transmits one portion.

Teacher note: If you do not have colored filters and projectors for this demonstration you could use flashlights and colored cellophane or have the students examine the images at this site or project them.

Prompt students to record their observations and write a brief explanation. See [Activity sheet: Nature of light \(RSS-3\)](#) questions 2,3,and 4.

Ask which types of EM radiation would be most useful for locating active lava flows.

- See [Activity sheet: Nature of light \(RSS-3\)](#), question 5.
- You should be able to lead them to visible and infrared radiation as the logical choices of what to detect.

We can learn about volcanoes from what we can see and we can learn about them based on the heat they give off in the form of infrared radiation.

Student activities

Student activities:

- Record and explain observations on [Activity sheet: Nature of light \(RSS-3\)](#) questions 2,3,and 4.
- Answer [Activity sheet: Nature of light \(RSS-3\)](#), question 5.

Sample student responses:

- Visible and infrared radiation

We can learn about volcanoes from what we can see and we can learn about them based on the heat.

Teacher activities

TRY using new knowledge. In the KaAMS mission, a remote sensing device called AVIRIS was used. A device such as this has an array of sensors on it and each sensor is capable of sensing and recording information from only a small portion of the EM spectrum.

Check students' understanding of terminology.

See **Activity sheet: Defining the terms (RSS-4)**.

- Array
- Spectrum
- Electromagnetic (EM)
- Radiation
- EM spectrum

Lead students into an exploration of what it is like to detect only small parts of the visible spectrum, have them participate in the [Introduction To The Study of Remote Sensing](#) lesson. Students will experience what it is like to see only certain colors through glasses they make from colored filters.

Student activities

Student activity:

- Students should complete **Activity sheet: Defining the terms (RSS-4)**.

Example definitions:

- **Array** - an orderly arrangement or display
 - **Spectrum** - an ordered array of the components of an emission or wave, several colored and other rays of which light is composed
 - **Electromagnetic (EM)** - the transfer of energy by the rapid oscillations (vibrations back and forth) of electromagnetic fields, that travel in the form of electromagnetic waves.
 - **Radiation** - the shooting forth of anything from a point or surface, like the diverging rays of light; as, the radiation of heat
 - **EM spectrum** - the range of frequencies (or wavelengths) over which EM radiation can be sent (propagated).
- Participate in the activity [Introduction To The Study of Remote Sensing](#).

Teacher activities

Ask why do you think you could only see pipe cleaners of certain colors through your special glasses?

Teacher note: There are two important connections to make that will be built upon throughout the rest of this lesson:

- The sensors on a device such as AVIRIS are only sensitive to certain frequencies or wavelengths of EM radiation.
- The filters in this activity allow only certain colors, i.e., frequencies or wavelengths of EM radiation to be sensed by the device (the eyes). They absorb some wavelengths and permit others to pass through.

Prompt students to list other questions they have about color and how it relates to remote sensing.

- This an opportunity to suggest further study to answer questions such as these.
- Objects often have a "signature" of wavelengths they reflect (not unlike fingerprints).
- Examining individual wavelengths or combinations of wavelengths can often bring out detail in remotely sensed images impossible to identify from images that are formed from many wavelengths like photographs.

Remind students to complete the **Activity sheet: Reflection page (RSS-6)** for this lesson in their student journals.

Student activities

Sample student responses:

- The filters allow only certain colors to be sensed by the eyes.
- This is similar to the AVIRIS sensors they are each sensitive to certain forms of EM radiation.

Sample student responses:

- Why is it useful to use RS detectors that measure the amount of EM radiation present at each small portion of the spectrum as opposed to just measuring all EM radiation at all wavelengths combined into a single signal?

Student activity:

Students complete the **Activity sheet: Reflection page(RSS-6)** for this lesson in their student journals.

Student reflection activities:

Prompt students to think about the following and record their responses on **Activity sheet: Reflection (RSS-5)** in their journals.

- What would a visible or infrared image of the crater of a very active volcano look like?
 - How do our own sensory systems sense things that are hot without physically touching them?
 - If we fly over a volcano in an attempt to sense light and heat, what factors will need to be considered when to flying over the volcano.
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Assessment:

- Review definitions of wavelength and frequency.
See [Activity sheet: How does remote sensing work? \(RSS-2\)](#).
 - Review descriptions of each type of EM radiation and examples.
See [Activity sheet: How does remote sensing work? \(RSS-2\)](#).
 - Review students definitions of the following terms: array, spectrum, electromagnetic (EM), radiation, EM spectrum.
See [TRY section](#).
 - Review explanations of color filters and invisible light demonstration. See [Activity sheet: Nature of light \(RSS-3\)](#).
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Ideas for math lesson enhancements:

- Students learn power of ten (scientific) notation and compare the power of ten associated with different types of EM radiation.
- Students use the relationship: wave speed = frequency X wavelength ($v = f \lambda$) to solve for one of the variables when the other two are given.
- Students determine the energy of EM radiation of a certain frequency by using the relationship: energy of EM radiation = Planck's constant X frequency ($E = h f$). ($E = hc/\lambda$ is also suitable where c = speed of EM radiation in a vacuum and λ = wavelength)

Related National Education Math Standards:

- [numbers and operations](#)
 - [algebra](#)
 - [measurement](#)
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Ideas for geography lesson enhancements:

- Students identify different land forms, such as volcanoes, tropical forests, ice packs, water, etc., or places on earth while viewing remote sensing images.

Related National Education Geography Standards:

- [The World in Spatial Terms](#) (#1)
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Ideas for technology lesson enhancements:

- Students learn to consider EM radiation as a form of energy and investigate processes involving energy transformations to and from EM radiation such as those found in the harnessing of solar power.
- Students learn that power is the rate at which energy is converted from one form to another.

Related National Education Science Technology Standards:

- [The Designed World](#) (#17) Energy and Power Technologies
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Activity sheet: Invisible light observations (RSS-1) answer key

Name: _____

1. Draw or describe your observations of the Invisible Light demonstration.

- The prism separated white light coming from the room lights or from sunlight into the various colors of the visible spectrum. IR radiation was also separated as evidenced by the increased temperature at the location just beyond the color red in the resulting spectrum.

2. The light that passed through the prism was from the room lights or from light coming into the room from outside. What do you think the demonstration tells you about what that light is made up of?

- White light is actually made up of all colors or another way to say it is that if you combine light of all colors you get white light.
 - The sun gives off more than just light visible to our eyes and that IR energy is in the direction of red, not blue.
-

Activity sheet: How does remote sensing work? (RSS-2) answer key

Name: _____

1. Define the following terms:

- Wavelength - The wavelength is the length of one wave cycle, that can be measured as the distance between successive wave crests.
- Frequency - Frequency is usually measured as the number of cycles or vibrations each second. One cycle/second is called 1 Hertz (Hz).

2. Complete the following table. In the comparison section, compare the wavelength of a typical wave of that type to one meter. (For example: The distance across your fingernail is about 1/100th of a meter.)

Type of EM radiation	Comparison of wavelength of type to 1 meter	Examples/uses of this type
Radio waves	Any where from about 1 meter to over 10,000 kilometers	Radio communications such as AM or FM
Microwaves	Some where in the range of about a 1/10 th of a millimeter to a meter	Used in microwave ovens and RADAR
Infrared	Somewhere on the order of a micrometer (1 millionth of a meter) to 1/10 th of a millimeter	Heat that you feel without touching is infrared radiation. Heat lamps for keeping food warm is called thermal IR. Near and mid IR can't be felt or seen by humans but are very important in remote sensing, e.g. plants reflect strongly at various near and mid IR and this helps in detecting and identifying various types of vegetation.
Visible (light)	Very narrow range of wavelengths that we can detect with our eyes. In the range of 400-700 nanometers. One nanometer is one billionth of a meter.	The light that we see.
Ultraviolet	Somewhere on the order of one ten millionth of a meter to one billionth of a meter	Form of radiation responsible for sunburn and integral component of energy changes occurring during photosynthesis in plants
X-rays	Somewhere on the order of one billionth of a meter to one one-hundred billionth of a meter.	Used for medical imaging of dense tissue and utilized in gaining insight into the structure of matter in X-ray diffraction
Gamma rays	Any wavelengths smaller than those associated with x-rays	This is the form of EM Radiation most commonly associated with nuclear radiation. Other nuclear radiation involves the emission of particles.

Activity sheet: Nature of light (RSS-3) answer key

Name: _____

1. What did you observe on the underside of the white paper when you placed construction paper of different colors underneath it?

- The white paper will have a hue the same color as the construction paper beneath it.

2. What did you observe when the color of the filter was the same as the color of the object?

- The object will look the same color as the filter. It looks the same color as it naturally does; the light it reflects is the same color that the filter allows to pass. There is no change. In this demo only a small portion of the EM spectrum is used. The objects have a particular color because they are absorbing all other colors except the one they are reflecting. We are separating out only a small portion by using a filter that only transmits one portion.

3. What did you observe when the color of the filter was different than the color of the object?

- The object will look a different color than its natural color; the object may look quite dark, perhaps even black. In this demo only a small portion of the EM spectrum is used. The objects have a particular color because they are absorbing all other colors except the one they are reflecting. If the filter doesn't allow that particular wavelength to pass then no light from the object can make it to your eyes and the object looks black.

4. Based on your experiences with the invisible light demonstration, construction paper investigation, and the color reflected from colored objects demonstration, how would you explain where the light comes from when you look at someone wearing a multi-colored shirt? How do the colors you see on the shirt end up getting to your eyes?

- The room lights or sunlight provide a source of all visible wavelengths. When looking at the shirt, the colors we see have been reflected by the shirt. Those we cannot see have been absorbed by it. Each part of the shirt has a particular color because different dyes absorb all wavelengths but one. That one is reflected and our eyes detect it.

5. Which types of EM radiation would be most useful for locating active lava flows?

- We can learn about volcanoes from what we can see (visible EM radiation) and we can learn about them based on the heat they give off in the form of infrared radiation.

Activity sheet: Reflection (RSS-5) answer key

Name: _____

1. Describe how the visible and infrared images of the crater of a very active volcano might look.

- Student answers will vary

2. How do you suppose our own sensory systems sense things that are hot without physically touching them?

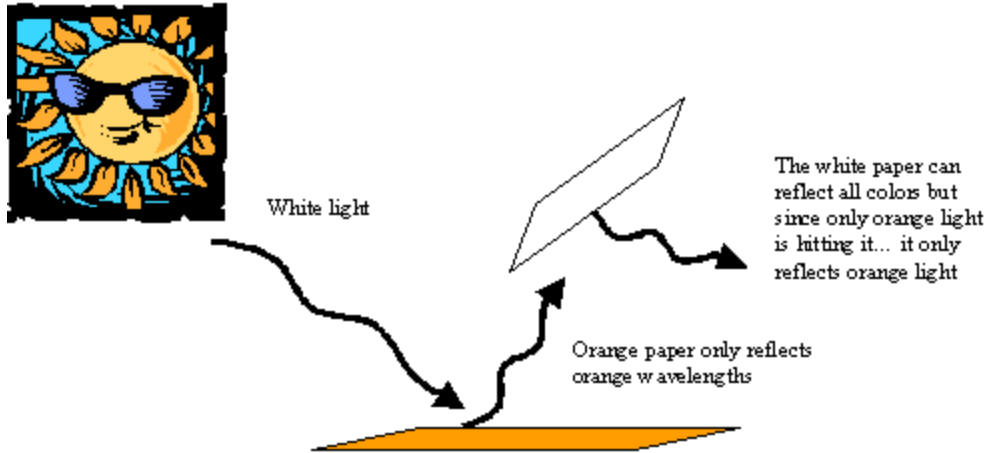
- The EM radiation is sensed by our skin or our eyes and is translated into electrical nerve impulses that are recognized by our brains.

3. If we fly over a volcano in an attempt to sense light and heat, what factors will we need to consider when deciding when to fly over the volcano.

Teacher note: Teachers will use this question as an introduction to the next lesson.

- How high to fly
 - How fast to fly
 - What wavelengths to sense
 - How many times to pass over
 - Weather conditions
 - Time of day
 - Where to take off and land
-

Teacher notes to accompany Construction Paper investigation:



White paper will reflect all colors (visible wavelengths). Orange paper absorbs all colors (visible wavelengths) except orange. Students are likely to have a difficult time visualizing this phenomenon and may not "believe" that something is actually being reflected by the orange paper. The white paper is used in this demonstration to "prove" to the students that light is actually being reflected by the orange paper. In reality it proves that white paper reflects orange light but experienced teachers have used this demonstration successfully.

It is important that you explain the purpose of the white paper and then help them understand that many objects appear the color they do because of the light they reflect.