

IMAGERS:

The Adventure of Echo the Bat

Teacher's Guide

Unit 1: Understanding Light

<http://imagers.gsfc.nasa.gov>

Teacher's Guide

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Introduction to Teacher's Guide

Welcome to the IMAGERS Adventure of Echo the Bat Teacher's Guide! The Adventure of Echo the Bat is an interactive web site featuring an Interactive Adventure and Teacher's Guide, which combine to introduce students to remote sensing and biodiversity from a constructivist approach. The Teacher's Guide contains classroom activities and lesson plans that provide a structure to integrate the interactive adventure into the classroom. The activities introduce concepts basic to the understanding of remote sensing including understanding light and the introduction to the electromagnetic spectrum. The Adventure engages students in exploring concepts of remote sensing and biodiversity. After completing the Adventure, these concepts are reinforced back in the classroom with hands-on activities provided in the Teacher's Guide.

Participants begin with classroom activities from the Understanding Light unit. The activities allow students to explore the concepts of light. They continue investigating different electromagnetic energy with the IMAGERS Electromagnetic Spectrum web site. After introductory remote sensing activities, they start the interactive component of the IMAGERS site. A story of Echo the Bat sets the stage for the interactive adventure using a Landsat mosaic of Arizona as the interface. Students need to interpret satellite imagery to receive clues to Echo's location. As students find Echo, additional content about remote sensing and biodiversity is introduced. This web site provides teachers with a vehicle for introducing complex content that can be reinforced back in the classroom through the Remote Sensing and Biodiversity units

We created three thematic units targeted for grades 5-8: Understanding Light, Remote Sensing, and Biodiversity. Within each unit, you will find lesson plans, reproducible worksheets, visuals, and links to useful resources. The lesson plans are organized according to the 5-E constructivist model.

Engagement: capture attention, stimulate their thinking, assess their prior knowledge

Exploration: activity to introduce concept, an investigation

Explanation: discussion of concept, analysis of their exploration

Extension: apply concept to real world situation, expand their understanding

Evaluation: a short activity to assess students' understanding

Though IMAGERS is intended for grades 5-8, we encourage you to customize the activities to fit your class and curriculum. Depending on your students' prior knowledge, you may choose to expand or omit certain activities. See Appendix A for specific national and local standards covered in our lesson. We hope IMAGERS enables you to introduce new and exciting science concepts to your students through interactive multimedia and constructivist activities. Happy exploring!

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IMAGERS: UNIT I Understanding Light

This unit introduces students to the basics of light as a preface to understanding how remote sensing works. In Lesson 1, **The Primary Colors of Light**, students experiment with mixing colors of light to discover that the primary colors of light are red, green, and blue. They continue with Lesson 2's **What Color is it?** where they model how objects absorb and reflect colors of light. In Lesson 3, **Introducing the Electromagnetic Spectrum**, students are introduced to different electromagnetic energy through the Electromagnetic Spectrum web site. This content is reinforced in the Wavestown activity. This unit prepares them for the Remote Sensing unit.



LESSON 1 - The Primary Colors of Light

Students will:

- Use the primary colors of light to create new colors.
- Demonstrate their new knowledge of the primary colors of light by coloring a diagram.

Materials Needed:

Worksheet 1 - Mixing Colors of Light (1 per group)
Small flashlights (3 per group)
Red, blue, and green theatrical gels or cellophane
Tape
White paper
Copies of blank venn diagram (provided)
Crayons

Engagement

Show students the three flashlights. Ask them if they can identify anything unique about this combination of colors. Explain that today's activity will give them the opportunity to experiment with colored lights.

Exploration

Divide students into groups of four. Provide each group with three flashlights, a red, green, and blue color theatrical gel, and three pieces of tape. Each group should also have a copy of worksheet 1. Have students tape the gels around the face of the flashlight so that no white light leaks out. Assign one to each student in the group. One will be the recorder and three will hold a flashlight. Tell students to use their flashlights to mix the colors of light. As they make discoveries, ask the recorder to describe the color they created. Have the group quantify the amount, or intensity, of colored light used. (See directions and example on worksheet 1.) After a few minutes, have the students exchange roles and continue mixing colors (see answer key).

Explanation

After students complete the chart, as a class discussion, ask them to describe the colors they created. Make a list on the board. (Optional: Use stage lights to demonstrate the colors they name. See directions following worksheet 1.) Review the following combinations and give students the “proper names” for them.

Red + Green = Yellow

Red + Blue = Magenta (pinkish purple color)

Blue + Green = Cyan (turquoise)

Red + Blue + Green = White

The absence of light = Black

Then, ask students why red, green, and blue are so unique. Lead them to understand that the three colors make the primary colors of light. Explain that red, green, and blue mix to make all colors.

Distinguish the primary colors of **LIGHT** and the primary colors of **PIGMENT** from each other. Red, green, and yellow equal the primary colors of **PIGMENT**, or paint and crayon. They cannot combine to make the products of the primary colors of **LIGHT**.

Extension

Relate this new information to computer monitors. Explain to students that computer monitors combine red, blue, and green to make the colors that we see. Our monitor can display hundreds and thousands of colors. Give students a copy of the blank venn diagram. Have them label and color in the diagram using the information they learned in this lesson.

Evaluation

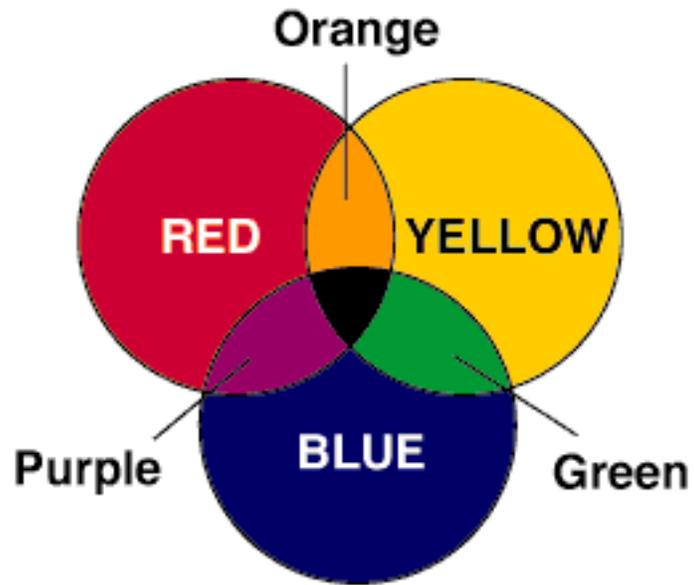
Ask students to name the primary and secondary colors of light. Use the complete venn diagram to assess their understanding of the primary color combinations.

Tips for Teachers

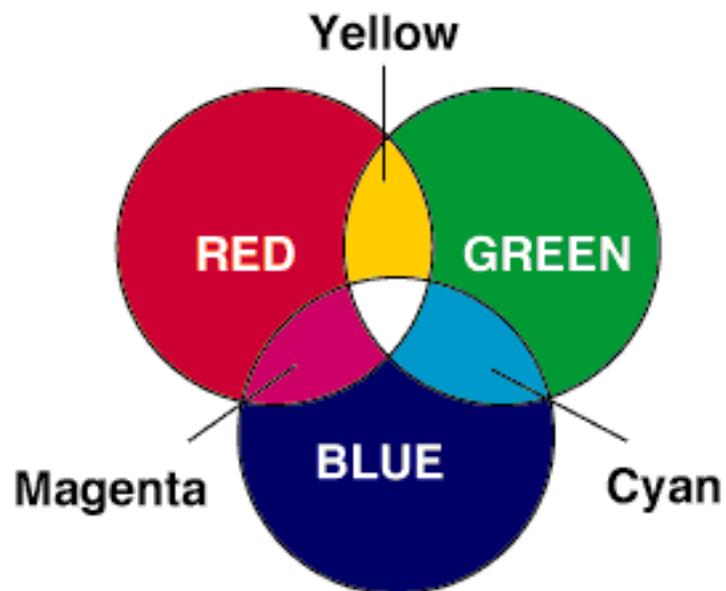
- Flashlights - Have each student bring in a flashlight for this activity. Or, ask a local company to donate mini-flashlights.
- Color filters - Purchase a large sheet and cut it into small squares. Or, find a theatrical store and ask for a filter swatch book. Make sure to select a red, blue, and green filter combination that best represents white when combined. Because filters are traditionally used on high-powered stage lights, the exact same color filters used for stage lighting may not produce the desired effects with low-powered flashlights.
- Unlike adding more paint or crayon to get a darker color, adding more colored light does not give a darker color. Higher numbers (amounts of) will create a lighter color (i.e. all 9's equals white). Lower numbers will create a dark color (i.e. 1,0,0 would be a dark red.)

Diagrams

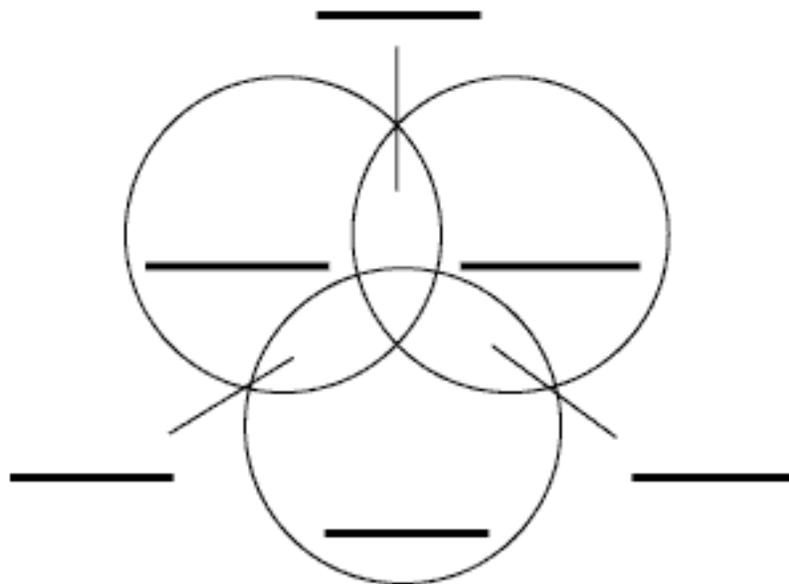
The Primary Colors of Pigment



The Primary Colors of Light



Blank diagram for assessment use



Name _____

Date _____

Mixing Colors of Light

Directions: As a group, shine the three flashlights onto a piece of white paper and create as many colors as possible. List the colors in the chart below. Then, use the numbers in the key to describe how much colored light you use to make each color. The first one is done for you.

Key: 0 = No light used 5 = Some light used 9 = All light used

Color Created	Red	Green	Blue
1. Red	9	0	0
2. _____	_____	_____	_____
3. _____	_____	_____	_____
4. _____	_____	_____	_____
5. _____	_____	_____	_____
6. _____	_____	_____	_____
7. _____	_____	_____	_____
8. _____	_____	_____	_____
9. _____	_____	_____	_____
10. _____	_____	_____	_____

Note: Be creative and make new colors! Experiment with your flashlights by pulling them back from the paper. Use numbers 1 to 9 to describe the brightness of the colored flashlights - use 0 if the flashlight is off and 9 if the flashlight is on.

Mixing Colors of Light Answer Key

(colors may vary)

Color Created	Red	Green	Blue
1. Red	9	0	0
2. Green	0	9	0
3. Blue	0	0	9
4. Cyan (turquoise like)	0	9	9
5. Magenta	9	0	9
6. Yellow	9	9	0
7. White	9	9	9
8. Black	0	0	0
9. Brown (sample)	5	3	0

Instructions on building Parcans (stage lights)

Materials:

- 3 inexpensive directional lamps
- 3 reflector lamp light bulbs (best to use 3 exact same bulbs)
- 3 dimmer switches (like an extension cord with a dimmer switch)
- 3 file folders
- 3 filters, red, green and blue
- 9 clothes pins
- masking tape

Directions:

Assemble filter holders. Cut a hole the size of the lamp shade through both sides of a file folder. Slip one of the filters inside the folder and tape shut. Repeat for the other two folders.

Attach clothes pins to the edge of the lamp shade. Tape the file folder to the clothes pins so that there is a slight spacing between the lamp and the folder. This is to allow heat to escape and not melt the filter. **NOTE: DO NOT LEAVE LAMPS ON UNATTENDED FOR THE FOLDERS OR FILTERS MAY BECOME HOT AND BECOME A FIRE HAZARD.**

Plug lamps into the dimmer switches and plug switches into an electrical outlet. Position the lamps so that they are the same distance from and point to a common area on a white surface (such as a projection screen). It may take some adjustment. When all three lights are on and point to the same location on the screen, they should give the appearance of white light.

By dimming the lights down and back up, the colored light mixes to create a variety of colors. Numbers can be written on the dimmer switches so that the colors can be described as a numerical value. To label the dimmers, start with the dimmers off and mark a zero on the switch. Then turn the lights all the way on and mark a 9 on the switch. If more numbers are desired, estimate the numbers on the switch between 0 and 9.



LESSON 2 - What Color is it?

Students will:

- Identify whether an object reflects or absorbs red, green, and/or blue light.
- Reinforce their knowledge of the primary colors of light.
- Create a simple spectral signature.

Materials Needed:

White file folders or 11”x 14” poster board (1 per group)
Flashlights (1 per group)
Solid-colored blocks (red, green, blue, cyan, magenta, or yellow)
Worksheet - What color is it? (1 per group)
Worksheet - answer key
Worksheet - Spectral signatures
Worksheet - answer key
Digital picture worksheet
Digital picture answer key
Crayons

Engagement

Ask students “Why is does grass look green to us?” Record their responses. Explain to them that objects absorb and reflect the color of light we see. In this lesson, they will model this concept.

Exploration

Divide students into groups of three. Give each group a flashlight, a white file folder, and 5 different colored blocks. (If you use poster board, have students fold it in half, width-wise.) Have groups stand their folder on the width edge. Tell them to place an object at the vertex of the folder, then shine the flashlight on the object. Students’ task is to identify whether the object reflects or absorbs red, green, and/or blue light. Have students complete the chart on worksheet 1. Tell students to use the “Primary Colors of Light” diagram from Lesson 1 as a guide.

Explanation

When students finish this exercise, discuss their results. Students should observe that an object reflects the color of light that we see and absorbs all other colors. Continue by discussing students' answers for the "Think about it" questions. Lead them to understand that white objects reflect all colors of light and black objects absorb all colors of light.

Extension

Explain to students that there are scientists who study the amount of light objects reflect. When scientists study the Earth from space, they look at the color of light reflected. The amount of light reflected describes the characteristic of an object. Using the chart they just created, have the students graph the amount of light reflected by the objects they used in the activity on worksheet 2. The y-axis will be the amount of reflected light and the x-axis will be the red, green, and blue light.

After students complete this, explain that scientists use sensors which look at the amount of light an object reflects, such as a rock or a pond. These sensors give a numeric value for the amount of light reflected, then this data is graphed. The graphs, also called spectral signatures, of different objects such as a rock, water, or a plant are unique. By knowing the "signature" of a particular object, a scientist can identify similar objects over a large geographic area.

Because the amount of light reflected can be represented by numbers, by having just the numbers, we can make an image. Give students the digital picture worksheet. Before creating the digital picture, have students label the intersections of the venn diagram with the corresponding colors. Then, as a class, determine the colors represented by the combinations of numbers. Have students color in the picture using that key. (This activity may also be used for homework.)

Evaluation

Use the "What Color is it?" worksheet to assess whether students understand the combinations the primary colors of light create. Review the answers of the worksheet. In the chart, students should identify which of the red, green, and blue are absorbed and reflected for each object. For example, for a yellow object, red and green light are reflected while blue light is absorbed. Display a few colored objects and ask students to identify whether it reflects or absorbs red, green, and/or blue light.

Tips for Teachers

- Flashlights - Have each student bring in a flashlight for this activity. Or, ask a local company to donate mini-flashlights.
- Blocks - Use small pieces of colored-construction paper.

NAME _____

DATE _____

What Color is it?

Directions: In the chart below, describe an object in the left column. Include the color of the object. Then, place the object inside the propped up folder. Shine a flashlight on top of the object. Record the color of light reflected in the second column. Then, determine whether the object reflects or absorbs red, green, and/or blue light. Use the provided abbreviations.

A = Absorbed R = Reflected

Object description	Color reflected	Red	Green	Blue
1. Red apple	red	R	A	A
2. _____	_____	_____	_____	_____
3. _____	_____	_____	_____	_____
4. _____	_____	_____	_____	_____
5. _____	_____	_____	_____	_____
6. _____	_____	_____	_____	_____
7. _____	_____	_____	_____	_____
8. _____	_____	_____	_____	_____
9. _____	_____	_____	_____	_____
10. _____	_____	_____	_____	_____

Think About It:

1. What colors do a BLACK object absorb and reflect? Why?

2. What colors do a WHITE object absorb and reflect? Why?

What Color is it? - Answer Key

(answers may vary)

A = Absorbed R = Reflected

Object description	Color reflected	Red	Green	Blue
Ex. Red apple	red	R	A	A
Yellow block	yellow	R	R	A
Green block	green	A	R	A
Pinkish colored block (magenta)	magenta	R	A	R
Blue block	blue	A	A	R
Turquoise block	cyan	A	R	R

Think About It:

1. What colors do a BLACK object absorb and reflect? Why?

Black objects absorb all colors of light because the absence of light means no light is reflected.

2. What colors do a WHITE object absorb and reflect? Why?

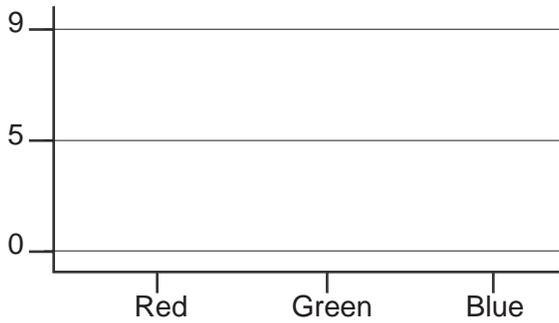
White objects reflect all colors of light. All colors of light combine to make white, so all colors are reflected.

Name _____

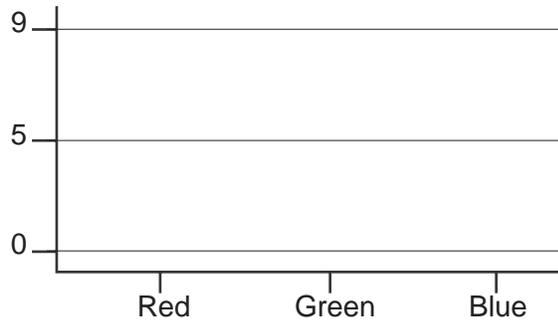
Date _____

Spectral Signatures

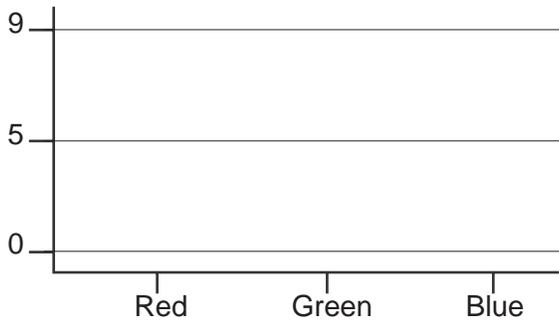
Object: _____
Color of object: _____



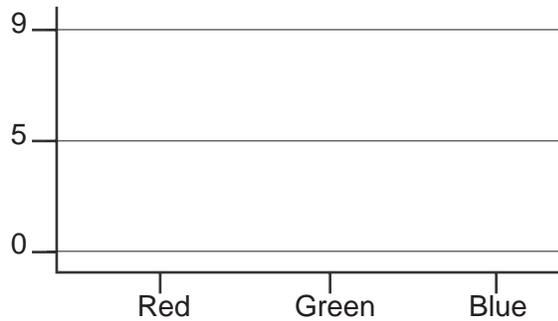
Object: _____
Color of object: _____



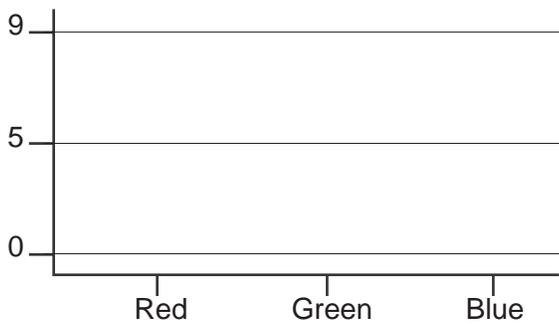
Object: _____
Color of object: _____



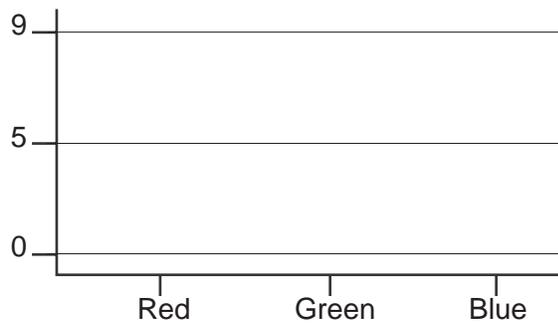
Object: _____
Color of object: _____



Object: _____
Color of object: _____

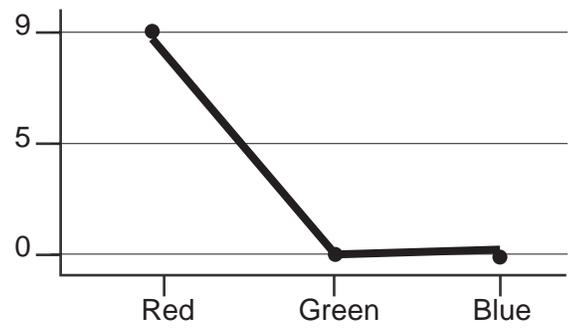


Object: _____
Color of object: _____



Spectral Signature Sample

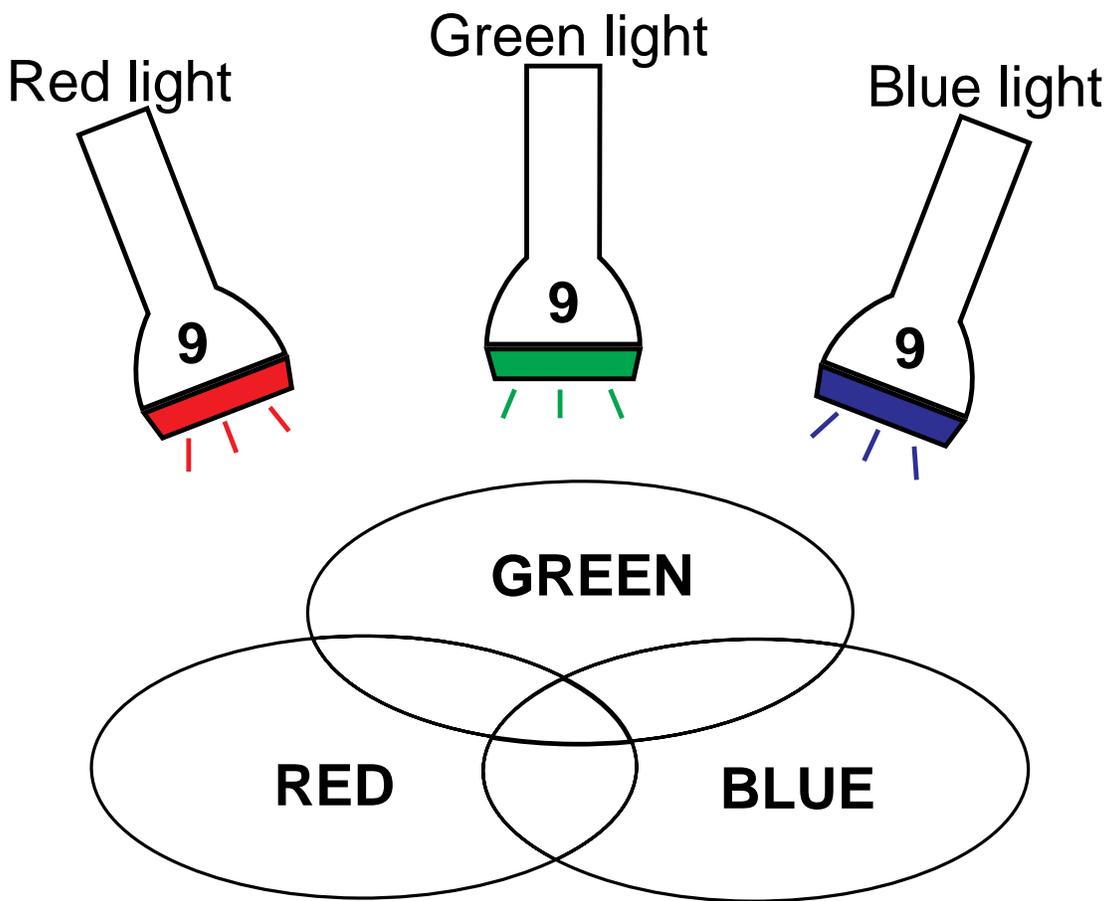
Object: Apple
Color of object: Red



Digital Picture Activity

Take a look at the picture on the back of this worksheet. The numbers in each square represent the amount of red light, green light and blue light from 0-9. These three colors of light (also called the primary colors of light) can be mixed to create different colors. This is how your computer monitor can display thousands, even millions of colors.

- 0 = light off
- 9 = light on
- 5 = about 1/2 the amount of light



Example:

red	green	blue
0,0,9		

0 red = red light off
0 green = green light off
9 blue = blue light on

Therefore:
0,0,9 makes blue

Digital Picture Answer Key

Digital Image: Fill in the blanks with the color each set of numbers make. Then color the squares.

0,0,0 _____ 9,0,9 _____
 9,9,9 _____ 0,9,0 _____
 0,0,9 _____ 9,9,0 _____
 9,0,0 _____ 5,3,0 _____

The numbers in the squares represent the amount of red, green and blue light from 0 - 9. Together they make a color.
 Example: $\begin{matrix} \text{red} & \text{green} & \text{blue} \\ & \text{0,0,9} & \\ & \text{0 red, 0 green, 9 blue (0,0,9 = blue)} & \end{matrix}$

9,9,0	9,9,0	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9
9,9,0	9,9,0	9,9,0	0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9
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0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	9,0,0	0,9,0	0,9,0	0,0,9	0,0,9	0,0,9
0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	9,0,0	0,9,0	0,9,0	0,9,0	0,9,0	0,0,9	0,0,9	0,0,9	0,0,9
0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,0,9
0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,0,9
0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,0,9
0,0,9	0,0,9	0,0,9	0,0,9	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	9,0,0
0,9,0	0,9,0	9,0,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0
0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0	0,9,0



LESSON 3 - The Electromagnetic Spectrum

Students will:

- Be introduced to the Electromagnetic Spectrum.
- Realize that there is energy beyond visible light that we cannot see.
- Identify examples of parts of the EM Spectrum in the Wavestown picture.

Materials Needed:

Prism
Strong flashlight
Wavestown picture (1 per student)
Wavestown answer key
Electromagnetic spectrum description worksheet (1 per student)
IMAGERS Electromagnetic Spectrum web site
(<http://imagers.gsfc.nasa.gov/ems/ems.html>)
Digital satellite image worksheet
Digital satellite image answer key
Crayons

Engagement

Ask students “what is light?” White light is all colors, like the colors of the rainbow. Explain that Isaac Newton discovered the color of light by shining white light through a prism. Demonstrate his experiment using a flashlight and a prism. Tell students that this is called the “visible light spectrum.” The visible light spectrum is a part of a larger spectrum called the electromagnetic spectrum. Explain that light is energy and that there is energy beyond visible light. In this lesson, they will be studying the electromagnetic spectrum.

Exploration

Take students to computer lab. Begin on the IMAGERS Student’s Site (<http://imagers.gsfc.nasa.gov/student.html>) and select the Electromagnetic Spectrum site. Read the first page titled “What are waves?” together. Then, give each student the Wavestown picture. Have students use the electromagnetic spectrum site to help them label examples of the electromagnetic spectrum found in Wavestown. Students should read the description on the site then look for examples in Wavestown. (If access to computer lab is unavailable, use the worksheet provided.)

Explanation

When students complete this exercise, discuss their answers as a class. Begin with radio waves. Ask students to give examples found in Wavestown. Continue with microwaves and the other wavelengths to gamma rays.

Extension

Continue the lesson by giving students the digital satellite image worksheet. Explain that satellite have sensors which can detect infrared energy, a part of the electromagnetic spectrum. Have them label the key with the correct color, then complete the picture.

Evaluation

Use the Wavestown picture to assess students' understanding of the different energies in the electromagnetic spectrum.

Tips for Teachers

- **IMAGERS Electromagnetic Spectrum web site** - Preview the electromagnetic spectrum web site the day before teaching this lesson. Find objects to represent different electromagnetic energy, i.e. pocket radio, microwave popcorn, remote control, etc...
- **Wavestown activity** - You may want to review the answers to this activity prior to the lesson because some answers may surprise you.

Wavestown

"Wavestown"

Label the chart below, then match the items in the picture to the Electromagnetic Spectrum.

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ 7. _____

300m 30m 3cm 300μm 30μm 3μm 0.3μm 30nm 3nm 0.3nm 0.03nm 0.003nm

Wavestown Answer Key

Radio Waves

Ray's TV - TV reception uses radio waves

Satellite Dish on top Ray's - receives movies via radio waves from a satellite

Taxi - Car radio reception uses radio signals

Taxi - Driver receives instructions on a CB radio which uses radio waves

Radio Tower - broadcast's radio signals

Large Satellite dish in field - receives radio waves from distant stars

Microwaves

Microwave in Waves Grill - uses microwaves to cook food

Disk-like antennas on tower - send microwave communications

Infrared

Heat lamps above food in Waves Grill - use infrared waves to keep food hot

Ray's TV - Remote controls use infrared waves to communicate with the TV

Trees, bushes, grass, and farm - vegetation reflects short infrared waves

Observatory - astronomers study thermal infrared (long infrared waves) from stars

Visible Light

Rainbow - water droplets cause white light to break apart into the colors of the rainbow

Photographer's studio - portrait photographers use film sensitive to visible light

Observatory - astronomers look at visible light from planets and stars

Ultraviolet

Tanning Salon - use ultraviolet waves to tan our skin

sunglasses store - sunglasses protect our eyes from the ultraviolet waves

Suntan lotion - protects our skin from ultraviolet waves

Observatory - astronomers see some ultraviolet radiation from planets and stars

X-rays

Dr. Bob's Health Clinic - uses x-rays to study our bones

High energy x-rays are also used to treat cancer

Gamma Rays

Dr. Bob's Health Clinic - gamma radiation is used to kill sick cells through nuclear medicine

Gamma radiation is given off by nuclear explosions that occur within stars, like our sun

Note: Stars give off gamma rays and x-rays but we cannot see them from Earth because they cannot pass through our atmosphere

NAME _____

DATE _____

The Electromagnetic Spectrum

Directions: Use the descriptions below to help locate examples of electromagnetic waves in the wavestown picture.

Radio waves have the longest wavelength in the electromagnetic spectrum. These waves carry the news, ball games, and music you listen to on the radio. They also carry signals to television sets and cellular phones.

Microwaves have shorter wavelengths than radio waves, which heat the food we eat. They are also used for radar images, like the Doppler radar used in weather forecasts.

There are **infrared waves** with long wavelengths and short wavelengths. Infrared waves with long wavelengths are different from infrared waves with short wavelengths. Infrared waves with long wavelengths can be detected as heat. Your radiator or heater gives off these long infrared waves. We call these thermal infrared or far infrared waves. The sun gives off infrared waves with shorter wavelengths. Plants reflect these waves, also known as near infrared waves.

Visible light waves are the only electromagnetic waves we can see. We see these waves as the colors of the rainbow. Each color has a different wavelength. Red has the longest wavelength and violet has the shortest wavelength. These waves combine to make white light.

Ultraviolet waves have wavelengths shorter than visible light waves. These waves are invisible to the human eye, but some insects can see them. Of the sun's light, the ultraviolet waves are responsible for causing our sunburns.

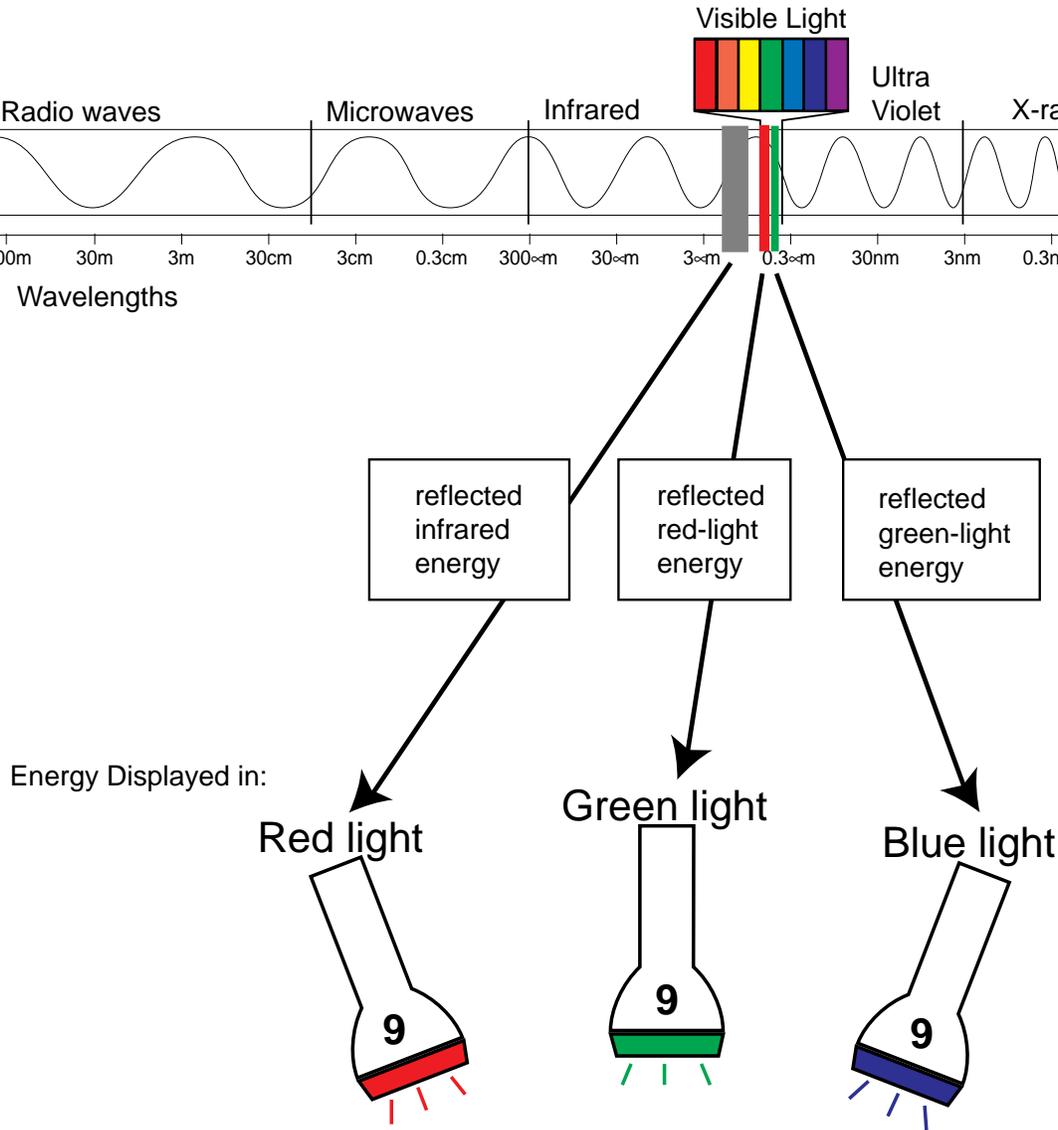
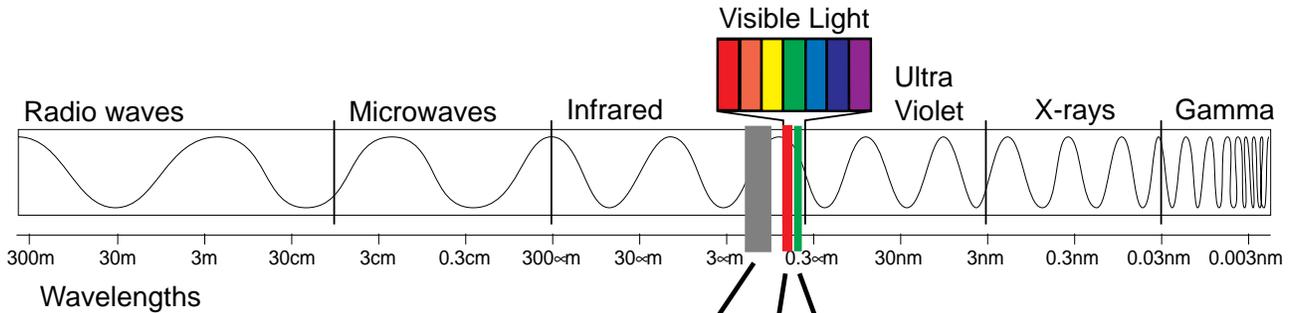
X-Rays: As wavelengths get smaller, the waves have more energy. X-Rays have smaller wavelengths and therefore more energy than the ultraviolet waves. X-Rays are so powerful that they pass easily through the skin allowing doctors to look at our bones.

Gamma Rays have the smallest wavelength and the most energy of the waves in the electromagnetic spectrum. These waves are generated by radioactive atoms and in nuclear explosions. Gamma rays can kill living cells, but doctors can use gamma rays to kill diseased cells.

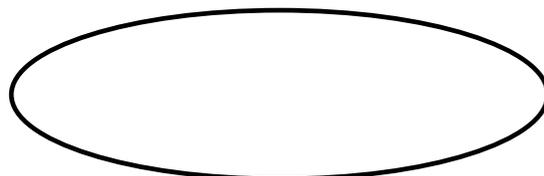
Name: _____ Date: _____

Digital Satellite Image

Digital Satellite Image: How do we picture energy we cannot see?



Data collected about how much energy is reflected, can be displayed using the primary colors. (Energy we can see)





Web Sites

- *Patterns in Nature: Light and Optics "Color and the Spectrum"* <http://accept.la.asu.edu/PiN/mod/light/colorspectrum/pattLight3Obj2.html> Three lesson modules created by Arizona State University on color, mixing colors, and the electromagnetic spectrum. A good resource for teachers.
- *Science Education Gateway* <http://csc.ssl.berkeley.edu/sii/SEGway/> A NASA-sponsored project featuring lesson modules on light for grades 3-12.
- *NASA Observatorium Education-Reference Module* <http://observe.ivv.nasa.gov/nasa/education/reference/emspec/empectrum.html> A basic reference site on the electromagnetic spectrum for middle school students or teachers.
- *Imagine! The Electromagnetic Spectrum* <http://imagine.gsfc.nasa.gov/docs/introduction/empectrum.html> A thorough resource on the electromagnetic spectrum. Includes some illustrations and a glossary.

Books

- *Rainbows to Lasers* by Kathryn Whyman, Gloucester Press, 1989. Introduces the properties of light. Includes brief descriptions and simple experiments. Appropriate for upper elementary grades.
- *Light and Lasers* by Kathryn Whyman, Gloucester Press, 1986. Introduces the properties of light. Also illustrates the difference between the primary colors of light and the primary colors of pigment. Includes a few experiments.
- *The Science Book of Light* by Neil Ardley, Harcourt Brace Jovanovich, 1991. A book of simple light experiments demonstrating the principles of light. Accompanied by colorful photographs. Suitable for elementary grades.
- *What do you see & how do you see it?* by Patricia Lauber, Crown Publishers, 1994. A good informative book for middle school students introducing the properties of light. Also covers infrared light and its applications. Concise text and large, colorful photographs.
- *Light and Color* by Gary Gibson, Copper Beech Books, 1994. A step-by-step guide introduces students to the principles of light and color.
- *Waves: The Electromagnetic Universe* by Gloria Skurzynski, National Geographic Society, 1996.
- *How Science Works* by Judith Hann, Reader's Digest Association, 1991. An excellent reference book for students, featuring easy-to-do experiments, clear descriptions, and colorful photographs. Includes a section on light.
- *The Magic School Bus Makes a Rainbow: A Book about Color* by Joanna Cole, Scholastic, 1997. A fiction book introducing the secrets of light and color in an adventure through a pinball machine.

NASA Publications

- *Astro-1 Teacher's Guide with Activities Seeing in a New Light*, 1990. This guide includes activities on the color of light, the electromagnetic spectrum. For grades 6-8.
- *Space Based Astronomy*, 1994. This teacher's guide includes a unit on the electromagnetic spectrum. Each unit contains activities and provides information for discussion. For grades 5-8.

Related Science Standards

Understanding Light Unit

AAAS Project 2061 Benchmarks

- **4F (6-8)** Light from the sun is made up of a mixture of many different colors of light, even though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.
- **4F (6-8)** Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation — visible light. Differences of wavelength within that range are perceived as differences in color.

National Science Education Standards

Grades 5-8

- **Transfer of Energy** - Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection.) To see an object, light from that object — emitted by or scattered from it — must enter the eye.
- **Transfer of Energy** - The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as a light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Maryland School Performance Assessment Program Concept Indicators

Physical Science

- **(6-8)** - Energy can be changed from one form to another. Visible light behaves in a variety of ways.