National Aeronautics and Space Administration

In a Different Light

An Educator's Guide with Activities in Physical Science

http://son.nasa.gov/tass/iadl.htm

Educational Product	
Educators & Students	Grades 6-12

www.nasa.gov

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Introduction

IN A DIFFERENT LIGHT is a coherent unit of six lessons for grades 6-12 that develops the understanding that visible light is composed of a full range (spectrum) of colors of light from red to violet, which extends the concept of a spectrum to include non-visible light (infrared and ultraviolet) through discovery, and which develops tools and strategies for student inquiry.

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

How to Use the Teacher Resources

The Introduction gives information on the entire unit, IN A DIFFERENT LIGHT. Here you will find Grade Levels, the Purpose for the Unit, the Overview of Lessons, national educational standards applicable to these lessons, a discussion of teaching methods, and material lists for each lesson. The Introduction should help you to understand the What, How, and Why of this unit and its structure.

In addition, In a Different Light provides resources for you for each lesson. The Teacher Resource for each lesson provides information specific to that lesson: Purpose, national standards, Background, Overview of Student Assignments, Materials, and Preparation and Procedures. The Background and the Preparation and Procedures sections, in particular, should be read carefully with the Student Assignments (contained in Student Assignment packet) for that lesson in hand. The Background provides information on the content of that lesson. Web resources are identified that will support your learning. In addition, the Background discusses the preconceptions your students might have as they begin the exploration.
An Appendix contains a variety of resources you will need for this unit. Some of these are assignments that are used in several different lessons. Many of these student assignments, such as Report/Presentation formats and rubrics, Prediction Reflections, and Peer Review Guidelines, can be used in other units you teach. The Appendix also contains a short list of vendors for supplies. This is for your convenience and should not be considered an endorsement of any vendor.

For Whom Is This Unit Designed? Grade Levels

IN A DIFFERENT LIGHT is for grades 6–12 and can be used in any physical science class that includes the introduction of light and the electromagnetic spectrum. These topics may arise in a Physical Science curriculum, Astronomy, Earth and Space Science, Physics, and Chemistry. While these lessons can be used in a wide range of grade levels, you may need to make some modifications. For example, in Lesson 3—Exploring Spectra, the activity Analysis of Stars may be more appropriate for grades 10–12 and courses such as Astronomy/Space Science, Chemistry, and Physics. This one activity can be omitted or conducted as an in-class activity with teacher support in grades 8 and 9. Lesson 1 and Lesson 2 may be more appropriate for grades 6–8, however, older students would benefit from beginning with these lessons if they have little experience with these topics.

The unit is designed to develop inquiry skills. It begins with a fair amount of structure in the inquiry process and gradually places more control of inquiry with your students. The final lesson requires your students to develop a question and design and conduct the inquiry. You may wish to modify early lessons to be less structured, however, remember that all students need some degree of support and guidance in the inquiry process. If your students are struggling with independent inquiry, you may wish to provide more structure in the final lessons; however, remember that students will never learn to pose and answer questions independently if they are not asked to do so. It is better to provide the challenge and then provide coaching as needed. If you wish more information on inquiry, log on to Science Inquiry Model (**http://www.nwrel.org/msec/science_inq/index.html**).

Purpose of Unit

There are three specific goals for **IN A DIFFERENT LIGHT**. The first goal is to develop the understanding that visible light is composed of a full range (spectrum) of colors of light from red to violet. This is an essential understanding that should be developed before studying the entire electromagnetic spectrum ranging from radio to gamma rays. In the process, you need to confront the preconceptions that many students have (see Background for **MIX IT UP** and **GETTING HOTTER**).

The second goal is to extend the concept of a spectrum to include non-visible light (infrared and ultraviolet) through discovery. Lessons 4 and 5 guide the student to a discovery of infrared and ultraviolet light, respectively. A reading that shows them how scientists use infrared light and ultraviolet light to study phenomena not accessible to visual inspection follows each discovery. The third goal is to develop tools and strategies for student inquiry.

Overview of Lesson and Student Assignments

Lesson 1—Mix It Up

Students will develop an understanding that the color of an object is a particular color of light reflected from the object. This activity will also introduce the concept that white light is a combination of other colors. Student assignments are:

1. **Colors and Light** is a journal assignment to start your students thinking about light. It will also reveal your students' ideas about light. (15 minutes)
2. **Exploration with Colored Light and Colored Paper: Predictions**
   Students make predictions about different experiments with colored light and colored paper based on the ideas they hold before they begin their explorations.
   (15 minutes)
3. **Exploration with Colored Light and Colored Paper: Data**
   The students use the Data sheet to record the results of the experiments with colored light and colored paper. (30–45 minutes)
4. **Making Conclusions**
   Students answer questions that lead them to make conclusions about light and color.
   (Homework assignment)
5. **Class discussion of results**
   (20–25 minutes)
6. **Prediction Reflection** (Appendix)
   After the exploration is completed and you have discussed the data and conclusions, assign the Prediction Reflection. This will help them to be more aware of their thought process. (15 minutes)
7. **Inquiry Reflection—Mix It Up**
   This reflection is designed to focus the attention of your students on the process and elements of inquiry. (20 minutes—may be a homework assignment)

Lesson 2—Prisms and Rainbows

In this lesson, students will develop the understanding that "white" light from the Sun and "white" light from an artificial light source is a full range of colors from red to violet. Students will also learn how droplets of water function as prisms to separate this full range of colors into rainbows. Student assignments are:

1. **Rainbows** is a journal assignment to be done in class. The purpose of the assignment is to explore the student's previous knowledge about spectra and rainbows and to engage them in the exploration. (15 minutes)

2. **Exploration with Prism and Light** is a two-part lab investigation. Part 1 investigates the light from a light bulb, and Part 2 uses light directly from the Sun. (Two to three 45-minute periods)
3. **Making Conclusions** should be completed immediately after the students complete Exploration with Prism and Light. The students can be working on this short-essay format conclusion outside of class while they are proceeding to the next exploration.
4. **Exploring Rainbows** is a computer-based activity that develops an understanding of rainbows and how they are formed. If students do not have access to computers, you can conduct a lecture/demonstration using materials from the Web site. (One 45-minute period)
5. **Rainbows—Revisited** is a journal assign ment that asks the same questions as **Rainbows**, the opening journal assignment of this lesson. You can treat these as pre- and post-assessment tools. (15 minutes)
6. **Class discussion of results** (20–25 minutes)
7. **Prediction Reflection** (Appendix) is a reflection for students to compare their predictions from **Rainbows** with their answers to the same questions from **Rainbows—Revisited** or they might choose the prediction from the Exploration with Prism and Light. (Homework assignment)
8. **Inquiry Reflection—Prisms and Rainbows**
   This reflection is designed to focus the attention of your students on the process and elements of inquiry. (Homework assignment)

Lesson 3—Exploring Spectra

Students will develop the understanding that elements emit light in a distinct spectrum that can be used to identify the elements and that this information can be used to identify the composition of complex light sources such as stars. Students will expand on their understanding of the visible light spectrum. Student assignments are:

1. **Student Lab** Investigation investigates the properties of spectroscopes and uses spectroscopes to investigate a variety of light sources. Students will need the Spectra Data Sheet to record data. (One to two 45-minute periods)
2. **Making Conclusions—Spectra** asks students to interpret the data obtained in the investigation. (30 minutes—may be a homework assignment)
3. **Analysis of Stars** is an application and extension of the knowledge gained in the investigation. (30 minutes)
4. **Class Discussion** (20 minutes)
5. **Cosmic Questions: Our place in space and time** is an excellent extension activity available from the Harvard-Smithsonian Center for Astrophysics (http://cfa-www.harvard.edu/seuforum/exhibit/resources/resources.htm).

Lesson 4—Getting Hotter

Students will discover the existence of the non-visible light—infrared light—which is outside of the visible light spectrum, and will discover the use of infrared light in science. Students will also develop experimental techniques useful for further exploration of the light spectrum. Student assignments are:

1. **How Are Parts of the Spectrum Different?** is a journal assignment to

engage your students in thinking about characteristics of the spectrum. Their ideas will be used in Lesson 6 to develop an inquiry of their choosing. (Homework or 5–20 minutes in class followed by a 20 minute in-class discussion.)

2. **Laboratory Investigation** is a formal lab to determine whether different colors in the light spectrum heat objects differently. (One 45-minute period)
3. **Data Sheet** is used to record data.
4. **Conclusions** requires the student to write a thoughtful, short essay that answers the central question of the lab. (Homework)
5. **Class Discussion of Results and Conclusions**
6. **Prediction Reflection** (Appendix) will allow the students to reflect on the prediction they made at the beginning of the Laboratory Investigation. (Homework)
7. **Reading Assignment**
   Students will read "Seeing Our World in a Different Light" at **http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/our_world_different_light/**.
8. **Inquiry Reflection—Getting Hotter**
   This reflection is designed to focus the attention of your students on the process and elements of inquiry.

Lesson 5—Mystery Light

Students will develop research techniques useful for further exploration, using models developed in previous lessons. Students will design their own experiment to explore the conditions under which special beads change color. Because these beads actually change in the presence of UV light, this lesson will allow them to discover the existence of another non-visible light—ultraviolet light—outside of the visible light spectrum. Students will also learn how ultraviolet light is used in science. Peer Review is introduced as a tool to aid in experimental design. **The entire lesson will take four to seven 45-minute class periods**. Student assignments are:

1. **Student Investigation Procedure and Guide Questions** is a laboratory investigation that provides the problem to be solved by the investigation and leaves the design of the investigation to the student.
2. **Peer Review in the Science Classroom** (Appendix) provides a process to aid the students in the development of more effective designs for inquiry.
3. **Lab Report Format, Journal Article Format**, and **PowerPoint/Web page/Poster Presentation**
   (Appendix) are three different formats students can use to present the results of their investigation.
4. **Prediction Reflection** (Appendix) asks your students to reflect on their process, their thinking, what went right, and what they would improve.
5. **Reading Assignment**
   Students will read "Electromagnetic Spectrum" **http://son.nasa.gov/content/electrospectrum.htm** and "How Astronomers Use the Electromagnetic Spectrum" **http://son.nasa.gov/content/emspec.htm**

Lesson 6—Independent Investigation

Students will develop a question about light spectra and design their own experiment to answer the question. Peer Review is used as a tool to aid in experimental design. **The entire lesson will take four to seven 45-minute class periods**. Student assignments are:

1. **Independent Investigation** is a laboratory investigation in which the students provide

the problem to be solved by the investigation, design the investigation, use Peer Review to refine the design, conduct the investigation, and communicate their results.

2. **Peer Review in the Science Classroom** (Appendix) provides a process that aids the students in the development of more effective designs for inquiry.
3. **Lab Report Format, Journal Article Format**, and **PowerPoint/Web page/ Poster Presentation** (Appendix) are three different formats from which you can choose for students to communicate the results of their investigation.
4. **Prediction Reflection** (Appendix) asks your students to reflect on their process, their thinking, what went right, and what they would improve.

Appendix

The Appendix contains supporting resources, including sources for materials and a bibliography.

1. **Exploring Spectra—Constructing a Spectroscope** provides directions for making your own spectroscope from a shoebox or paper tube.
2. **A Modified Ritter Experiment: Discovering Ultraviolet Light** is an alternative activity for Lesson 5 and a resource for you to see an "ideal" investigation for the discovery of UV light.
3. **Prediction Reflection** is an activity to help students think about how they solve
4. **Lab Report Format** provides a structure and rubric for a traditional lab report.
5. **Journal Article** provides a format and rubric for a journal article presentation.
6. **PowerPoint/Web page/Poster Presentation** provides a structure and scoring for a third type of student presentation of results.
7. **Peer Review in the Science Classroom** gives the guidelines and rationale for using peer review in inquiry science.
8. **Independent Investigation** provides a structure and timeline for independent inquiry.
9. **5Es** is a useful chart showing the 5Es of Constructivism (Engage, Explore, Explain, Extend, and Evaluate) and the types of activities representative of each E.
10. Supplies and Vendors
11. Bibliography

Benchmarks for Science Literacy

(Bold print indicates essential Benchmarks or part of a Benchmark.)

Chapter 1, The Nature of Science

B. Scientific Inquiry
Grades 6–8

- **Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.** 1B/1 (6–8)
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but **collaboration among investigators can often lead**

to research designs that are able to deal with such situations. 1B/2 (6–8)

Grades 9–12

- Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. 1B/1 (9–12)
- Sometimes scientists can control conditions in order to focus on the effect of a single variable. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9–12)

Chapter 3, The Nature of Technology

C. Technology and Science
Grades 6–8

- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation and communication of information. 3A/2 (6–8)

Chapter 4, The Physical Setting

A. The Universe
Grades 9–12

- **The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the Earth and to behave according to the same physical principles**. Unlike the Sun, most stars are in systems of two or more stars orbiting around one another.
- **Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves**; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3 (9–12)

E. Energy Transformation
Grades 9–12

- When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, the **light emitted or absorbed by separate atoms or molecules (as in a gas) can be used to identify what the substance is**. 4E/5 (9–12)

F. Motion
Grades 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/1 (6–8)
- **Something can be “seen” when light waves emitted or reflected by it enter the eye**—just as something can be “heard” when sound waves from it enter

the ear. 4F/2 (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**. 4F/5 (6–8)

Grades 9–12

- Accelerating electric charges produce electromagnetic waves around them. **A great variety of radiations are electromagnetic waves: radio waves, micro waves, radiant heat, visible light, ultraviolet radiation, x-rays, and gamma rays**. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light." 4F/3 (9–12)

National Science Education Standards—Content:

(Bold print indicates an essential Standard or part of a Standard)

Grades 5–8

Science As Inquiry—Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models**.
- **Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories**. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- **Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations**.

Physical Science—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**.
- 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 light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation**.

History and Nature of Science—Science as a Human Endeavor

- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such asl intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

History and Nature of Science—Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

History and Nature of Science—History of Science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Grades 9–12
Science as Inquiry—Abilities Necessary to do Scientific Inquiry

- Communicate and defend a scientific argument. **Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments**.

Physical Science—Interactions of Energy and Matter

- Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays**. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.
- **Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance**.

Teaching Methodology

Philosophy

It is constructive to begin with the basic assumption about our students that they are innately curious—that they want to learn, discover, and create. This doesn't mean that they are curious about Chapter 1 of a science book, but that learning normally originates from a desire to know, as much as a need to know. Recognizing that people learn through a variety of modes (aural, oral, visual, and kinesthetic), we attempt to engage their problem solving in as rich an experiential matrix as possible. Learning can be described as the interaction between the self and an experience that brings about a change. There must be an experience, and, while this could include a lecture or a reading, the greatest interaction occurs when an individual is engaging more of the learning modes. It also helps if the person desires and needs to know. The richer the experience is, the richer the interaction will be, and the more substantial the change will be. With this approach, our language of teaching changes from controlling, molding, giving, ... to enhancing, opening, challenging, nourishing, guiding, ... (See Science Teaching Standards—Changing Emphasis, p52 NSES)

Learning Environment

It is essential to create an environment in which our students are active participants in the learning process. In this environment. the students are the essential workers in the educational process. They construct, discover, and develop central concepts. They create and solve problems. They read, write, talk, think, pose questions, and solve problems. They observe and manipulate aspects of their environment, and in the manipulation, confront problems about which they think, talk, write, and read. They take risks. Students exhibit the ability to learn how to learn. Students exhibit understanding of the central concepts and competence with the essential skills in a problem-solving environment. Students exhibit competence in individual and group problem solving. Students exhibit a willingness to accept different kinds of solutions to the same problem. They exhibit a willingness to work with other students outside of class.

Within this changing emphasis, the teacher is committed to presenting learning experiences, not necessarily information, and to using open-ended questions whenever appropriate. Teachers guide the experience. Teachers define the problem field, and sometimes define the central question. This does not mean that teachers do not ever give information. The criteria, it seems, must be, "Is this information closing down investigation or enabling and enhancing investigation? Is it giving the answer, or providing the framework in which questions can be asked, problems posed, and investigation begun?" Teachers respect the student's ability to solve problems. Whenever we give an answer, we run the risk of communicating that we believe the student is incapable of solving the problem. Teachers praise careful thought and process publicly and often, recognizing the risks taken. Teachers encourage different problem-solving techniques and the involvement of as many different learning modes as a student needs. Teachers also encourage students to develop problem-solving techniques that are weaker than their preferred style. For example we encourage intuitive problem-solvers to marry analysis to their intuition, and we encourage analytical problem-solvers to use intuition.

Inquiry

"Students … should be provided opportunities to engage in full and in partial inquiries. In a full inquiry, students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, they develop abilities and understanding of selected aspects of the inquiry process. Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognize and analyze several alternative explanations for a natural phenomenon presented in a teacher-led demonstration" (NSES, p143). This unit is designed to help students become more proficient within the inquiry process, as well as to learn specific content. Make the structure of the unit explicit for your students; discuss the structure and the modeling of the inquiry process as you progress through the unit. The first lesson involves the student in partial inquiry with a great deal of structure. The teacher manipulates the experimental tools, questions are provided for students, and the analysis of data is guided by questions that require short answers. In Lesson 2, students follow directions that require them to manipulate equipment themselves. Guide questions are provided in the Observation part of the investigation, but the student is required to provide more of the problem-solving structure in the Conclusion than they did in Lesson 1. Modeling of experimental technique and of the problem-solving process is provided throughout the unit allowing the student to become more responsible for the inquiry process. In the final lesson, the student provides the question, the design for the inquiry, the planning, the execution of the inquiry, and the communication of results.

Unique Assignments to Promote Inquiry and Learning Strategies

Several types of assignments are used in this unit that may be unfamiliar to your students. Journals, Predictions, Prediction Reflections, and Peer Review are powerful tools that can enhance the learning experience for your students in any inquiry.

Journals

Although there are journal assignments in this unit, you are encouraged to make more assignments. The journal assignments in this unit are designed to engage your students in the problem presented by the lesson and to reveal your students' preconceptions about the concepts before instruction. In addition, in Lesson 2 the journal assignments can be used as pre-test/post-test evaluations of student understanding. You can assign intermediate journal entries to monitor student progress and to help your students organize their thoughts. Many teachers use journal reflections as a regular part of the daily schedule. Students enter the room, get their journal from a central location, and respond to a question the teacher has provided. The question is connected to the day's activity. Students begin work immediately, and the teacher completes administrative chores while the students are working.

Journals are evaluated on the basis of careful thought. The emphasis should not be on the correctness of an answer. You want to know what your students are thinking, not what they think you want them to think. Because of the role of the journal assignments included in this unit, you need to read each student's entry. For other entries, you can decide to read each, or read one from each team. In some cases, teachers have asked each student to identify one for each week she/he wants the teacher to read. Teachers can then scan the others.

Predictions

Students may not have much experience making predictions formally. Ask them to think about what they know—what experiences they have had to guide them. Physics Education Research (PER) has shown that student performance and investment are enhanced when they make predictions. Stress to your students that their predictions will not be graded except for completion and the thoroughness of their answers. Do stress, however, that the predictions are important.

Prediction Reflections

Research also indicates that students can learn to learn more effectively if you ask them to reflect on their predictions after they complete the activity. A Prediction Reflection assignment is provided in the Appendix that can be used after any exploration in which the students make predictions. Introduce the Prediction Reflection to students before they start the prediction, and tell them a Prediction Reflection will be an assignment later on. Ask them to be aware of their reasons for making each prediction in preparation for this assignment.

Peer Review

Many scientists, engineers, and business people use peer review to improve the quality of their efforts. Some review is evaluative. One person or team presents and defends a business plan or the results of an investigation to peers who critique the work. Many groups use a more informal review to assist in the planning stages. It is this formative review that is used in this unit. The benefits to the presenter and to the reviewers are explained in the guidelines in the Appendix.

Materials

Lesson 1

- 5 pieces of large sized (at least 9” x 12”) colored construction paper (one each of red, blue, green, white, and black)
- Red, blue, and green gels (gelatin filter), Wratten filters or cellophane (your theater department may help you obtain the gels, and they are available in art supply stores)
- An overhead projector, 3 slide projectors or powerful flashlights with the colored gels or cellophane fixed securely over the lens. You may also use red, blue, and green floodlights from a hardware store.
- A very large (3’ x 5’) sheet of white paper, white wall, or a white board
- A dark room
  (You may wish to run this exploration as a small group activity. In that case, you will need 3 flash lights for each group, and small sized gels or cellophane for each group.)

Lesson 2A—Exploration with Prism and Light

- An equilateral glass prism per group (see Appendix for source)
- White paper per group
- Colored pencils or crayons per group
- Overhead projector, slide projector or strong flashlight per group
- A dark room for first part of activity
- Copier paper box per group

Lesson 2B—Exploring Rainbows

- Computer with Internet connection
- Water glass
- Flashlight, or other directed beam of light
- Round-bottomed flask, or some spherical glass container (a round fishbowl would work)
- Small piece of cardboard or poster board that fits over the head of the flashlight
- 10” x 14” piece of white poster board

Lesson 3

- Spectroscopes for each group or spectro scope kits or materials for the shoebox spectroscope (see **Exploring Spectra—Constructing a Spectroscope**: Appendix)
- 1 CD per group (use old CDs such as promotional CDs)
- 1 or 2 Spectrum tube power supplies (see Appendix for source)
- Spectrum tubes—at least hydrogen, helium, neon (see Appendix for source)
- Incandescent light bulb and lamp (60W)
- Fluorescent (mercury) light source
- 1 or 2 microscopes (low power or dissecting) or magnifying lenses
- Periodic Table of the Elements (individual or large display)
- A fairly dark room

- Crayons or colored pencils (full set per group, optional)
- Spectrum glasses (optional, see Appendix for source)

Lesson 4

- Equilateral glass prism per group (see Appendix for source)
- 3 alcohol thermometers per group (see Appendix for source)
- Tape per group
- Cardboard box per group (a photocopier paper box works very well)
- Black spray paint (black marker will work)
- White paper for bottom of box per group
- Scissors per group
- Prism holder (optional) per group

Lesson 5

- 15 special (UV) beads per group (see Appendix for source)
- 5 dark film canisters per group
- Equilateral glass prism per group (see Appendix for source)
- Tape per group
- Cardboard box per group (have available the copier paper boxes used in Getting Hotter?)
- Equipment to be determined by group
- Prism holder (optional) per group

Lesson 6

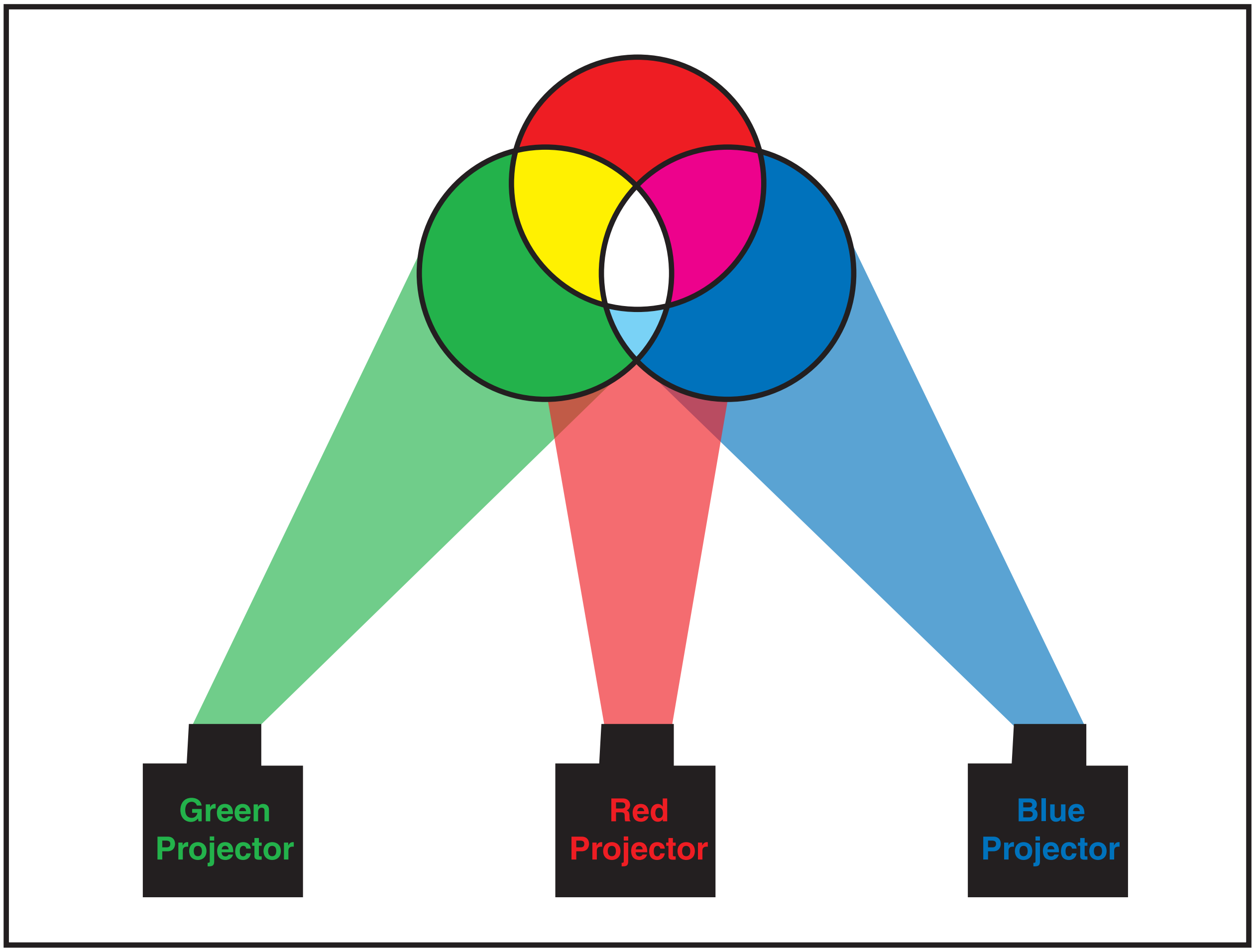
- To be determined by groups

National Aeronautics and Space Administration

Lesson 1

Mix It Up

An Educator's Guide with Activities in Physical Science



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EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Mix It Up

Teacher Resource

http://son.nasa.gov/tass/iadl.htm

www.nasa.gov

Purpose

Lesson 1, **Mix It Up**, is designed to help your students understand that the color of an object is a particular color of light reflected from the object. This activity will also introduce the concept that white light is a combination of other colors.

Benchmarks for Scientific Literacy

- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations. 1B/2 (6–8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable**. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9–12)
- **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/1 (6–8)
- **Something can be "seen" when light waves emitted or reflected by it enter the eye**—just as something can be "heard" when sound waves from it enter the ear. 4F/2 (6–8)

National Science Education Standards

Grades 5–8
Science As Inquiry—Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events**; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
- **Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories**. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

Physical Science—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.**

Background

Many students (and adults) are confused about colors and light. The ancient Greek scientist, Parmenides, believed that light for vision originated in the eye. Another early scientist, Aristotle, wrote that light picks up color from the object from which it is reflected. Some of your students may express these ideas (Driver, 41-45). Many students do not connect the act of seeing with the arrival of light at the eye. Sources of light (a candle or light bulb) are seen, but students don't think of them as sending out light. Students believe that mirrors reflect, but don't believe that a sheet of paper reflects (Arons, 226 and Driver, 129). In addition, many people are confused by primary colors. In fact, there are different primary colors for mixing light and for mixing pigments.

There are two critical ideas that need to be understood about seeing color. The first is that the eye responds to specific colors (wavelengths) of light. No provision is made to teach this information in this unit, and students may not need to know how the eye works; however, you will probably feel more comfortable if you have some information in case questions arise. To increase your understanding of the eye's response to light, read about "Rods and Cones" and color vision from *Hyperphysics*" **http://hyperphysics.phy-astr.gsu.edu/hbase/vision/rodcone.html**.

The second critical idea is that we see the light that reaches our eye either from a direct source or where it is reflected to our eye. When a traffic light turns red, red light comes directly to our eye. Red paper is red because the paper reflects red light and absorbs other wavelengths. The green paper will reflect green light, and the blue paper reflects blue light. So what happens if red light falls on green paper? Under ideal conditions, red light contains **only** red light and green paper perfectly absorbs all colors but green. Consequently, no light will be reflected—the paper will be black! The ideal conditions are remarkably difficult to attain. Unless you have access to pure emitters of red, blue, and green light (e.g., lasers), colored light is usually produced by filtering white light, as in this exploration. While red filters tend to be pretty good at filtering out light from the green and blue end of the spectrum, there is some "leakage." Green filters tend to filter blue somewhat, but emit red and yellow. Blue filters that don't also transmit considerable amounts of green and red are extremely difficult to find and are expensive. The transmission spectrum of filters depends on the filter. You can sometimes obtain the transmission spectrum with the filter. Also, you can check what other colors are coming through a filter and how much by looking at the light from the filter with a spectroscope (Lesson 3). Similarly, it is difficult to obtain red surfaces that reflect only red, green surfaces that reflect only green, and blue surfaces that reflect only blue. These limitations are critical to Activity 1 of **Exploration with Colored Light and Colored Paper**!

When **two** colors of light are mixed, both colors reach the eye. For example, if a red pixel and a green pixel are right next to each other on your computer screen or if you reflect red light and green light off white paper, the brain will interpret the combination of red light and green light as yellow. ("Colors" at the National Taiwan Normal University [NTNU] *Virtual Physics Laboratory* **http://www.phy.ntnu.edu.tw/java/image/rgbColor.html** allows you to mix primary colors virtually. Another site allows you to explore different intensities of red, blue and green light at *Mixing Primary Colors* **http://www.omsi.edu/visit/hightech/techinit/phase2/content/colormix.cfm.)**

Pure pigments, however, absorb all colors except the reflected color(s). A pure red pigment subtracts all colors but red. Pure blue pigment subtracts every color but blue. While a mixture of **unsaturated** red and blue is purple, a mixture of vivid red and blue creates a combination that subtracts all light and you get black. Mixtures of pigments and mixtures of light do different things to light. This is why there are different primary colors for mixing light and for mixing pigments. (For more information, visit the *Color Mixing* Web site **http://home.att.net/~RTRUSCIO/COLORSYS.htm.**)

The color of light can be correlated with the wavelength of light. The red end of the visible spectrum is around 700 nanometers (nm) and the blue end is around 400 nm with a smooth transition from red to red-orange to orange to yellow to yellow-green to green to blue-green to blue to violet. Many different colors have been left out of this description. Every possible wavelength corresponds to a different color, even though our eye may not be able to distinguish differences between similar wavelengths, and we certainly have not given names of colors to each distinct wavelength. In fact, it would be impossible to give a name to each wavelength because of the infinite number of wavelengths. Discussion of wavelength is not essential or even appropriate to Lesson 1. Wavelength and the wave properties of light should be developed carefully in separate explorations.

Overview of Student Assignments

1. **Colors and Light** is a journal assignment to start your students thinking about light. It will also reveal your students' ideas about light. (15 minutes)
2. **Exploration with Colored Light and Colored Paper: Predictions**
   Students make predictions about different experiments with colored light and colored paper based on the ideas they hold before they begin their explorations. (15 minutes—may be a homework assignment)
3. **Exploration with Colored Light and Colored Paper: Data**
   The students use the Data sheet to record the results of the experiments with colored light and colored paper. (30–45 minutes)
4. **Making Conclusions**
   Students answer questions that lead them to make conclusions about light and color. (Homework assignment)
5. **Class discussion of results**
   (20–25 minutes)
6. **Prediction Reflection**
   After the exploration is completed and you have discussed the data and conclusions, assign the Prediction Reflection. This will help them to be more aware of their thought process.
   (15 minutes)
7. **Inquiry Reflection—Mix It Up**
   This reflection is designed to focus the attention of your students on the process and elements of inquiry. (15 minutes—may be a homework assignment)

Colors And Light: Journal Assignment

Purpose

This journal assignment is designed to encourage your students to think about what they know about light and color. It is also designed to help you to know the commonly held ideas of your students.

Students will begin this unit with a variety of ideas about color and light. Some of these commonly held ideas are discussed in the **Background** of Lesson 1. Students will reveal their ideas if they respond thoughtfully to these questions, therefore, answers to the journal questions are not right or wrong. The evaluation of the journal should be on the thoughtfulness of the answer and the presence or absence of reasoning to support the answer. This is not a group activity. You will learn much more if each student completes the journal to the best of his or her ability.

Materials List

5 pieces of large sized (at least 9” x 12”) colored construction paper (one each of red, blue, green, white, and black)

Preparation and Procedures

At the beginning of the class period, have each of the pieces of construction paper prominently displayed in the classroom and hand out the journal assignment. Direct your students’ attention to the pieces of paper. Allow about 15 minutes to have your students reflect on, and answer, the questions. You may assign the journal as a homework assignment, however, they need the pieces of paper in front of them as they answer the questions. You know your students best, and you know best which format will achieve the desired goals for this assignment.

Exploration With Colored Light And Colored Paper

Purpose

This exploration is designed to help your students to understand that the color of an object is a particular color of light reflected from the object. This activity will also introduce the concept that white light is a combination of other colors. Implied, but not proven by this activity, is that the sources of light used (the projector bulb, fluorescent lights, or the Sun) emit a mix of many colors of light. Question #5 of **Making Conclusions** directly addresses this question. Do not provide an answer to Question #5. (This idea will be expanded on in **Prisms and Rainbows**.) Ask students to consider the question as they proceed in their investigation of light. The journal assignment, **Colors and Light**, may have revealed some other ideas that your students have about color and light. Be alert to these as you conduct the exploration. Help them to confront misconceptions by challenging them with evidence that is in opposition to their ideas—use evidence from this lesson.

Materials

- 5 pieces of large sized (at least 9” x 12”) colored construction paper (one each of red, blue, green, white, and black)
- Red, blue, and green gels (gelatin filter), Wratten filters or cellophane (your theater department may help you obtain the gels)
- An overhead projector, or 3 slide projectors, or 3 powerful flashlights with the colored gels or cellophane fixed securely over the lens. An overhead projector works especially well for Activity 1. If you use an overhead projector, you should get a filter as large as the glass top so that the filter covers the entire surface. Don’t put the filter over the upper lens—the heat could melt it. If you use a small filter, use a piece of cardboard as a mask for the glass surface and cut a hole in the cardboard a bit smaller than the filter. You may also use red, blue, and green floodlights from a hardware store. (You will need to check the spectra of the floodlights with a spectroscope because they may project a broad band of wavelengths in addition to the dominant color.)
- A very large (3’ x 5’) sheet of white paper, a white wall, or a white board
- A dark room
- **Predictions**
- **Data**
- **Making Conclusions**

(You may wish to run this exploration as a small group activity. In that case you will need 3 flashlights for each group and small size gels or cellophane for each group.)

Preparation and Procedures
Practice these activities before you do them with your students.

1. Display the 5 pieces of construction paper across the front of the room so that all students can see them clearly.

2. Begin by having the students share their reflections from the journal assignment, **Colors and Light.** Be careful not to communicate that an answer is correct or incorrect, or that one answer is better or worse than another is. Ask questions to help reveal the preconceived ideas students have. Different ideas will help stimulate interest in the activity.

3. After sharing the various ideas, demonstrate each filter one at a time. Shine the colored light on the large piece of white paper or on the white board.

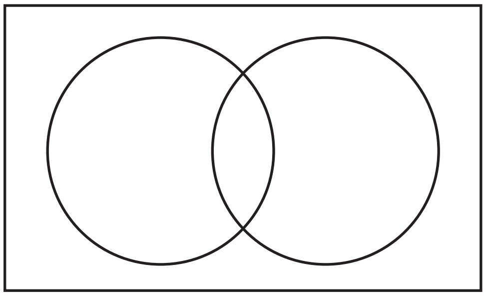
4. Have students complete the **Prediction Sheet** in small groups. Walk them through the first combination of red light on red paper to help them understand the task. Ask them to be aware of their reasons for making each prediction. Allow about 15 minutes so that discussion can occur within each group.

Note: Students may not have much experience making predictions formally. Ask them to think about what they know—what experiences they have had—to guide them. Physics Education Research (PER) has shown that student performance and investment are enhanced when they make predictions. Stress to your students that their predictions will not be graded except for completion and the thoroughness of their answers in Activity 3. Do stress, however, that the predictions are important. Research also indicates that students can learn to learn more effectively if you ask them to reflect on their predictions after they complete the activity. **A Prediction Reflection** assignment is provided in the Appendix that can be used after any Exploration in which the students make predictions. Introduce the **Prediction Reflection** to students **before** they start the prediction, and tell them a **Prediction Reflection** will be an assignment later on. Ask them to be aware of their reasons for making each prediction in preparation for this assignment.

5. Proceed with Activity 1 of **Exploration with Colored Light and Colored Paper**. Make the room as dark as you can. You can shine the red light on each piece of paper separately, or if you use a projector, you could shine the light on all pieces of paper simultaneously. Caution the students to record what they see and not what they think they should see because they know what the original color of the paper was. The pieces of paper will probably have different shades of dark gray or black. Students should now use the **Data** sheet to record what they actually see. If you shine the light on each piece of paper separately, have a copy of the Data sheet for yourself to guide you. In Activity 1, you will shine the red light on the color of paper indicated in the middle column. For example, you will first shine red light on the red paper, and the students will record the color they see. Then shine the red light on the blue paper, and the students will record the color they see. Continue until you have tested all combinations of Activity 1. Note that you are not shining green light or blue light on the paper. As discussed in the **Background**, green and blue filters that only transmit green or blue light are difficult to obtain. The data obtained from imperfect green or blue filters are difficult to interpret and will introduce unnecessary confusion; however,

students may wish to explore the green and blue light on colored paper in their Independent Investigation (Lesson 6).

6. Proceed with Activity 2 of **Exploration with Colored Light and Colored Paper.** Again use the Student Data sheet to guide you. Shine the color of light 1 and the color of light 2 on a white surface so that the colors overlap as shown. Strong flashlights covered by gels or filters can work well.

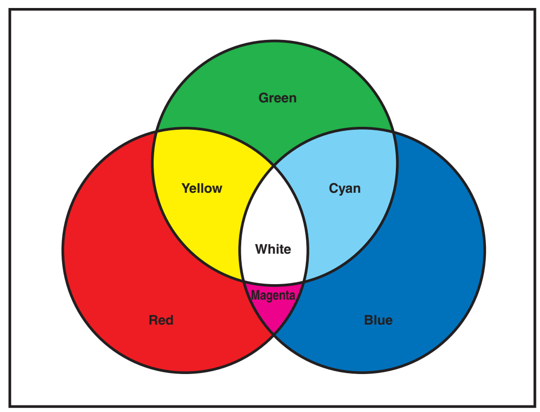


Have students try to describe or match the color in the region of overlap as accurately as possible. Continue until you have tested all combinations. A mixture of red and green light should look yellow. A mixture of red and blue light should give magenta, and a mixture of blue and green should give cyan. You can observe these mixtures at the *ChemConnections* Web site "Emission Spectrum Java Applet" **http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html**.

7. Open a class discussion to generate solutions to Activity 3 and test the solutions. Have the students record the solutions that work on their Data sheet. (If you run this exploration as a small group activity, this class discussion is not necessary.)

Results

You should find that overlapping the light from all three sources makes the white paper appear white. If the lights have different intensities, you may see a tinge of the brighter color. Test this before you begin work with the students. You may be able to eliminate any color tinge by moving the brighter projector, flashlight, or floodlight away from the white surface. If you cannot get the right conditions, plan on showing your students that white light is indeed produced by an equal balance of red, blue, and green and that any intensity difference will produce a tinge by showing them the *ChemConnections* Web site "Emission Spectrum Java Applet" **http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html**. Where the three colors overlap red, blue, and green are reflected to your eye. The color receptors in your eye send signals to the brain that interprets this condition as white light. It is powerful to arrange the lights to overlap as shown below.



This allows a large area of overlap, yet it allows the students to still see the individual colors of the lights reflected off the white paper.

The black color results when no light reaches the eye. This can occur if you turn off the lights. Students may also remember from Activity 1 that black (or nearly black) occurs when red light falls on blue or green paper.

Note: Students may be confused at this point. Your students may remember from art class that mixing red, blue, and green paint produces black—or a dark, muddy brown. There is a difference between mixing colored light and mixing pigments. If they mix red, blue, and green pigments, they will get black; however, if they mix red, blue, and green light, they will get white. If this question comes up, schedule a time to go to the Web page “Colors” from the NTNU Virtual Physics Laboratory at http://www.phy.ntnu.edu.tw/java/image/rgbColor.html. This Web site allows you to switch between color mixing and pigment mixing. Another site allows you to explore different intensities of red, blue and green light at Mixing Primary Colors http://www.omsi.edu/visit/hightech/techinit/phase2/content/colormix.cfm. You and some of your students may enjoy the Web page “Color and Light” produced by Arizona State University’s Patterns in Nature http://acept.la.asu.edu/PiN/rdg/color/color.shtml. Another good Web site to explore color and light is Color Science http://www.physics.sfasu.edu/astro/color.html.

8. Assign **Making Conclusions**. Remind students that it is important for them to supply reasons for their answers. Remind them to use evidence from the exploration as reasons.

9. After the students have completed their conclusions, engage them in a discussion. Ask them to explain their reasoning as completely as possible. Students may not use the words *reflected* and *absorbed*, but these words may help them to express their understanding more clearly. The sheets of white and black paper serve as special controls. Direct their attention to the controls. An engaging way to begin the discussion (if you can get your room dark enough) is to make the room dark and ask the students what “color” they “see.” (They could close their eyes, but that may involve another misconception.) Then ask what conditions resulted in black and why they saw black. Now have them begin to consider the conditions that resulted in color—red light on red paper and white paper, blue light on white, green light on white. Ask them how white paper can be so “flexible” and show the color of the light. If they cannot provide a complete and correct answer, don’t supply one and don’t tell them the answer is wrong. Go on (however, by the end of the discussion about Activity 2 and Activity 3 they should be able to answer the question). If they do supply a complete and correct answer, don’t tell them the answer is correct. Ask them if they have evidence from the exploration to support their answer. This should lead you into a discussion of Activities 2 and 3.

   At the completion of this activity, students should understand that we see the colors of light that are reflected. Red paper reflects only red light and absorbs all other colors. White paper can look red in red light, blue in blue light and green in green light because white paper reflects all colors. When red, blue, and green were mixed and reflected, they saw white—so white paper is only white in white light. It is implied, therefore, that room light and sun light are white light and are made of all colors. This will be explored in Prisms and Rainbows, so do not force the issue. Perhaps you can end the discussion with a question: “What color is sunlight and the light from the room lights?”

10. Assign **Prediction Reflection** (Appendix). They should choose predictions from the Prediction sheet and compare their predictions with the results from the Data

sheet. They are only asked to respond to two predictions. The quality of their reflection on their thought process is more important than quantity.

11. Assign **Inquiry Reflection—Mix It Up**. After they have completed the Inquiry Reflection engage them in a discussion of the structure of the lesson using the Inquiry Reflection. This is a very teacher-centered lesson. You have generated the question. You have provided an experiment that controls variables. The assignment **Making Conclusions** even provides the students with guide questions to help them focus on the most important issues. In Lesson 5, the students have to design everything except the question to be answered, and in Lesson 6 they even have to provide the question. They can learn from the modeling in earlier lessons, but only if you draw their attention to variables, control of variables, the importance of asking questions, and how to make conclusions.

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and Space Administration

Mix It Up

Student Assignments

www.nasa.gov

Colors And Light

Journal Assignment

Please answer the following questions in your journal as completely as you can. Your entry will be evaluated on the thoughtfulness of your answers and the reasoning you give in support of your answer.

1. Look at the 5 pieces of paper of different color. Briefly describe what you see.

2. Why are you able to see each of these pieces of paper as distinctly different colors? In other words, why does the one paper appear red and another paper appear blue?

3. If the room were completely dark, would you be able to determine the color of each piece of paper? What does this tell you?

4. If you took these pieces of paper outside into the sunlight, would they look different than they did with the room lights? Explain.

5. Are there any differences between light from the Sun and light from the room lights (fluorescent or incandescent)? Explain. (Please go beyond the obvious difference that the light from the Sun is much more intense and would blind you if you looked directly at it.)

6. What do you know about light?

Exploration with Colored Light and Colored Paper

Predictions

Questions: What do we need to see colors? What do we need to see white?

Activity 1 **Shine red light on different colored paper**

Color of Light	Color of Paper	Predict the Color You Will See. Briefly explain the reason for your prediction.
Red	Red	
Red	Blue	
Red	Green	
Red	White	
Red	Black	

Activity 2 **Mix different colored lights on the white surface**

Color of Light 1	Color of Light 2	Predict the Color You Will See. Briefly explain the reason for your prediction.
Red	Blue	
Red	Green	
Blue	Green	

Activity 3	Solution
How would you use the colored lights to get a white color on the white paper?	
How would you use the colored lights to get a black color on the white paper?	

Exploration with Colored Light and Colored Paper

Data

Questions: What do we need to see colors? What do we need to see white?

Activity 1 **Shine red light on different colored paper**

Color of Light	Color of Paper	Color You See
Red	Red	
Red	Blue	
Red	Green	
Red	White	
Red	Black	

Activity 2 **Mix different colored lights on the white surface**

Color of Light 1	Color of Light 2	Color You See
Red	Blue	
Red	Green	
Blue	Green	

Activity 3	Solution
How would you use the colored lights to get a white color on the white paper?	

Making Conclusions

Exploration with Colored Light and Colored Paper

Give reasons for your answers. Use evidence from the exploration.

Questions

1. What conditions do you need to see red?

2. What conditions do you need to see black?

3. Based upon your answers to #1 and #2, what do the results of Activity 1 tell you about seeing color?

4. What is white light? How do you know? Why did you never see white in Activity 1?

5. When the lights in your classroom or sunlight illuminate the different pieces of paper, each has a distinct color (red, blue, green, white, or black). What does this tell you about your classroom lights or sunlight?

6. Describe in writing and draw a picture explaining how you see an object.

7. Based on the evidence you gathered in Exploration with Colored Light and Colored Paper, what can you conclude? (A conclusion is not a summary of what you did. It is not simply a few ending statements. A conclusion is a new understanding that you have based on the evidence gathered.)

8. Write two or three questions that you have because of this exploration with colored light and colored paper.

Inquiry Reflection—Mix It Up

These questions are designed to make you think about the process scientists use to explore and discover. Reflect upon and answer these questions in your journal. You will be evaluated on the completeness of your answers and the depth of your thinking, not on the correctness of your answers.

1. What are the variables in Activity 1, **Exploration with Colored Light and Colored Paper**?

2. What are the variables in Activity 2, **Exploration with Colored Light and Colored Paper**?

3. Why did you do the three activities in **Exploration with Colored Light and Colored Paper**?

4. Would you add any activities to **Exploration with Colored Light and Colored Paper**? Why? What would you add?

5. What is the purpose of questions #1–7 in the assignment **Making Conclusions**?

6. What is the purpose of **Exploration with Colored Light and Colored Paper**? How do the questions in Making Conclusions help you to achieve the purpose?

National Aeronautics and Space Administration

Lesson 2

Prisms and Rainbows

An Educator's Guide with Activities in Physical Science

Educational Product	
Educators & Students	Grades 6-12

www.nasa.gov

EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Prisms and Rainbows

Teacher Resource

http://son.nasa.gov/tass/iadl.htm

Purpose

Our eyes and brain interpret the simple mixing of only 3 colors of light (red, green, and blue) as white. The students were able to confirm this in the last lesson. In this lesson, students will develop the understanding that "white" light from the Sun and "white" light from an artificial light source is a **full range** of colors from red to violet. Students will also learn how droplets of water function as prisms to separate this full range of colors into rainbows.

Benchmarks for Scientific Literacy

- **Increasingly sophisticated technology is used to learn about the universe**. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computa tions to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9–12)

- **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/1 (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**. 4F/5 (6–8)

National Science Education Standards

Grades 5–8
Science As Inquiry

- **Different kinds of questions suggest different kinds of scientific investiga tions. Some investigations involve observing and describing objects**, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.

- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

- **Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.**

Physical Science—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 light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

History and Nature of Science—Nature of Science

- **Scientists formulate and test their explanations of nature using observation, experiments**, and theoretical and mathematical models.

Physical Science—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.**

Background

Visible light from the Sun is a full spectrum of colors ranging from red to violet; and is not limited to red, blue, and green (or even red, orange, yellow, green, blue, indigo, and violet—Roy G. Biv). This means that 64 colors of crayons or even 100 would not accurately reproduce the visible spectrum. There are an infinite number of colors gradually shading from red to violet, although our eyes cannot perceive all of these subtle differences. Understanding this is an essential first step to understanding the entire electromagnetic spectrum that ranges from radio waves to gamma waves. It is necessary for students to understand the visible spectrum before they can fully understand that there are more parts to the electromagnetic spectrum outside of our visible range. The first exploration will help the students understand this critical concept. The existence of infrared light and ultraviolet light will be discovered in later activities, so it is counterproductive to mention these ideas now.

Natural phenomena have explanations that can be modeled and understood. The second activity, **Exploring Rainbows**, is designed to help students make the connection between prisms and rainbows. Students often believe that lab equipment is somehow removed from the real world. It is helpful to point out that lab equipment was designed by scientists to help scientists study natural phenomenon more thoroughly. This activity is also included because knowing why a rainbow exists is a wonderful thing. Some teachers have found it interesting (and poetic) to declare that each person, admiring a rainbow, stands looking at the center of his or her own personal rainbow. Then, challenge the students to explain.

Exploring Rainbows uses one of the topics in *Patterns in Nature* (**http://acept.la.asu.edu/PiN/info/patt.html**), produced and supported by the Department of Physics and Astronomy at Arizona State University. This Web site is rich in activities and readings. There are two activities and four readings for the exploration, **Exploring Rainbows**, beginning with the activity *What Causes Rainbows*? (If students do not have access to computers, you may wish to cover this material in class as a lecture/demonstration.) Alternatively, you might choose to do the two activities as a class demonstration and assign the readings. A third option is to make the entire assignment a reading assignment without doing the activities. The results are described clearly enough in the activity. The first two readings have links within the activity, *Seeing Rainbows*. The third and fourth readings have links in each preceding reading. There are two questions at the end of the fourth reading that you may use as enrichment readings.

Overview of Student Assignments for Prisms and Rainbows

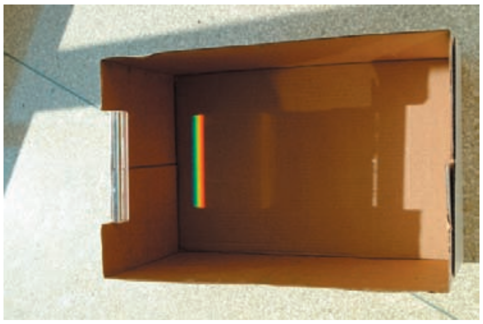
1. **Rainbows** is a journal assignment to be done in class. The purpose of the assignment is to explore the student's previous knowledge about spectra and rainbows and to engage them in the exploration. (15 minutes)
2. **Exploration with Prism and Light** is a two-part lab investigation. Part 1 investigates the light from a light bulb, and Part 2 uses light directly from the Sun. (Two to three 45-minute periods)
3. **Making Conclusions** should be completed immediately after the students complete Exploration with Prism and Light. The students can be working on this short-essay format conclusion outside of class while they are proceeding to the next exploration.
4. **Exploring Rainbows** is a computer-based activity that develops an understanding of rainbows and how they are formed. If students do not have access to computers, you can conduct a lecture/demonstration using materials from the Web site. (One 45-minute period)
5. **Rainbows—Revisited** is a journal assignment that asks the same questions as **Rainbows**, the opening journal assign ment of this lesson. You can treat these as pre- and post-assessment tools. (15 minutes)
6. **Class discussion of results** (20–25 minutes)
7. **Prediction Reflection** (Appendix) is a reflection for students to compare their predictions from Rainbows with their answers to the same questions from Rainbows—Revisited or they might choose the prediction from the Exploration with Prism and Light. (Homework assignment)
8. **Inquiry Reflection—Prisms and Rainbows** This reflection is designed to focus the attention of your students on the process and elements of inquiry. (Homework assignment)

Exploration with Prism and Light

Materials (per group)

- An equilateral glass prism
- Tape
- Cardboard box (a box that contained photo copier or printer paper is ideal)
- White paper
- Colored pencils or crayons
- Overhead projector, or slide projector, or strong flashlight
- A dark room for the first part of the activity
- Direct sunlight into a somewhat dark room for **Part 2: Light from the Sun**. (You may have to shade the window, allowing only a beam of sunlight to come into your experiment area.). You can also do this exploration outside.
- **Rainbows** for each student
- **Exploration with Prism and Light** for each student
- **Making Conclusions** for each student

Note: Construct, or have your students con- struct, a prism holder. Use a copier paper box. Cut out a rectangular notch in the middle of the top edge of the narrow side of the box. The notch should provide a tight fit for the prism. Place the prism in the notch, and project the spectrum onto the bottom of the box. If the Sun is high in the sky and shines into the box, or if the Sun is too low to get a spectrum in the box, prop up the box until a spectrum is visible in the darkened area inside the box. Don't do this exploration on concrete. The prism may shatter if it falls on the concrete.



Preparation and Procedures

1. Hand out the Prisms and Rainbows Journal Assignment at the beginning of class. Students should spend about 10–15 minutes on the journal. Have colored pencils or crayons available as they walk into class. This should not be a homework assignment. The journal functions as a way of making a personal prediction. At home they might research the questions. You want them to tell you what their current ideas are. The journal helps you to know what pre-conceptions they have; also, they will be more invested in testing their own answers during the exploration. Tell them to be aware of their thought process as they answer the questions. There will be a **Prediction Reflection** at the end of this lesson.
2. When they have finished their journal, give them **Exploration with Prism and Light**.
3. Students should then move into groups and begin the exploration by making the prediction at the beginning of **Exploration with Prism and Light**. Have them complete the **Observations** during the exploration in the lab.

Note: Students may have difficulty getting a “rainbow” either in Part 1 or in Part 2. In Part 1 students may get a broad “rainbow” with a wide area of white in the middle. They can get a better “rainbow” by rotating the prism and by moving the light source away from the prism. Be available and help students get a good “rainbow.”

4. Assign **Making Conclusions** after the exploration has been completed and they have had time to write their observations. Give them time to think about the exploration and to write a good essay. “Students of all ages find it difficult to distinguish … between description of evidence and interpretation of evidence” (Benchmarks for Science Literacy, 332). Stress that a conclusion is not a restatement of evidence. A conclusion is an interpretation of evidence; it is a new understanding of the world based on the evidence. They can begin the next exploration, **Exploring Rainbows**, in class while they work on the essay as homework.

Exploring Rainbows

Overview of Exploring Rainbows
First Activity: **What Causes Rainbows?**
http://acept.la.asu.edu/PiN/act/rainbow/rainbow.shtml

First Reading: **Rainbows**
http://acept.la.asu.edu/PiN/rdg/rainbow/rainbow.shtml#top

Return to Activity:
http://acept.la.asu.edu/PiN/act/rainbow/rainbow.shtml#Return

Second Reading: **Rainbows, part II**
http://acept.la.asu.edu/PiN/rdg/rainbow/rainbow2.shtml

Third Reading: **Rainbow, part III**
http://acept.la.asu.edu/PiN/rdg/rainbow/rainbow3.shtml

Fourth Reading: **Rainbows, part IV**
http://acept.la.asu.edu/PiN/rdg/rainbow/rainbow4.shtml

Materials (per group)

- Computer with Internet connection
- Water glass
- Flashlight, or other directed beam of light
- Round-bottomed flask, or some spherical glass container (a round fishbowl would work)
- Small piece of cardboard or poster board that fits over the head of the flashlight
- 10” x 14” piece of white poster board

Preparation and Procedures

1. Provide the materials above in a “wet lab” away from the computers. Assign each group to a computer and, if possible, have each computer already connected to *Seeing Rainbows* at **http://acept.la.asu.edu/PiN/act/rainbow/rainbow.shtml**. Students should follow the procedures in the activity and readings.
2. After the students have completed the activity and readings, assign **Rainbows-Revisited.**
3. Have students complete a **Prediction Reflection** (Appendix) and compare their predictions from **Rainbows** with their answers to questions in **Rainbows—Revisited**.
4. Assign **Inquiry Reflection—Prisms and Rainbows**

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and
Space Administration

Prisms and Rainbows

Student Assignments

Rainbows

Journal Assignment

Please answer the following questions in your journal as completely as you can. Your entry will be evaluated on the thoroughness and thoughtfulness of your answers and the reasoning you give in support of your answer.

1. Draw a rainbow. What colors are in a rainbow? What is the order of colors? Which color is on top?

2. What conditions do you need for a rainbow?

3. What is your explanation for a rainbow?

Exploration with Prism and Light

Predictions

What happens when light from the Sun or an overhead projector shines through a prism?

Part 1: Light from a bulb

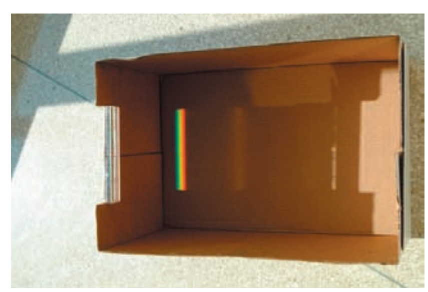
Materials (per group)

- An equilateral glass prism
- Tape
- Cardboard box (a box that contained photocopier or printer paper is ideal)
- White paper
- Scissors or utility knife
- Colored pencils or crayons
- Overhead projector, or slide projector, or a strong flashlight
- A dark room

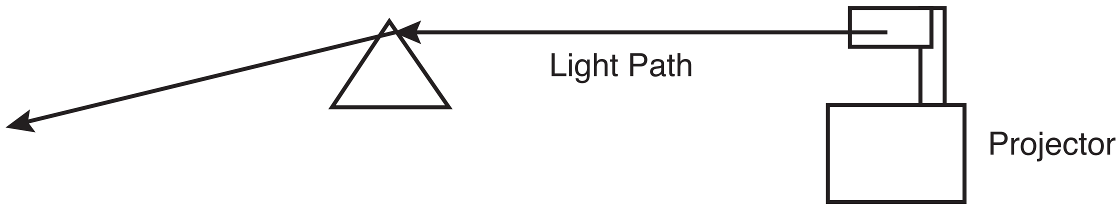
Procedure

1. Cut a notch in the top of one edge of the narrow side of the box. The notch should be just big enough to hold the prism **securely**.

2. Position a strong, focused light source about 4–5 feet from the box. Put the sheet of white paper in the bottom of the box.



3. Insert the prism into the notch and secure with tape, if necessary. One flat side of the prism should be down. The **opposite** edge should be horizontal and perpendicular to the light source. (The box is not shown in the figure below.)



4. Adjust the height of the prism. The prism should be in direct line with the light from the projector. You may have to rotate the prism slightly to get the light coming through it to be projected onto the white paper in the dark bottom of the box. You should see a small "rainbow"! Continue to rotate the prism until the "rainbow" doesn't have any white light in the middle.

5. Try placing the light source and the prism at different distances from each other. Does this make a difference? What is the difference?

____

____

____

6. When you get the best possible "rainbow," go to the next step.

7. Using colored pencils or crayons, draw what you see on the white paper.

Observations

1. What colors do you see? Look carefully. Attempt to describe as many different colors as you can.

____

____

____

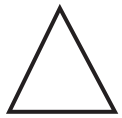
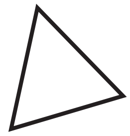
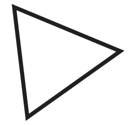
2. What is the order of colors?

____

____

____

3. Draw the experimental set-up showing the prism and light source from the side. Note especially the angle of the prism. How much was it rotated?

This  or this  or this 

Part 2: Light from the Sun

Materials (per group)

- An equilateral glass prism
- Tape
- Cardboard box (a box that contained photocopier or printer paper is ideal)
- White paper
- Colored pencils or crayons
- A support stand with a short horizontal rod and rod clamp
- Direct sunlight

Procedure

Use the same experimental equipment that you used in Part 1. Position the prism in the sunlight. Turn the prism so that the “rainbow” is projected onto the bottom of the box. Draw the “rainbow” on white paper.

Observations

1. What colors do you see? Look carefully. Attempt to describe as many different colors as you can.

____

____

____

2. What is the order of colors?

____

____

____

3. Are there any differences between the “rainbow” from the projector and the “rainbow” from sunlight?

Making Conclusions

Scientists call the "rainbow" that you saw in the exploration a **light spectrum**. When you shine light from the projector on white paper, the paper looks white. When you place white paper in sunlight, the paper looks white. When you shine light from the projector or sunlight through a prism, a light spectrum appears. Think about the results from **Mix It Up**. Think carefully about all your evidence. Answer the following question in a short essay (1 to 2 pages).

What does your evidence tell you about visible light from the projector or from the Sun?

Rainbows—Revisited

Journal Assignment

You have just completed one exploration of the properties of light. You have used a prism to create a light spectrum, and you have seen how water drops create a spectrum (rainbow). Use your new experiences as you answer these questions. Please answer the following questions in your journal as completely as you can. Your entry will be evaluated on the thoroughness and thoughtfulness of your answers and the reasoning you give in support of your answer.

1. Draw a rainbow. What colors are in a rainbow? What is the order of colors? Which color is on top?

2. What conditions do you need for a rainbow?

3. What is your explanation for a rainbow?

Inquiry Reflection—Prisms and Rainbows

These questions are designed to make you think about the process scientists use to explore and discover. Reflect on, and answer, these questions in your journal. You will be evaluated on the completeness of your answers and the depth of your thinking, not on the correctness of your answers.

1. How is the structure of **Exploration with Prism and Light** different from **Exploration with Colored Light and Colored Paper**? Why is the structure different?

2. What is the function of the questions in the **Observations** sections of **Exploration with Prism and Light**? Would your responses have been different if you had just been asked to record your observations?

3. How is the **Making Conclusions** assignment in Lesson 2—Prisms and Rainbows different from the **Making Conclusions** assignment in Lesson 1—Mix It Up?

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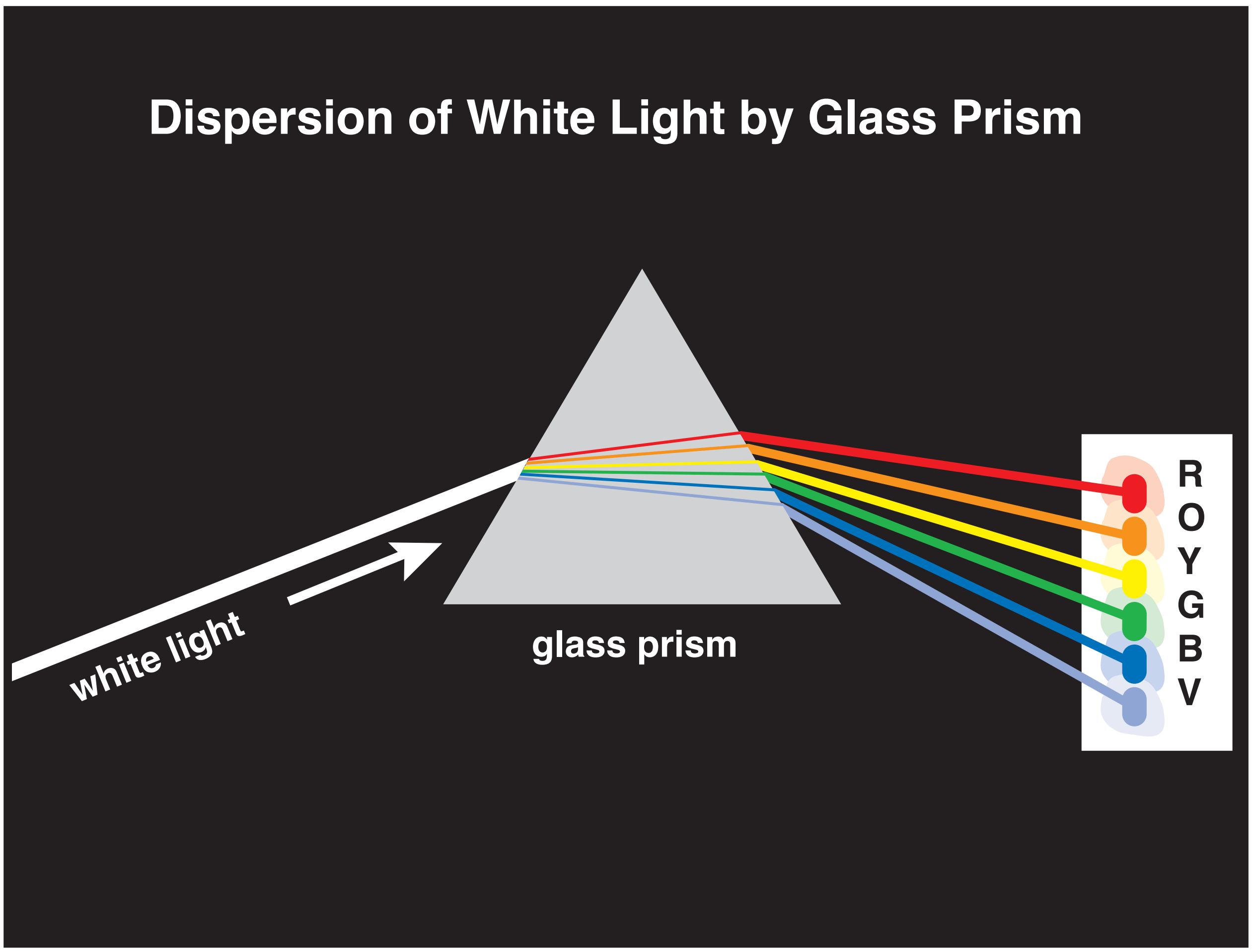
Lesson 3

Exploring Spectra

An Educator's Guide with Activities in Physical Science



Educational Product	
Educators & Students	Grades 6-12

www.nasa.gov

EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Exploring Spectra

Teacher Resource

http://son.nasa.gov/tass/iadl.htm

Purpose

Students will understand that elements emit light in a distinct spectrum, which can be used to identify the elements, and that this information can be used to identify the composition of complex light sources such as stars. Students will expand on their understanding of the visible light spectrum.

Benchmarks for Scientific Literacy

- **Technology is essential to science for such purposes as access to outer space and other remote locations**, sample collection and treatment, measurement, data collection and storage, computation, and communication of information. 3A/2 (6–8)
- The stars differ from each other in size, temperature, and age, **but they appear to be made up of the same elements that are found on the Earth and to behave according to the same physical principles**. Unlike the Sun, most stars are in systems of two or more stars orbiting around one another. 4A/1 (9–12)
- **Increasingly sophisticated technology is used to learn about the universe**. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9–12)
- When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, **the light emitted or absorbed by separate atoms or molecules (as in a gas) can be used to identify what the substance is**. 4E/5 (9–12)

National Science Education Standards

Physical Science—Interactions of Energy and Matter

- **Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance**. Grades 9–12

Science and Technology

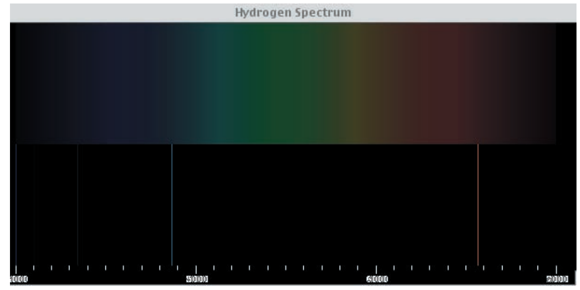
- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. **Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis**. Grades 5–8

- **Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understand ing and introduce new areas of research**. Grades 9–12

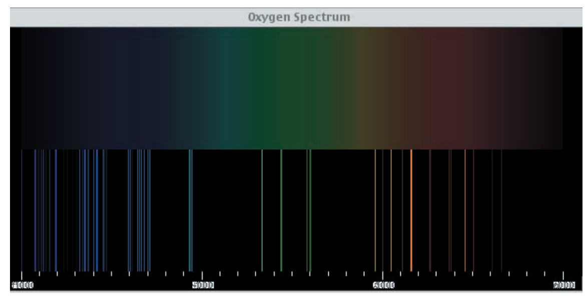
Background

Whenever an electric charge is accelerated, an electromagnetic field (light) is generated. When electrons oscillate in a radio antenna, low energy, long wavelength, electromagnetic waves (radio waves) are generated. Visible light is generated when an electron "falls back" from a higher energy level in an atom to a lower energy level. The electron got to the higher energy level by some input of energy. In this investigation, the spectrum tubes use a large voltage to supply the energy. In the Sun, nuclear and magnetic processes supply the energy. This is a very simplified explanation. More detail can be found on the ***Electromagnetic Spectrum*** Web page **http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html** of the ***Imagine the Universe*** Web site. The Physics 2000 Web page on ***Electromagnetic Wave***s **http://www.colorado.edu/physics/PhysicsInitiative/Physics2000/waves_particles/index.html** is another excellent source of background information.

Each element has characteristic energy levels, so that only certain changes in energy level are allowed for each element. Each change in energy level corresponds to one wavelength of light emitted. Each wavelength is characterized by a different color of light (although our eyes may not distinguish between colors that are very similar). Hydrogen has very few possible changes of energy in the visible range, so the spectrum for hydrogen that has been excited by a high electrical voltage is very simple (see top right).



The full spectrum on top is for reference only. Hydrogen only emits red, blue, and a faint violet light in the visible region. The spectrum of oxygen (below) is more complex.



Spectra were obtained from AtomicMac™. See Supplies and Vendors, Appendix

The Sun produces the entire visible spectrum (as well as all nonvisible wavelengths) because the composition and energetics of the Sun are complex. Only students in chemistry or upper level physics need to understand the mechanism of electromagnetism, however, the **mechanism** is not taught in this unit. Younger students who do this lesson can discover that each element has its own characteristic spectrum. An online source of spectra for every element is available at **http://javalab.uoregon.edu/dcaley/elements/Elements.html**.
It is preferable that students construct their own spectroscope to help them understand its simple structure. **Learning Technologies** (see **Supplies and Vendors**, Appendix) and the Stanford Solar Center (Colors of the Sun **http://solar-center.stanford.edu/posters/colors.html**) offer kits that are simple, durable,

and inexpensive. These kits are preferred if you wish to introduce numerical values for the spectral lines, however, **Constructing a Spectroscope** (see Appendix) offers a procedure for students to construct a spectroscope from a shoebox or paper tube. These spectroscopes will not provide a numerical analysis. Pre-made student spectroscopes are also available (see **Supplies and Vendors**). If you choose to use pre-made spectroscopes, make certain that you have diffraction gratings (**see Constructing a Spectroscope** in the **Appendix**) and CDs available for students to examine as part of the investigation.

Overview of Student Assignments for Exploring Spectra

1. **Student Lab Investigation** provides students with the opportunity to investigate the properties of spectroscopes and uses spectroscopes to investigate a variety of light sources. Students will need the Spectra Data Sheet to record data. (One to two 45-minute periods)
2. **Making Conclusions—Spectra** asks students to interpret the data obtained in the investigation. (30 minutes—may be a homework assignment)
3. **Analysis of Stars** is an application and extension of the knowledge gained in the investigation. There are two versions of this assignment: one is for grades 7–9 and the other is for grades 10–12. In addition, there are two pages of worksheets that accompany these assignments. (30 minutes)
4. **Class Discussion** (20 minutes)
5. **Cosmic Questions: Our place in space and time** is an excellent extension activity available from the Harvard-Smithsonian Center for Astrophysics **(http://cfa-www.harvard.edu/seuforum/exhibit/resources/resources.htm)**.

Exploration with Prism and Light

Materials (per group)

- Spectroscopes for each group or spectro scope kits or materials for the shoebox spectroscope (see **Exploring Spectra—Constructing a Spectroscope**: Appendix)
- 1 CD per group (use old CDs such as promotional CDs)
- 1 or 2 Spectrum tube power supplies (see Appendix for source)
- Spectrum tubes—at least hydrogen, helium, neon (see Appendix for source)
- Incandescent light bulb and lamp (60W)
- Fluorescent (mercury) light source
- 1 or 2 microscopes (low power or dissecting) or magnifying lenses
- Periodic Table of the Elements (individual or arge display)
- A fairly dark room
- Crayons or colored pencils (full set per group, optional)
- Spectrum glasses (optional, see Appendix f or source)

Note: Spectrum tubes and power supplies are available for this activity. See Supplies and Vendors in the Appendix for sources. It is best to have several different elements as light sources, such as hydrogen, helium, nitrogen, oxygen, and neon spectrum tubes. Fluorescent lights have mercury that will give 4–5 clear spectral lines. If you cannot purchase the spectrum tubes and power supplies, you may be able to borrow them from high schools, colleges, or science centers. Alternative light sources might be red or green LEDs, the yellowish outdoor security lights or streetlights (sodium vapor lamps), or the bluish mercury vapor streetlights.

Preparation and Procedures

1. Before class prepare each diffraction grating. Be careful not to touch the grating with your fingers. One orientation of the diffraction grating will diffract up and down, but rotating the grating 90° causes it to diffract to the side. You want the students to construct the spectroscope so that the grating diffracts to the side. In a dark room with one small light source, hold the grating near your eye and look to the side. If you don't see a spectrum, rotate the grating 90°. You should now see a spec trum to the side. Write 'up' on the top of the grating. This will help students to assemble their spectroscopes correctly.
2. At the beginning of class, hand out **Student Lab Investigation** and **Spectra Data Sheet**. Have the materials available and instruct students to read activity and get materials for the group. One person from each group should be responsible for materials. **Note**: Read the **Student Lab Investigation** carefully. Timing and organization are important. For some of the activities, students will need room lights on and sometimes they will need only the single light source. Give them clear time limits to perform activities. They should be able to complete steps 1–3 of the student procedure in 10 minutes. Constructing a spectroscope will take 15–20 minutes.
3. Instruct the students to begin the activity. It is helpful for students to know that thin, closely spaced grooves on the grating and the CDs separate light. Older students (grades 11 and 12) may explore the physics and math of diffraction.
4. Students should now make their own spectroscopes.
5. After the students have made their spectro scopes, turn off room lights and begin the 5th step of the procedure of the **Student Lab Investigation**. Red filters generally transmit light only in the red end of the spectrum, but the band of red wavelengths is fairly broad. Depending on the quality of the green filter, more or less red is also transmitted and yellow is often present. It is very difficult to obtain blue filters that transmit only blue. Usually, the blue filter also transmits green and red. This is a wonderful opportunity for students to think about Lesson 1 and test what happens when green light and blue light are used to illuminate the various colors of paper. This could be a topic for the Independent Investigation.
6. Examine the gas spectrum tubes. (Note: Students need to be reminded to point the slit directly at the light source and look to one side to see the spectrum. Students do not usually know that they should see distinct lines of different color. If there is even a faint light from the Sun or lights outside the room, students will see a faint full spectrum with distinct, brighter lines from the spectrum tube. Direct their attention to the bright lines. It is assumed that your students have heard of elements and had some exposure to the Periodic Table of the Elements. It would be helpful to have the Periodic Table available for the students to refer to as you tell them what elements are being used as a light source.) Ask the students to record the color of the glowing gas to their unaided eye before using the spectroscopes. Start with the hydrogen gas tube in the power supply. The room should be dark. If you are using spectroscopes that show numerical values for wavelengths, you may find it helpful to have the single incandescent light bulb on near the spectrum tube to illuminate the numbers. Students may have to get close to the spectrum tube to see the spectrum clearly.

Give each group time for every member to see the spectrum for hydrogen and to record the lines on the **Spectra Data Sheet**. Switch to the helium gas tube. The hydrogen tube may be very hot! Continue the process for every gas. If you do not have a mercury tube, you can use the fluorescent lights in your classroom—they contain mercury.

7. Identifying unknowns: This is an important step and, hopefully, you were able to obtain helium and nitrogen spectrum tubes. The colors of these two glowing gases appear very similar to the naked eye. Both appear bluish with pink tones. Tell your students that you are going to energize one of the gases and they have to tell you which gas it is without using their spectroscopes. Choose one tube and energize the gas. The color of the glowing gas to the naked eye will not help them. Then ask them to identify the element using their spectro scopes. The spectra of helium and nitrogen are very different.
8. Assign **Making Conclusion—Spectra**
9. It is recommended that you assign **Analysis of Stars** to be completed in class by each student after the completion of the investigation. Students will need **Worksheet 1: The Spectra of Seven Elements and Worksheet 2: The Absorp tion Spectra of Five Stars**. This assign ment is an application and an assessment of what they have learned in this lesson; therefore, it is important that each student work independently to allow you to assess how she/he is working with the new information.
10. You can extend this exploration of spectros copy with a unit offered by The Stanford Solar Center on the Sun and the use of spectroscopy to study the Sun and other stars. The unit is titled Sun and Stars at **http://solar-center.stanford.edu/webcast/wcpdf/sun&stars5-8.pdf**. Another series of extension activities is available through Cosmic Questions from the Harvard-Smithsonian Center for Astrophysics <**http://cosmicquestions.org**>

Results for Analysis of Stars

What elements are in each star?

a. Star 1: **helium, hydrogen, lithium**
b. Star 2: **helium, hydrogen, iron, lithium, magnesium, neon, sodium**
c. Star 3: **helium, hydrogen, iron, lithium, magnesium, sodium**
d. Star 4: **helium, hydrogen**
e. Star 5: **helium, hydrogen, iron, lithium, magnesium, sodium**

1. What stars, if any, contain all seven elements? **Star 2**

2. What elements, if any, are in every star? **Helium and hydrogen**

3. Hypothesize an explanation for #2.

Look for thoughtful hypotheses. Depending on the age and background of your students, their knowledge base will vary. Hydrogen and helium are the most abundant atoms in the universe and in stars. In our Sun, approximately 92.1% of the atoms are hydrogen and approximately 7.8% are helium. Stars convert hydrogen to helium by fusion. Further conversions are made by fusion of helium and eventually fusion of heavier elements. (See We Are All Star Stuff http://son.nasa.gov/tass/content/article1.htm). The remaining 0.1% is made of oxygen, carbon, nitrogen, neon, iron, silicon, magnesium, sulfur, and a few trace elements. Other stars will have slightly different compositions as this activity shows, but hydrogen and helium will be common to all.

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and Space Administration

Exploring Spectra

Student Assignments

www.nasa.gov

Exploring Spectra

Predictions

You have seen that white light has a definite spectrum. Would you predict that different colors of light have different spectra from each other? Will they be different from white light? If you think there is a difference, how will the spectra be different?

Materials (per group)

- Spectroscope or spectroscope kit
- CDs
- Various light sources including a single light bulb
- Dark room
- Red, green, and blue filters from Lesson 1
- Microscope or magnifying lens
- Optional—crayons or colored pencils

Procedure

Your teacher will provide you with a spectroscope or the material and instructions to build one.

1. Examine the diffraction gratings on the viewing end of the spectroscope (or from the spectroscope kit if you are making one) with the microscope or magnifying lens. Describe what you see. Examine the non-label side of the CD with the microscope and describe what you see.

2. Look at the light source through the spectroscope (or through the diffraction grating if you are making a spectroscope). You will have to look to the side toward a dark wall. Describe what you see. (The room needs to be fairly dark with a single light bulb as a light source.)

3. Hold the CD so that the light reflects off the non-label side. Rotate the CD slightly. Describe what you see. (The room needs to be fairly dark with a single light bulb as a light source.)

4. If you are making your own spectroscope, do so now. The room lights may have to be turned back on.

5. Examine the light coming through each of three filters (red, green, and blue). Describe what you see. Draw the spectrum using colored pencils or crayons.

6. In a darkened room, your teacher will show you light from several different light sources. Each light source produces light by passing a very high voltage through a gas such as neon, hydrogen, mercury vapor, sodium vapor, etc. Record the name of the chemical element providing the light in each light source. Look at each light through your spectroscope. If you are having difficulty seeing lines of color, ask your teacher for help. On the **Spectra Data Sheet** draw the lines you see. Try to place the lines as accurately as you can in each color range. You may wish to try to match the color with colored pencils or crayons. If your spectroscope provides the wavelength of each colored line, write the number above the line on the **Spectra Data Sheet**. Your teacher will tell you how to find the wavelength value of each line.

Spectra Data Sheet

7. Draw the lines you see in your spectroscope. Try to match the position of each line in each color range. You may wish to try to match the color with colored pencils or crayons. If your spectro scope provides the wavelength of each colored line, write the number above the line on the **Spectra Data Sheet**.

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Red	Orange	Yellow	Green	Blue	Violet

Element 1: ________________Color of glowing gas to naked eye ___________________________

Making Conclusions—Spectra

What can you conclude about the visible spectrum of different sources of light? Defend your conclusion with data obtained in the investigation. (Remember, a conclusion is not a restatement of data; a conclusion is a new idea or concept that you learned from analyzing the data available. A conclusion is a short statement supported by your data that can be further tested by acquiring new data.)

Analysis of Stars (Grades 7–9)

You will be given two worksheets containing information about the spectra of specific elements and the spectra of five stars. Worksheet 1 contains the spectra for seven elements commonly found in stars. These spectra do not show colors, however, the numerical scale at the bottom of the spectra can be used to determine the wavelength of light. The scale measures the wavelength in angstroms (Å). An angstrom is 10^{-10}m or 0.1 nanometer (1 nm = 10^{-9}m). Light at the 4000Å end of the spectrum is violet, and light at the 6800Å end of the spectrum is red. Worksheet 2 shows the spectra from five different stars. Stars are made of a variety of elements. Use these worksheets to answer the following questions.

What elements are in each star?

	Hydrogen	Iron	Neon	Sodium	Lithium	Magnesium	Helium
Star 1							
Star 2							
Star 3							
Star 4							
Star 5							

1. What stars, if any, contain all seven elements? Compare with another student.

2. What elements, if any, are in every star?

3. Hypothesize an explanation for #2.

Analysis of Stars (Grades 10-12)

The following two pages contain information about the spectra of specific elements and the spectra of five stars. Worksheet 1 contains the spectra for seven elements commonly found in stars. These spectra do not show colors, however, the numerical scale at the bottom of the spectra can be used to determine the wavelength of light. The scale measures the wavelength in angstroms (Å). An angstrom is 10^{-10}m or 0.1 nanometer (1 nm = 10^{-9} m). Light at the 4000Å end of the spectrum is violet, and light at the 6800Å end of the spectrum is red. Worksheet 2 shows the spectra from five different stars. Stars are made of a variety of elements. Use these worksheets to answer the following questions.

What elements are in each star?

	Hydrogen	Iron	Neon	Sodium	Lithium	Magnesium	Helium
Star 1							
Star 2							
Star 3							
Star 4							
Star 5							

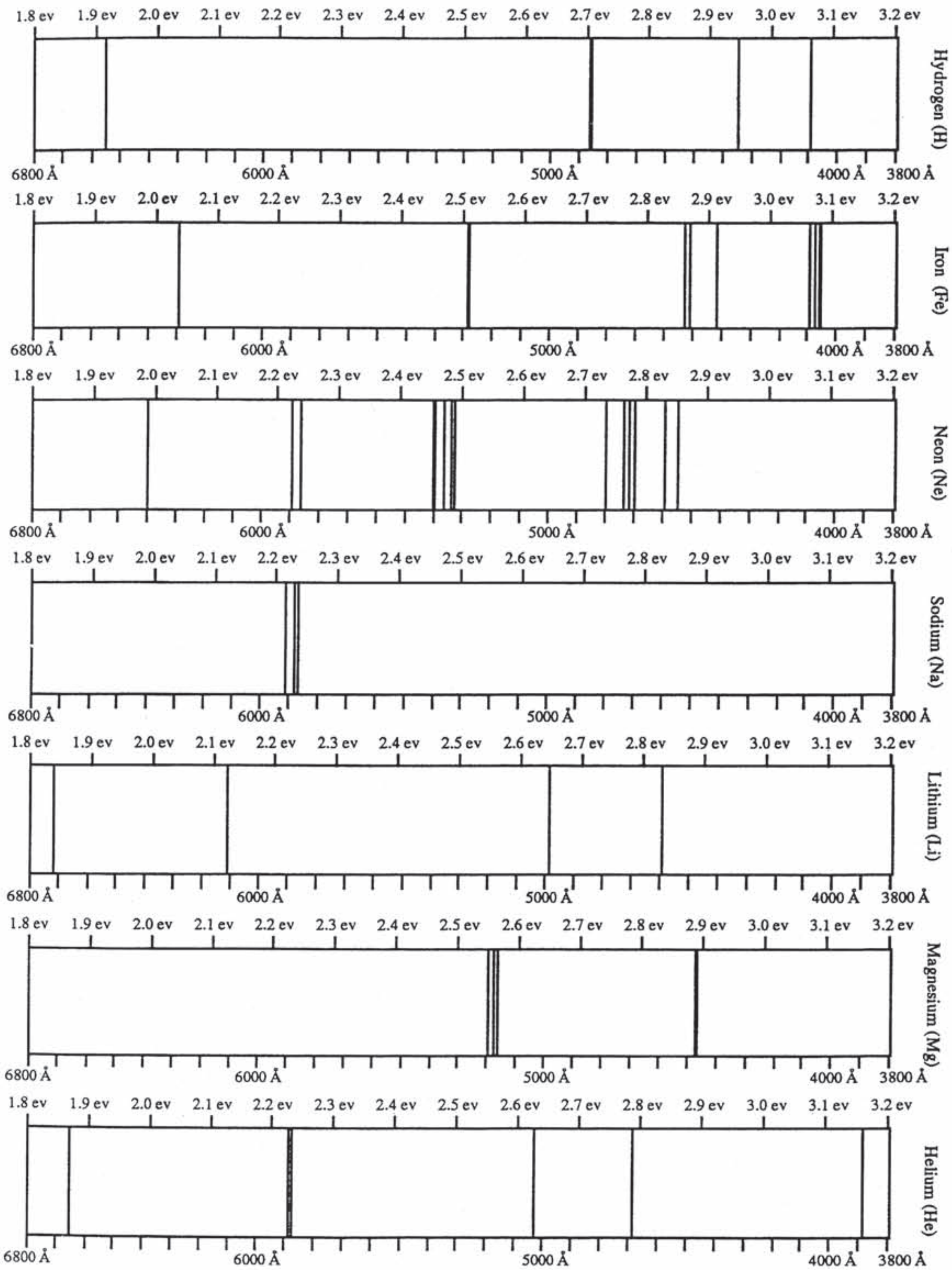
What conclusion(s) can you make from these data?

Worksheet 1

Name ______________________________

Date ______________________________

THE SPECTRA OF SEVEN ELEMENTS



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Worksheet 2

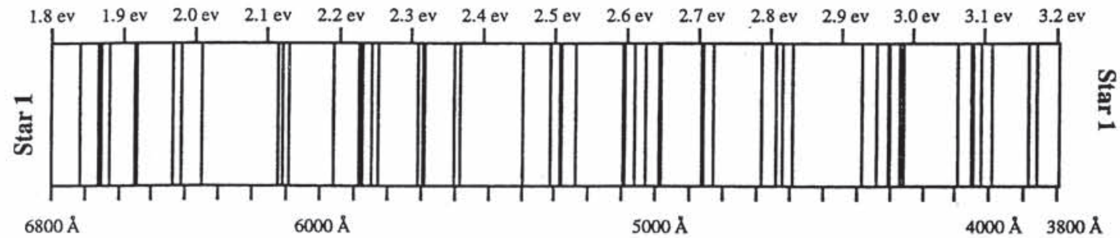
Name ____________________

Date ____________________

THE ABSORPTION SPECTRA OF FIVE STARS

Determine which of the elements on Worksheet 1 are present in these stars

Contains:



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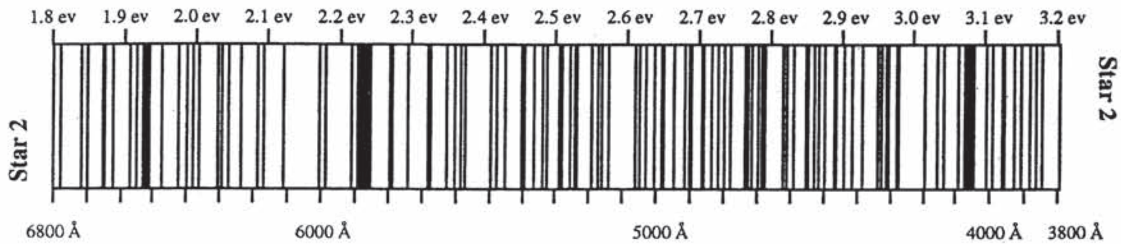

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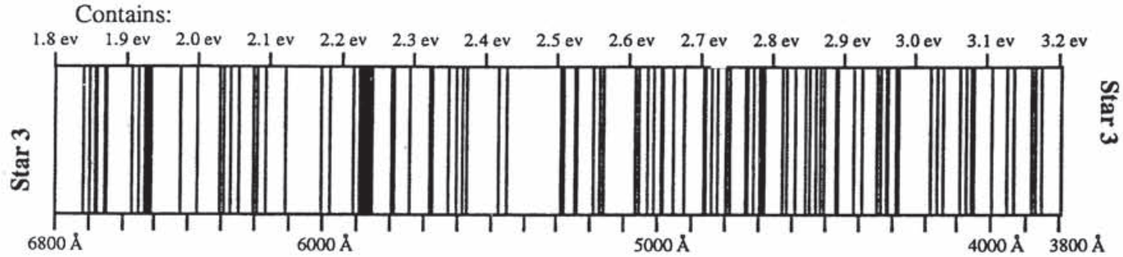

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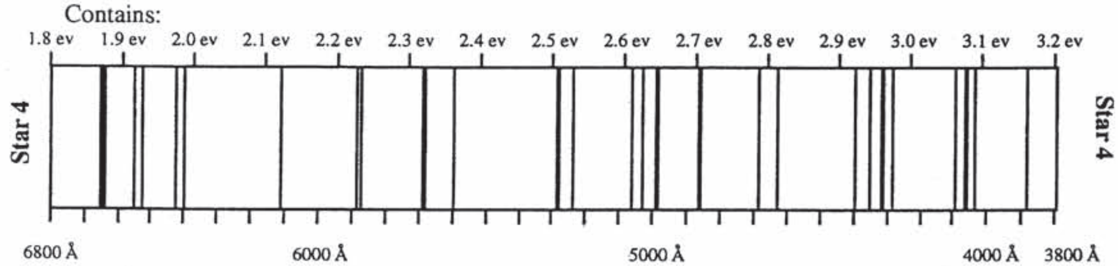

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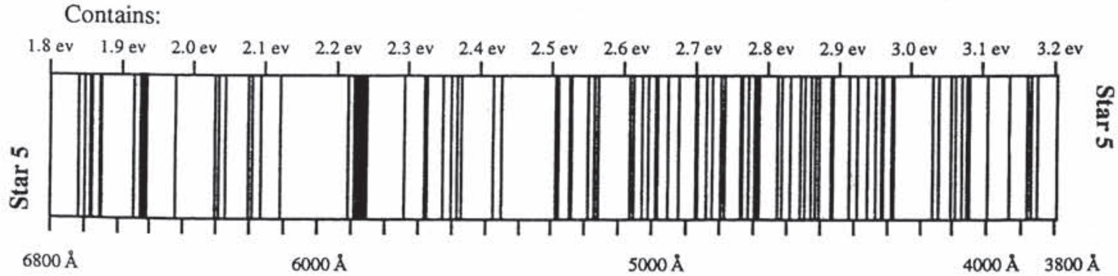

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National Aeronautics and Space Administration

Lesson 4

Getting Hotter

An Educator's Guide with Activities in Physical Science

Educational Product	
Educators & Students	Grades 6-12

EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Getting Hotter

Teacher Resource

http://son.nasa.gov/tass/iadl.htm

Purpose

Students will discover the existence of non-visible light, infrared, outside of the visible light spectrum. Students will learn how infrared light is used in science. Students will also develop experimental techniques useful for further exploration of the light spectrum.

Benchmarks for Scientific Literacy

- Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence. 1B/1 (6–8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable**. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9–12)
- **Increasingly sophisticated technology is used to learn about the universe**. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9–12)
- Accelerating electric charges produce electromagnetic waves around them. **A great variety of radiations are electro magnetic waves**: radio waves, microwaves, **radiant heat**, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electro magnetic waves move at the same speed—the “speed of light.” 4F/3 (9–12)

National Science Education Standards

Grades 5–8

Physical Science—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 light with a range of wavelengths, consisting of visible light, infrared**, and ultraviolet radiation.

**History and Nature of Science—
Nature of Science**

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

**History and Nature of Science—
History of Science**

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Grades 9–12

Science as Inquiry—Abilities Necessary to do Scientific Inquiry

- **Communicate And Defend A Scientific Argument—Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments**.

Physical Science—Interactions of Energy and Matter

- Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include** radio waves (the longest wave length), microwaves, **infrared radiation** (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Background

Infrared light is a range of wavelengths of the electromagnetic spectrum that is adjacent to red visible light. While the wavelengths of visible light range from about 390 nm (violet) to about 770 nm (red), the infrared range is from 770 nm to about 1,000,000 nm. Sir William Herschel discovered the existence of infrared light in 1800 when he was attempting to discover why different colored telescope filters passed more heat than others. Herschel separated visible light with a prism and placed the bulbs of thermometers in different parts of the visible spectrum. He found that the hottest temperatures are recorded for the thermometer just beyond the red band where there was no visible light. He concluded that there was light invisible to our eyes beyond red. (He further tested this invisible light and found that it was reflected, refracted, absorbed, and transmitted like all visible light.) It may be difficult, however, for your students to conclude that something is there that they can't see.

Infrared light is not visible to humans. You and your students cannot see or touch it. This presents difficulties for some students. Even visible light presents difficulties for many students. "Few students hold a conception of light as a physical effect existing apart from its source and effects." (Arons, p226) The only evidence for infrared light that students will record is the higher temperature measured by the thermometer that is placed just adjacent to the red part of the spectrum. According to their previous experience, this may not be sufficient evidence. They may dismiss the results as experimental error; therefore, it is important that students be aware that all of the groups recorded the same results.

Note: There is an excellent explanation of an experiment similar to the one described here on the Web page called “An Example of the Herschel Experiment” <**http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_example.htm**l>.

The Web page “Herschel and His Discovery of Infrared” gives an historical background to the problem **http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_bio.html** .

In addition, visit “Herschel Infrared Experiment” for a procedure with drawings of the equipment <**http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_experiment2.html**>. Do not, however, provide your students with a history lesson about Herschel before the investigation. You want your students to gather the data and attempt to interpret it. If you mention Herschel, they may research Herschel instead of thinking about the data.

Overview of Student Assignments for Getting Hotter

1. **How Are Parts of the Spectrum Different?** is a journal assignment to engage your students in thinking about characteristics of the spectrum. Their ideas will be used in Lesson 6 to develop an inquiry of their choosing. (Homework, or 15–20 minutes in class followed by a 20 minute in-class discussion)
2. **Laboratory Investigation** is a formal lab to determine whether different colors in the light spectrum heat objects differently. (One 45-minute period)
3. **Data Sheet** is used to record data.
4. **Conclusions** requires the student to write a thoughtful, short essay that answers the central question of the lab. (Homework)
5. **Prediction Reflection** will allow the students to reflect on the prediction they made at the beginning of the Laboratory Investigation. (Homework)
6. **Reading Assignment** “Seeing Our World in a Different Light” at <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/our_world_different_light/>
7. **Inquiry Reflection**—Getting Hotter
This reflection is designed to focus the attention of your students on the process and elements of inquiry.

Materials List (per group)

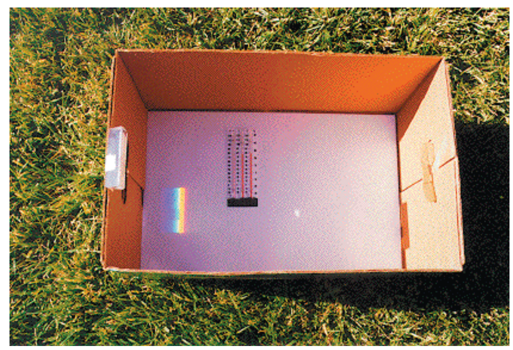
- Equilateral glass prism
- 3 alcohol thermometers
- Tape
- Cardboard box (a photocopier paper box works very well)
- Black spray paint (black marker will work)
- White paper for bottom of box
- Scissors
- Getting Hotter Procedure sheets for each student
- 3 Getting Hotter Data sheets per group
- Getting Hotter Conclusion sheets for each student
- Prediction Reflection for each student (Appendix)
- Prism holder (optional)

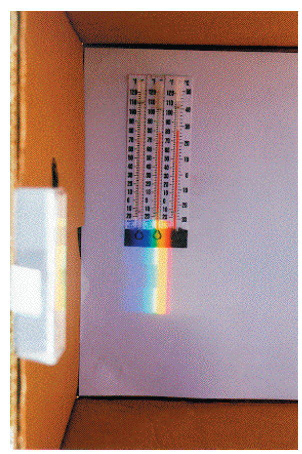
Preparation and Procedures

1. Assign the journal assignment **How Are Parts of the Spectrum Different**? It is recommended that you assign the journal as a homework assignment; however, you may use part of a class period to have your students reflect on and answer the questions. You know your students best, and you know best which format will achieve the desired goals for this assignment. Do not give your students any information about the exploration, **Getting Hotter**, yet.

2. When the students have completed the journal assignment, have them share their ideas about further investigations in a full class discussion. It is possible that a student will suggest investigating the temperature of different parts of the visible spectrum. However, if no one does, simply state at the end of the discussion that in 1800 a scientist wanted to know if different parts of the visible spectrum would heat objects differently. **Do not tell** students that the scientist was Sir William Herschel. You want them to evaluate evidence, not research Herschel and find out what he discovered. There is a reading activity about Herschel at the end of this unit. (20 minutes)
3. Remind your students that they will be designing their own investigations from these questions. It is important for them to know that their thinking is valued and will be incorporated into class work. Tell them that the exploration, **Getting Hotter**, will allow them to develop a better understanding of light and will also serve as a model for their own investigation later.
4. Blacken the bulbs of each thermometer with paint or marker before the exploration. Spray paint works best. The blackened bulbs will absorb heat and produce better results. After the paint has dried, tape three thermometers together so that the temperature scales line up. There should be about a half of a centimeter of space separating the bulbs.
5. If you do not have prism holders, cut a notch out of the top edge of the box on one of the narrow sides. The notch should hold the prism tightly and still allow it to rotate slightly. It is best to do this experiment outside on grass on a sunny day. Clouds or haze will interfere with your results.

The grass will protect the prism in case it is dropped; also, remind students that the Earth is turning so the spectrum will shift while they are recording temperatures. They must shift the thermometers to keep them in the same place in the spectrum.





6. Have the students post their results on the board or an overhead so that all class data are available to everyone. When all results have been posted, conduct a brief class

discussion of the data to focus on the fact that every group (should have) recorded the highest temperatures in the region beyond red. There is no reason to tell them the answer. There is still much for them to think about, but help them to realize that many groups recorded the result.

7. Assign the Conclusion. Give them time (1 or 2 days) to think and to write a carefully constructed essay.
8. **After the students have submitted their conclusions**, assign the reading "Herschel Discovers Infrared Light" found at <**http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_bio.html**>. This can be a computer assignment or you can print the article from the Web site.
9. Assign a **Prediction Reflection**. The students should reflect on the original prediction they made at the beginning of the experiment.
10. Assign reading, "Seeing Our World in a Different Light" at <**http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/our_world_different_light/**>. Optional: assign a 1–2 page paper in which students explain the benefits of the use of IR in one of 18 areas listed at the bottom of the first page of the above Web site. They will need to research the area in greater depth. If you can assign this as a computer assignment, students can insert images from the Web site. If you have sufficient time, students could prepare a PowerPoint or Web page presentation to be presented to the class.
11. Assign Inquiry Reflection

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and Space Administration

Getting Hotter

Student Assignments

www.nasa.gov

How Are Parts of the Spectrum Different?

Journal Assignment

Scientists use what they know about a subject—especially new ideas that they have learned from recent research—to generate new questions for further investigation. You have learned several new things about light, color, and the light spectrum.

In your journal, write two or three questions about the light spectrum that could be used to start new investigations. In addition, tell why you think these are important and interesting questions. You do not need to write a procedure, however, think about how reasonable it would be for you to do this investigation.

Your entry will be evaluated on the thoughtfulness of your questions and the completeness of your reasoning for doing the investigation.

Laboratory Investigation

Purpose

To determine whether different colors in the light spectrum heat objects differently.

Prediction

Predict whether a thermometer will record different temperatures in different parts of the light spectrum. If you believe the temperatures will be different, predict which color will be hottest and which will be coolest.

Materials

- 1 Equilateral glass prism
- 3 Alcohol thermometers taped together
- Tape
- Cardboard box (a photocopier paper box works very well)
- White paper for bottom of box
- Scissors
- 3 Data Sheets
- Prism holder (optional)

Procedure

1. Put all materials in the box and take them outside.
2. Use the prism holder or insert the prism into the notch in the side of the box so that one flat surface of the prism is toward the bottom of the notch.
3. Point this side of the box toward the Sun.
4. Place the white paper in the bottom of box.
5. Rotate the prism slightly until a clear spectrum is visible on the paper. You may have to prop up the Sun-side of the box to produce a wide, clear spectrum.
6. Place the three thermometers into the shade inside the box, wait approximately 30 seconds (until the temperature doesn't change), and then record the air temperature on your data sheet.
7. Very carefully place the thermometer bulbs in the spectrum so that bulb #1 is just outside the violet band (where there is no color). Bulb #2 will be in the blue and bulb #3 will probably be in the green. (Where the bulbs are depends on the width of the spectrum and the width of the thermometers.) Make certain that only the blackened bulbs and not the rest of the thermometers are in the spectrum.
8. On your data sheet, record the position (spectrum color) of each bulb and record the starting temperature.
9. Record the temperature at each bulb every 30 seconds until you obtain the same temperature for three readings (about 5 minutes). **Because the Earth is rotating, the position of the spectrum will change. Watch the bulbs carefully and move them as necessary so that they don't move from the starting position in the spectrum**.
10. Move the thermometers so that each bulb is in a new color band. Now bulb #1 will be in the violet.
11. On your data sheet, record the position (spectrum color) of each bulb and record the starting temperature.
12. Record the temperature at each bulb every 30 seconds until you obtain the same temperature for three readings (about 5 minutes). **Because the Earth is rotating, the position of the spectrum will change. Watch the bulbs carefully and move them as necessary so that they don't move from the starting position in the spectrum**.
13. Move the thermometers again so that bulb #1 is in the blue light. Repeat steps 10 and 11.
14. Continue to move the thermometers and record temperatures until bulb #3 is **just** beyond the red band. This position will be your last set of readings.
15. Place the thermometers in the shade, allowing them to reach air temperature, and repeat steps 1–13. Try to place the thermometers in the same places as before.

Data Sheet

Name ______________________________

Time	Thermometer #1 Spectrum Color ____________	Thermometer #2 Spectrum Color ____________	Thermometer #3 Spectrum Color ____________
In Shade			
0 seconds			
30 seconds			
60 seconds			
90 seconds			
120 seconds			
150 seconds			
180 seconds			
210 seconds			
240 seconds			
270 seconds			
300 seconds			
330 seconds			
360 seconds			

Graph the data from each set on the same graph. Use different colors for each data set. Match the color of the points and lines to the color of light falling on the bulb. Use a dotted black line for the temperature of the bulb in the region beyond the violet. Use a solid black line for the temperature of the bulb in the region beyond the red.

Conclusions

Write a thoughtful, short essay answering the following questions. Defend your assertions with evidence from your investigation.

Did different regions of the light spectrum heat the thermometer differently? If there was a difference, which region heated the thermometer the most? What can you conclude from your data?

Inquiry Reflection—Getting Hotter

Think
In each of the last three lessons you have performed an investigation to explore light. Think about those investigations and what was necessary for you to make a good conclusion. How were those investigations organized? What kinds of tests did you need to perform to figure out what conditions were needed to see the color red?

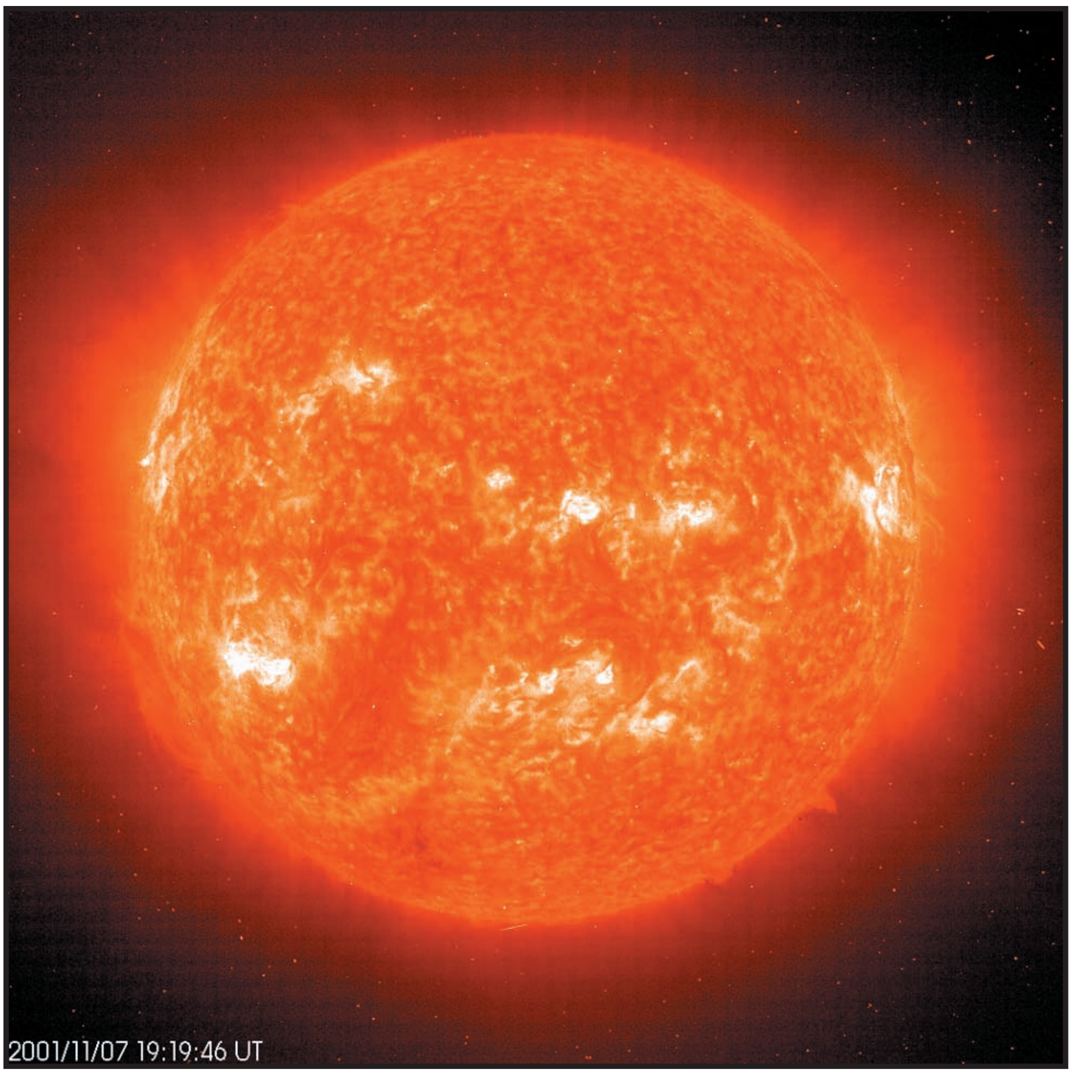
Write
In a careful reflection, describe what you need to do to investigate a question and be able to defend the answer to that question. You will be evaluated on the completeness of your written work.

National Aeronautics and Space Administration

Lesson 5

Mystery Light

An Educator's Guide with Activities in Physical Science



Educational Product	
Educators & Students	Grades 6-12

www.nasa.gov

EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Mystery Light

Teacher Resource

http://son.nasa.gov/tass/iadl.htm

Purpose

Students will develop research techniques useful for further exploration, using models developed in previous lessons. Students will design their own experiment to explore the conditions under which special beads change color. Because these beads actually change in the presence of UV light, this lesson will allow them to discover the existence of another non-visible light, ultraviolet, outside of the visible light spectrum. Students will also learn how ultraviolet light is used in science.

Benchmarks for Scientific Literacy

- Scientists differ greatly in what phenomena they study and how they go about their work. **Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence**. 1B/1 (6–8)
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but **collaboration among investigators can often lead to research designs that are able to deal with such situations**. 1B/2 (6–8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable**. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9–12)
- **Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves**; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9–12)
- Accelerating electric charges produce electromagnetic waves around them. **A great variety of radiations are electromagnetic waves**: radio waves, micro waves, radiant heat, **visible light**, **ultraviolet radiation**, x-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electro magnetic waves move at the same speed—the "speed of light." 4F/3 (9–12)

National Science Education Standards

Grades 5–8
Science As Inquiry—Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investiga tions. Some investigations involve observing and describing objects, organisms, or events; some involve**

collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.

- **Scientific explanations emphasize evidence, have logically consistent** arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Physical Science—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 light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation**.

History and Nature of Science—Science as a Human Endeavor

- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

History and Nature of Science—
Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

History and Nature of Science—
History of Science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Grades 9–12
Science as Inquiry—Abilities Necessary to do Scientific Inquiry

- COMMUNICATE AND DEFEND A SCIENTIFIC ARGUMENT. Students in school science programs should develop the abilities associated with accurate and effective communication. **These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments**.

Physical Science—Interactions of Energy and Matter

- Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include** radio waves (the longest wavelength), microwaves, **infrared radiation (radiant heat), visible light, ultraviolet radiation**, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Background

When Johann Wilhelm Ritter heard of Herschel's work, Ritter reasoned that there might be invisible radiation on the other end of the spectrum—beyond violet. Ritter was an accomplished chemist, and he used his knowledge of chemistry to test his theory. He knew that blue light decomposed silver chloride to silver more efficiently than red light. He reasoned that non-visible light beyond blue might be even more efficient. He was right! When he exposed paper covered with silver chloride to the complete spectrum of sunlight that had passed through a prism, the silver chloride in the region beyond violet (where there was no visible light!) decomposed the fastest. From this experiment, Ritter knew that there must be light beyond violet. This radiation came to be known as ultraviolet light.

If you need more background information on the electromagnetic spectrum, you might want to start with two readings that will be assigned to your students at the end of this lesson; "Electromagnetic Spectrum" <**http://son.nasa.gov/tass/content/electrospectrum.htm**> and "How Astronomers Use the Electromagnetic Spectrum" <**http://son.nasa.gov/tass/content/emspec.htm**>. These readings will lead you to other sources if you desire more depth.

This investigation will be very challenging for your students. The primary goal, however, is to engage them in the process of inquiry. The content goal—to discover ultraviolet light—is secondary. Your students have seen several different models for inquiry in the past lessons. There are structures provided within this lesson to help them to design a more effective procedure—and you will be available for coaching. The following information is provided to help you provide the coaching.

This investigation will use special beads that change color when exposed to ultraviolet light. ***Do not tell this to your students***. The color change is fast and dramatic in strong UV light. In direct sunlight, the beads will change from white or silver to a deep color (there are six colors available from the supplies (see Appendix): red, blue, purple, orange, yellow, and copper). Normal indoor light sources, such as incandescent and fluorescent, do not produce sufficient UV radiation to change the beads. Depending on the filtering quality of your classroom windows, UV from sunlight may or may not penetrate. Because UV is scattered by the atmosphere in a manner similar to blue light (that is why the sky is blue), UV will come from all parts of the sky. This means that beads will change colors in shade and even on very cloudy days. The time it takes to reach a particular deepness of color will be longer, however.

An "ideal" apparatus and procedure for this investigation have been provided for you in **A Modified Ritter Experiment**: **Discovering Ultraviolet Light** contained in the Appendix. You will see in the description of the apparatus for **A Modified Ritter Experiment**: **Discovering Ultraviolet Light**, that the top is left on the box and a small flap is cut in the top to allow viewing while still screening reflected UV light. When students separate the direct sunlight into the spectrum, and place beads in various regions of the spectrum, all beads will change color **if they do not screen out reflected light**. You may wish to ask questions that will lead them to discover that the beads change color even when the beads are not in direct sunlight.

The procedure for **A Modified Ritter Experiment: Discovering Ultraviolet Light** works quite well. The beads are separated by knots and the shoelace used is thick to create a knot large enough to shield each bead from reflected UV. Without this shielding, the bead in the violet/blue may change color because of UV light reflected from the bead in the UV region.

Even though you still have a content goal—to discover UV light—the experimental process is more important. The purpose and questions on the student sheet, **Mystery Light**, will help to guide their investigation. The Peer Review process will further aid the refinement of their experimental design. In addition, you will need to provide guidance and coaching, however, do not defeat the discovery process by forcing the students to perform the “ideal” experiment. Hopefully, at least one group will discover UV light. This will come out in the final presentations. In the worst case, no one discovers UV, and you can then ask questions of their procedures (for example, “Did you examine both sides of the spectrum as we did in the previous experiment?” and “Did you protect your beads from reflected light? What would happen if you covered the box and only let light in through the prism?”). You could then have the class brainstorm further adjustments and repeat the experiment with these adjustments. Alternatively, you could have the materials from **A Modified Ritter Experiment: Discovering Ultraviolet Light** on hand and do the experiment with them immediately.

Overview of Student Assignments for Mystery Light (four to seven 45-minute class periods)

1. **Students Investigation Procedure and Guide Questions** is a laboratory investiga tion that provides the problem to be solved by the investigation and leaves the design of the investigation to the student.
2. **Peer Review in the Science Classroom** (Appendix) provides a process that aids the students in the development of more effective designs for inquiry.
3. **Lab Report Format, Journal Article Format, and PowerPoint/Web page/ Poster Presentation** (Appendix) are three different formats from which you can choose for student presentation of results of their investigation.
4. **Prediction Reflection** (Appendix) asks your students to reflect on their process, their thinking, what went right, and what they would improve.
5. **Reading Assignment** “Electromagnetic Spectrum” <**http://son.nasa.gov/tass/content/electrospectrum.htm**> and “How Astronomers Use the Electromagnetic Spectrum” <**http://son.nasa.gov/tass/content/emspec.htm**>. Then do the activities “Understanding Solar Spectra” on the Solar Extreme-ultraviolet Rocket Telescope (SERTS) Web site <**http://serts.gsfc.nasa.gov/classroom/understanding.shtml#sun**>.

Exploration with Prism and Light

Materials

- 15 special (UV) beads per group
- 5 dark film canisters per group
- Equilateral **glass** prism per group
- Tape per group

- Cardboard box per group (have available the photocopier paper boxes used in **Getting Hotter?**)
- **Peer Review Guidelines** (Appendix) for each student
- **Mystery Light** Student Investigation for each student
- Equipment to be determined by group
- Report guidelines for each student (**Lab Report Format**, **Journal Article Format**, and **PowerPoint /Web page/Poster Presentation** from Appendix or design your own)
- **Prediction Reflections** for each student
- Reading assignments for each student or assign as a computer assignment
- Prism holder (optional) per group

Preparation and Procedures

1. Assign the problem as defined in **Mystery Light: Student Investigation Procedure and Guide Questions** and discuss the process. Ask your students to describe the techniques of investigation used in previous lessons. Have them describe the structure of the investigations and the strengths and weaknesses of the procedures. Ask them questions about the control of variables in earlier lessons. Also hand out Peer Review instructions and describe the process and the advantages of peer review in design. Assign groups, hand out materials, and tell them when their preliminary procedures are due for presentation for Peer Review. As the students take on more responsibility for the design and execution of the investigation, your role changes as well. In this investigation, you provide the questions to be answered and a new technique, **Peer Review**, to aid them in the design of the investigation. Be prepared to provide gentle guidance in the form of questions. For example, "How would you find out what kinds of light cause the reaction?"
2. The final student activity in this investiga tion is the student presentation. You may choose from a variety of formats. Evaluative criteria for three report formats are provided in the Appendix. **The Lab Report Format** is a traditional lab report with Purpose, Procedure, Errors, Data and Conclusion sections. The **Journal Article** is modeled after the format used by scientists for scientific journals. You may find a **PowerPoint/Web page/Poster Presentation**, also used by scientists at conferences, to be more valuable to you and your students.
3. No matter what format you choose for stu dent presentations, you should conduct a class discussion of results and conclusions.
4. Assign a journal assignment using a modification of a **Prediction Reflection** to have your students reflect upon their process, their thinking, what went right, and what they would improve.
5. Follow the **Prediction Reflection** with a discussion of the nature of scientific research. Ask the students about their process of investigating the questions asked in the Purpose. Ask them how they might improve the process.
6. After students have completed the above assignments, extend their knowledge of light with the following applications to NASA science. Assign "Electromagnetic Spectrum" <**http://son.nasa.gov/tass/content/electrospectrum.htm**> and "How Astronomers Use the Electromagnetic Spectrum" <**http://son.nasa.gov/tass/content/emspec.htm**>. Then do the activities "Understanding Solar Spectra" on the Solar Extreme-ultraviolet Rocket Telescope (SERTS) Web site <**http://serts.gsfc.nasa.gov/classroom/understanding.shtml#sun**> .

7. An excellent extension to Lessons 1 through 5 is involvement in the research presented in the Student Observation Net work module “Tracking a Solar Storm” (**http://son.nasa.gov/tass**). Students can observe the Sun in many wavelengths of light and predict which sunspot regions might produce a solar flare or Coronal Mass Ejection (CME). Students can then monitor the Sun for evidence of a solar flare or CME using radio wave and X-ray emissions from the flare. Further investigations can reveal changes to the Earth’s magnetic field due to these solar storms with the possibility of intense auroral displays. All of these investigations involve the use and interpretation of data from student built equipment, from ground based professional observatories and from NASA satellites. In most cases, the data requires interpretation of data “In a Different Light”—ultraviolet, radio, and x-ray.

Evaluation of Investigation

Students should be able to achieve a very good evaluation even if they do not discover that the light that affects the beads comes from beyond the violet. Students might lose a couple of points if they didn’t determine if reflected light would affect the beads. It is a more serious omission if they did not follow the model from the previous lab to check on both sides of the visible spectrum. The primary goals are to design a thoughtful experiment appropriate to the question, to execute the experiment carefully, and to interpret the evidence effectively.

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and Space Administration

Mystery Light

Student Assignments

Mystery Light

Purpose

The beads you are given have a special reaction to light. Determine the special reaction of the beads to light. Determine what region(s) of the light spectrum causes the reaction.

Materials (per group)

- 10–15 special beads
- Other materials that you will determine

Procedure

1. Read the Purpose carefully. What are you asked to discover? Think carefully about what you need to find out and how you are going to achieve your goals. Design an experiment that will achieve your purpose. Your experimental design should be clearly written with detailed procedures. The following questions are offered as guide questions to help you in your design.
   - What is the special reaction of the beads?
   - What kinds of light (for example: fluorescent, incandescent, direct sunlight, indirect sunlight, weak light, strong light…) caused the reaction?
   - What do you know about the light spectrum emitted by the light sources you have studied? How do you know?
   - Are there any experimental procedures from previous investigations that might be modified for this investigation?
   - What part, or parts, of the spectrum cause the reaction of the beads? What is your evidence for this conclusion?

2. Present your design for Peer Review.

3. Revise your design based on questions raised during Peer Review.

4. Conduct your investigation.

5. Present your findings.

The table below provides tasks and deadlines for these tasks. During this investigation, use what you have learned about light, and what you have learned about conducting and constructing experiments.

Date Due	Complete	Task	Notes
		Preliminary experimental design procedure completed	
		Peer Review—design procedure must be complete, written, and copied for review team	
		Revised procedure completed	
		Materials list completed and presented to teacher	
		Data collection completed	
		Rough draft of presentation	
		Presentation of results	

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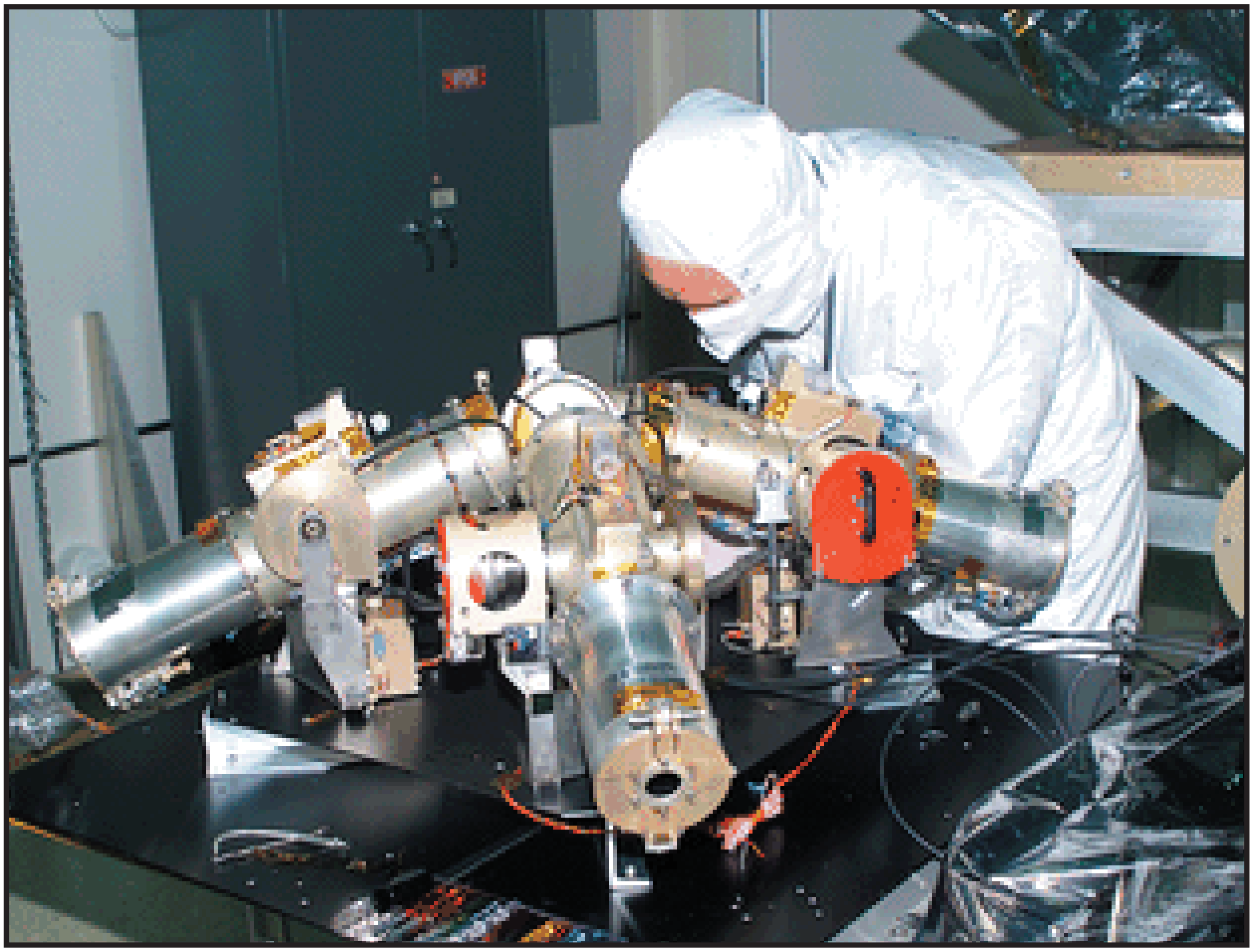
Lesson 6

Independent Investigation

Teacher Resource



Educational Product	
Educators & Students	Grades 6-12

www.nasa.gov

EG-2005-2-026-GSFC

National Aeronautics and Space Administration

Independent Investigation

An Educator's Guide with Activities in Physical Science

http://son.nasa.gov/tass/iadl.htm

www.nasa.gov

Purpose

Students will choose an inquiry into the nature of light, design a procedure to investigate their question, revise the procedure based upon peer review, collect data, and report their results and conclusions.

Benchmarks for Scientific Literacy

- **Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.** 1B/1 (6–8)
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations. 1B/2 (6–8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable**. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9–12)
- Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. 1B/1 (9–12)

National Science Education Standards

Grades 5–8
Science As Inquiry—Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investiga tions. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models**.
- **Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories**. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Grades 9–12
Science As Inquiry—Abilities Necessary to do Scientific Inquiry

- **Communicate And Defend A Scientific Argument—Students in school science programs should develop the abilities associated with accurate and effective communica tion. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.**

Background

Based on research over the past decades, **Benchmarks for Scientific Literacy**, and **National Science Education Standards** support student inquiry. All of the lessons in this unit have been building toward this independent investigation. Students have been engaged in partial inquiry since the first activity of the first lesson. Early lessons were more guided, helping students to learn steps of the inquiry process. The last lesson, **Mystery Light**, required them to design their own experiment to answer a given question. Peer Review techniques were introduced as a tool to aid in inquiry. Journal assignments, Predictions, Inquiry Reflections, and Prediction Reflections helped them to become more aware of their own problem-solving process. Short-answer conclusions developed into essay conclusions that required more student organization. In Lesson 6, students will define the problem, design and conduct the experiment, and present their results. Because of the structure of this unit, teachers may choose to use this final investigation as an assessment tool. If you choose to do this, design a rubric that reflects assessment of process, organization, communication, use of previous knowledge about light and light spectra, and analysis of data.

For many students this will be difficult. They may not have internalized the skills necessary for productive experimentation. They will need your coaching and guidance. Complete the Student Assignment with dates to provide a road map with checkpoints. Add additional checkpoints if you wish. For example, some teachers require students to submit rough drafts of critical steps. If a group loses focus or direction, remind them of some of the models for good design they have used in the past. Ask them questions. How much guidance you choose to give will depend on how you are using this independent investigation.

Many teachers find inquiry difficult because they believe they must know all of the content that students study, however, we cannot know everything. In research, the students become the experts in their own field. Your role is not to give answers! You are not there to provide answers or solutions! Your role is to guide and coach them in the process. You do, however, need to be alert for possible safety issues.

Overview of Student Assignments for Independent Investigation (four to seven 45-minute class periods)

1. **Independent Investigation** provides the schedule and basic guidelines for a laboratory investigation in which the students provide the problem to be solved by the investigation and the design of the investigation.
2. **Peer Review in the Science Classroom** (Appendix) provides a process that aids

the students in the development of more effective designs for inquiry.

3. **Lab Report Format, Journal Article Format, and PowerPoint/Web page/ Poster Presentation** (Appendix) are three different formats from which you can choose for student presentation of results of their investigation.
4. **Prediction Reflection** (Appendix) asks your students to reflect on their process, their thinking, what went right, and what they would improve.

Materials List

- **Independent Investigation** instructions and timeline
- Evaluation criteria in the format you choose
- **Prediction Reflection**
- Assorted materials to be determined by students

Preparation and Procedures

1. Establish dates for completion of activities and add to the student assignment **Independent Investigation** in the Due Date column. Hand out **Independent Investigation**. Have a conversation with the students. Make certain that your expectations are clear. Explain your role in the investigation. Answer questions about each of the tasks. Announce which presentation format you will require them to use when they report their findings. This will allow them to work on the lab report, journal article, or PowerPoint/poster presentation as they do the research. Establish research groups. Three students per group is an ideal number. Students need to agree on and tightly define the question they will research. They may use questions generated from the opening journal assignment to Lesson 4, or they may develop another question.
2. Examine problem proposals carefully. If you believe that the procedure will be impossible for them to accomplish or may not be safe, explain your concerns and ask them to redefine the problem.
3. Schedule enough time for Peer Review because each team will need to explain their problem before they explain their procedure.
4. Impress upon students that, if they need equipment from you, they must provide you with a materials list as soon as possible. Encourage them to be creative. Scientists can't go to a science supply catalog and order "an instrument to reveal the secrets of the universe"; they must design tools from materials at hand.
5. Schedule time to meet with each group frequently to coach them and problem solve with them. They will need some fresh ideas. You do not need to be an expert in each topic! You should not be solving problems for them.

All lessons have been field tested over several years in a high school classroom. The science content was reviewed by Dr. Art Poland. In addition, selected lessons were presented and analyzed in a Project 2061 training workshop in July 2002; however, we hope that your comments and suggestions will help us to improve the instructional value of this unit. Please contact Don Robinson-Boonstra at **Donald.W.Robinson-Boonst.1@gsfc.nasa.gov** with comments and questions.

National Aeronautics and Space Administration

Independent Investigation

Student Assignments

www.nasa.gov

Independent Investigation

Choose a question about light or the light spectrum and design and conduct an experiment to answer the question. You may choose a question from Journal Assignment #4: How are Parts of the Spectrum Different?, or you may develop a different question inspired by your investigations during **Getting Hotter** and **Mystery Light**. Choose a question that is interesting to you.

Date Due	Complete	Task	Notes
		Preliminary experimental design procedure completed	
		Peer Review—design procedure must be complete, written, and copied for review team	
		Revised procedure completed	
		Materials list completed and presented to teacher	
		Data collection completed	
		Rough draft of presentation	
		Presentation of results	

National Aeronautics and Space Administration

In a Different Light: Appendix

An Educator's Guide with Activities in Physical Science

Educational Product	
Educators & Students	Grades 6-9

www.nasa.gov

EG-2005-2-026-GSFC

Exploring Spectra
Constructing a Spectroscope

The shoebox spectroscope takes the light from a slit at one end and passes it through a grating. The grating diffracts or separates the different colors of visible light into the full visible spectrum. It can also be used to examine the spectra of colored light sources.

To make this simple instrument you will need:

1. A shoebox or something similar to a shoe box (a cardboard tube will work if you cover the ends with heavy cardboard)
2. An index card cut into 2 parts
3. A diffraction grating slide (see Supplies and Vendors in Appendix for source)
4. Scissors or a knife for cutting holes in the shoebox
5. Ruler with metric scale
6. Glass lens (optional) for clearer appearance of diffracted light
7. Tape or glue
8. A fairly dark environment

Construction of Spectroscope

1. Cut one hole, the size of the clear portion of the diffraction grating (2.5cm X 2.5cm), on one end of your shoebox.
2. Hold the diffraction grating near your eye and look toward a light. You should see a spectrum to the side of the light. If the spectrum is above and below the light, rotate the grating 90º and tape the diffraction grating over the hole as shown.
3. Cut another hole on the opposite side of the shoebox that is 0.5–1.0cm wide and 4cm high.
5. Tape the two pieces of index card over the new hole so that the index cards almost touch. Leave a tiny gap between the index cards of about 1mm.
5. Put the lid on the shoebox.

To check your spectroscope, aim the slit at a fluorescent ceiling light and look through the grating end. (Never look directly at the Sun.) You should see a spectrum with four prominent lines (violet, blue-green, green, and red) off to one side.

A Modified Ritter Experiment:
Discovering Ultraviolet Light

Purpose: Determine what region of the light spectrum causes the special beads to change color.

Materials:

1. 1 Equilateral **glass** prism
2. Prism holder (optional)
3. 6–10 special beads (UV beads-see Supplies and Vendors for source)
4. Thick shoelace (black, if possible) approximately 12 inches long
5. Tape—may be needed to hold prism in notch
6. Cardboard box with lid (a photocopier paper box works very well)
7. White paper for the bottom of the box
8. Scissors or sharp knife
9. Flashlight

Procedure:

a. Cut a notch out of the top edge of the box on one of the narrow ends. The notch should hold the prism snugly but still allow it to rotate slightly.
b. In the lid of the box cut a flap that is about 1 inch wider than the prism notch. The flap should extend about 6 inches toward the middle of the box. Score the flap slightly along its line of attachment to the rest of the lid and score it again slightly about 3 inches from the line of attachment. This will allow the flap to bend easily. The flap will allow you to look into the box without letting in reflected light from the sky.
c. Prepare special beads in a location out of direct sunlight. Cut shoelace in half. Tie a knot in the cut end. Thread one bead onto the lace and slide it to the knot. Tie another knot so that the bead is held firmly between the knots. Continue to add beads and knots until the shoelace is full. Tie a final knot to keep all of the beads on the shoelace. Put the beads and the shoelace in a black film canister.
d. Take the box, prism, and film canister with the beads outside on a sunny day.
e. Install the prism in the notch and point the prism end of the box toward the Sun. Rotate the prism slightly until a clear spectrum is visible on the bottom of the box. You may have to prop up the end of the box slightly to get the spectrum in the box. Carefully, put on the lid.
f. Put the canister in through the flap, remove the beads and shoelace, and lay the beads in the spectrum so that each bead is in a different color and one end bead is in the dark region just outside of the violet and another bead is in the dark region next to the red. Be very careful not to allow any reflected light from the sky hit the beads.
g. Replace the flap so that only direct sunlight passing through the prism can get into the box. Leave for 3–5 minutes.
h. Carefully, lift the flap and look at the beads. (You may need to use a flashlight to see inside the dark box.) Record which bead or beads have changed color.

Prediction Reflection

Within the activity you have completed were instructions to predict the outcome of an experiment. There is no correct or incorrect answer to these predictions. It can be very helpful to your understanding of the concepts, however, if you understand why your prediction matched or did not match the experimental outcome. In this journal entry, you will choose two predictions to reflect on. You should write about one prediction that did not match the outcome and one prediction that did match the outcome. (If, however, every prediction matched every outcome, or every prediction failed to predict every outcome, choose two that are interesting to you.)

Guidelines:

1. Explain what made you believe that your prediction was true. Have you had similar experiences, did you read about this experiment somewhere, has someone explained this concept to you, did you connect this activity with one you have experienced, did it just seem natural (why?), did you just wildly guess?
2. What did each of these predictions tell you about how you think about this concept? Describe what you learned (if you learned nothing, it is alright to say that...try to explain why).
3. This is not a “journal” in the sense that you would record the events of the day. These reflections are a chance to privately explore some of the questions we consider and your reactions to the ideas and experiences you encounter. It is a chance to think about how you think and learn. Don’t worry about “being right” or saying something “stupid.” Explore the problems and ideas that are of interest to you; examine your reactions, habits, opinions, and assumptions.

This reflection will be evaluated on the depth of your thinking. You should write 1–2 pages (assuming about 300 words per page). It is perfectly permissible to ask questions and to suggest further investigations that you think might help you to understand the ideas better.

Lab Report Format

Evaluative Criteria

Purpose: One or more concise sentences stating the question or questions that are to be answered by this investigation. The purpose should help you to focus your attention on important relationships. This will take the form of a thesis statement and the supporting assertions.

Grading:

8–10 points	4–7 points	0–3 points
thesis statement and all supporting assertions clearly stated with no extraneous detail	thesis statement with one or more supporting assertions missing, understandable but not clear, inclusion of some extraneous detail	missing purpose, missing or incorrect thesis statement, no supporting assertions (if there are some), not understandable, inclusion of too much extraneous detail

Procedure: The procedure is a step-by-step description of activities necessary to gather information to achieve the purpose of the experiment. If you have been given a written procedure, do not write a procedure in your report unless you have deviated from the instructions significantly. If you have deviated from the instructions, indicate what you did differently. Sometimes you may be asked to write a summary of the most important steps.

Grading:

8–10 points	4–7 points	0–3 points
concise, relevant detail, accurate sequential order, appropriate to achieve desired results, easily read	insufficient detail or too much detail, won't achieve purpose, unclear directions	(If a procedure is unnecessary, no points will be given for a procedure.) missing procedure, not understandable, lacks detail, won't achieve purpose

Errors: You must measure carefully, follow directions precisely, and set up your equipment with care. Still, no matter how carefully we measure, there are limits to the accuracy of our devices. Errors no not include doing a trial incorrectly! If you know you have erred in the execution of the experiment, do it over again. Errors are unavoidable inaccuracies in measurements, or unavoidable conditions that affect results. You must state the source and estimate the size of the most significant errors affecting your lab.

Grading:

11–15 points	5–10 points	0–4 points
includes all significant errors, correctly estimates the size of errors, does not include frivolous errors, is well written	includes most significant errors, size estimates are within a reasonable range, may contain some frivolous errors	does not include significant errors, does not include numerical estimate, contains many frivolous errors, lacks clarity

Data: All observations (qualitative and quantitative) and the data that you measure or collect directly in the lab must be recorded immediately. This is called "raw data." Often a table can present the data most effectively. In many cases, the raw data must be "processed" before valid conclusions can be reached. This processing of data may be mathematical or graphical.

Grading:

26–35 points	11–25 points	0–10 points
complete, clearly presented, correctly manipulated, well organized, properly labeled, thoughtful and effective mathematical and/or graphical treatment	missing some data, weak mathematical or graphical treatment of raw data, not well labeled, missing units	missing data section, disorganized, no labels or units, lacks mathematical or graphical treatment of raw data

Conclusions: In science, the conclusion is an interpretation of the data. It is new information that you believe to be true, which you did not know before you did the lab, and which is supported by the data. The conclusion should be the answer to the purpose. The conclusion should be in the form of an essay with a thesis statement and supporting assertions. Each must be stated separately and clearly and must be supported by data. **Do not** merely state the conclusion and then **tell** the reader that the data proves the conclusion true. **Prove** to your reader that the data proves the conclusion true. Cite the evidence directly in the conclusion even if it means repeating or copying certain **selected** parts of the data.

Grading:

26–40 points	13–25 points	0–12 points
correct thesis and supporting assertions, realistic interpretation, relevant and meaningful, complete, concise, terms well defined, considerable support of assertions, ideas vigorously expanded, appropriate use of data, good internal structure with units of thought carefully interrelated for the reader.	weak thesis, weak supporting assertions, vague definitions of key terms, some points of support not well related to thesis or each other, slight breakdown in internal structure, oversimplification of ideas	lack of clearly-defined thesis and support not carefully related, structural breakdown, imprecise word choice

Journal Article
Evaluative Criteria

Title: (2 points)
Use a descriptive title that is clear. Provide your name and a date.

Abstract: (8 points)
The abstract is a "mini-article." It must include the major points of the Introduction, Materials and Methods, Results and Conclusion sections. A fellow scientist should be able to read only this and know the important facts.

Grading:

6–8 points	3–5 points	0–1 points
concise, contains relevant information from each section, well-written and clear	insufficient detail or too much detail, missing one section, lacking some clarity	not provided or providing very little information or lacking clarity

Introduction: (20 points)
You must introduce your reader to the subject under investigation. Give background to the problem, include "library" research you have done, the theoretical framework underlying the problem, and any other information necessary for the reader to understand the question you are investigating. Then state the exact question you are attempting to answer.

Grading:

15–20 points	6–14 points	0–5 points
Well written, background information is complete, develops understanding of information, clearly states the question	Writing is unclear, or background information incomplete or not accurate, fails to clearly state question	Intro not present, question not appropriate to investigation, not enough explanation central of background

Materials and Methods: (20 points)
Provide a written description of what you did, how you did it, and what tools you used. The reader should be able to replicate your experiment precisely from this description. Do not, however, make this a "diary"; it is a set of instructions. Sample calculations should be provided in this section. A sample calculation is one without numbers that shows the math used to calculate results.

Grading:

15–20 points	6–14 points	0–5 points
concise, relevant detail, accurate sequential order, appropriate to achieve desired results, easily read	insufficient detail or too much detail, won't achieve purpose, unclear directions	missing procedure, not understandable, lacks detail, won't achieve purpose

Results: (20 points)

Provide charts of raw data, charts of calculated data, graphs when appropriate and drawings which are important, explanations of charts and graphs, and explanations of important results. Errors are presented and explained in a systematic order. The Results section is not a copy of your raw data; it is a neat reorganization of the data to make it clear and understandable. Results should be presented to make patterns and trends obvious.

Grading:

15–20 points	6–14 points	0–5 points
complete, clearly presented, correctly manipulated, well organized, properly labeled, thoughtful and effective mathematical and/or graphical treatment, includes all significant errors, correctly estimates the size of errors	missing some data, weak mathematical or graphical treatment of raw data, not well labeled, missing units, includes most significant errors, size estimates are within a reasonable range	missing data section, disorganized, no labels or units, lacks mathematical or graphical treatment of raw data, does not include significant errors, does not include numerical estimate

Conclusions: (20 points)

In science, the conclusion is an interpretation of the data. It is new information that you believe to be true, which you did not know before you did the lab and which is supported by the data. The conclusion should be the answer to the purpose. The conclusion should be in the form of an essay with a thesis statement and supporting assertions. Each must be stated separately and clearly and must be supported by data. **Do not** merely state the conclusion and then **tell** the reader that the data proves the conclusion true. **Prove** to your reader that the data proves the conclusion true. Cite the evidence directly in the conclusion even if it means repeating or copying certain **selected** parts of the data.

Grading:

15–20 points	6–14 points	0–5 points
correct thesis and supporting assertions, realistic interpretation, relevant and meaningful, complete, concise, terms well defined, considerable support of assertions, ideas vigorously expanded, appropriate use of data, good internal structure with units of thought carefully interrelated for the reader.	weak thesis, weak supporting assertions, vague definitions of key terms, some points of support not well related to thesis or each other, slight breakdown in internal structure, oversimplification of ideas	lack of clearly defined thesis and support not carefully related, structural breakdown, imprecise word choice

References: (10 points)

You must give credit for any information that you cite in **any section** of the article that is not from your own mind or experimentation. This includes information from a textbook. Within the body of the text (for example, in the Introduction) you will cite the source (Author, date) or (Editor, date) if no author is available. At the end of the article you must provide a bibliography of every source you cited in the article. Do not provide bibliographic information for a source never cited in the text. Use the following bibliographic formats:

For a book:
Bueche, F & Jerde, D. *Principles of Physics*. New York: McGraw-Hill, 1995.

For a journal or magazine article:
Hu, H & Yu, J (2000). “Another Look at Projectile Motion,” *The Physics Teacher*, 38:423–424.
Note: (38:423–424 means volume 38, pages 423–424)

For a Web site:
Fowler, Michael. “Aristotle.” *Galileo and Einstein Lecture Notes*.
<http://galileoandeinstein.phys.virginia.edu/lectures/aristot2.html>; date accessed.

PowerPoint/Web Page/Poster Presentation

Evaluative Criteria

By, Kris Deardorff

PowerPoint/Web Page/Poster	Possible points	Your points
Accurate Information	6	
Thorough Explanation	6	
Current Research	6	
Relevance	6	
Quality Science	6	
Attractive Design	6	
Effective Design	6	
Correct Spelling and Grammar	6	
Appropriate Length	6	
Correct Citations (at least 3 sources) with Correct Bibliography	6	

Presentation of PowerPoint/Web Page/Poster	Possible points	Your points
Accurate Information	5	
Thorough Explanation	5	
Current Research	3	
Relevance	2	
Quality Science	5	
Use of Visual Aids (in addition to PowerPoint, Web page, or Poster)	5	
Engaging Enthusiasm	5	
Clear, articulate, and organized presentation	5	
Appropriate Use of Time	5	
TOTAL	**100**	

Peer Review In The Science Classroom

Sharon Robinson-Boonstra
The Key School, Annapolis, Maryland

Guidelines

The goal of peer review is to provide a creator/presenter with productive critique in as gentle a manner as possible. It is important to the process that the creator/presenter is placed in the position of power and controls the process.
To create an environment that supports this goal the following process is recommended.

The creator/presenter is accompanied by a “secretary” of her/his choice who’s job it is to record the questions which will be asked by the reviewers.

The creator/presenter describes or reads the item to be critiqued (for example: a laboratory procedure for a proposed experiment).

After the presentation of the material to be critiqued, the other students are only permitted to ask questions of the creator/presenter. This is the essence of the process. Questioning, though often difficult, opens discussion, while statements close the discussion.

The creator/presenter controls the flow of questions and the secretary records the questions.

In response to a question, the creator/presenter has two options: 1) to answer the question directly or 2) to say something similar to “Interesting question, I’ll have to think about that.”

After the questioning session, the secretary provides the creator/presenter with the list of questions for her/his later review.

Individuals or small groups of students may be the presenter(s). The process may be done with the entire class asking questions or with a small group (4–6 students) acting as reviewers. If a small group reviews, it is suggested that those students take responsibility for their review by having their names placed on the final document as “reviewed by.”

Upon completion of the review process, the creator/presenter may use or reject any ideas discovered during the review process. The acceptable ideas are then incorporated into the original document and a final draft is created.

The Value of Peer Review In Inquiry Science

Some of the possible benefits of Peer Review for the **Creator/Presenter**:

- There are more minds working on the problem or question.
- The creator/presenter may gain clarification of her/his ideas.

- Discussion of experimental variables, experimental design, number of trials or subjects and statistical validity may occur.
- The accuracy of the document may be improved.
- The authenticity of the scientific and technological research process is more closely achieved.
- There may be an increase in the creator/presenter's accountability for her/his work.
- The creator/presenter may gain confidence.

Some of the possible benefits of Peer Review for the REVIEWERS:

- Ideas may be expressed to the creator/presenter that are directly applicable to someone else's proposed experiment.
- Discussion of experimental variables, experimental design, number of trials or subjects, and statistical validity may occur.
- Students may model good scientific processes for each other.
- A reviewer's listening skills may be improved.
- Class discussion may improve communication between class members.
- Reviewers may be challenged to think beyond their own ideas.

Many business organizations and scientific institutions employ peer review to ensure success. NASA, for example, implements peer reviews at many points in a project's development from early concept design and instrument selection to final design and testing.

Independent Investigation

Choose a question about light or the light spectrum and design and conduct an experiment to answer the question. You may choose a question from Journal Assignment #4: How are Parts of the Spectrum Different? or you may develop a different question after your investigations during Getting Hotter? and Mystery Light. Choose a question that is interesting to you.

Date Due	Complete	Task	Notes
		Preliminary experimental design procedure completed	
		Peer Review—design procedure must be complete, written, and copied for review team	
		Revised procedure completed	
		Materials list completed and presented to teacher	
		Data collection completed	
		Rough draft of presentation	
		Presentation of results	

5Es

	Suggested Activity	What the Teacher Does	What the Student Does
Engage	• Demonstration • Reading • Free Write • Analyze a graphic organizer • Brainstorming	• Creates interest. • Generates curiosity. • Raises questions. • Elicits responses that uncover what the students know or think about the concept/topic.	• Asks questions such as, Why did this happen? What do I already know about this? What can I find out about this? • Shows interest in the topic.
Explore	• Perform an investigation • Read authentic resources to collect information • Solve a problem • Construct a model	• Encourages the students to work together without direct instruction from the teacher. • Observes and listens to the students as they interact. • Asks probing questions to redirect the students' investigations when necessary. • Provides time for the students to puzzle through problems.	• Thinks freely but within the limits of the activity. • Tests predictions and hypotheses. • Forms new predictions and hypotheses. • Tries alternatives and discusses them with others. • Records observations and ideas. • Suspends judgment.
Explain	• Student analysis and explanation • Supporting ideas with evidence • Structured questioning • Reading and discussion • Teacher explanation • Thinking Skill Activities: compare, classify, error analysis	• Encourages the students to explain concepts and definitions in their own words. • Asks for justification (evidence) and clarification from students. • Formally provides definitions, explanations, and new labels. • Uses students' previous experience as basis for explaining concepts.	• Explains possible solutions or answers to others. • Listens to others' explanations. • Questions others' explanations. • Listens to and tries to comprehend explanations the teacher offers. • Refers to previous activities. • Uses recorded observations

Extend	• Problem solving • Decision making • Experimental inquiry • Thinking Skill Activities: compare, classify, apply	• Expects the students to use formal labels, definitions, and explanations provided previously. • Encourages the students to apply or extend the concepts and skills in new situations. • Reminds students of alternative explanations. • Refers the students to existing data and evidence and asks, What do you already know? Why do you think x happens? • Strategies for Explore apply here also.	• Applies new labels, definitions, explanations, and skills in new but similar situations. • Uses previous information to ask questions, propose solutions, make decisions, and design experiments. • Draws reasonable conclusions from evidence. • Records observations and explanations. • Checks for understanding among peers.
Evaluate	• Any of the above • Develop a scoring tool or rubric • Test • Performance assessment • Produce a product • Journal entry • Portfolio	• Observes the students as they apply new concepts and skills. • Assesses students' knowledge and/or skills • Looks for evidence that the students have changed their thinking or behaviors • Allow students to assess their own learning and group-process skills. • Asks open-ended questions, such as: Why do you think x happens? What evidence do you have? What do you know about x? How would you explain x?	• Answers open-ended questions by using observations, evidence, and previously accepted explanations. • Demonstrates an understanding or knowledge of the concept or skill. • Evaluates his or her own progress and knowledge. • Asks related questions that would encourage future investigations.

Supplies and Vendors

This list is for your convenience and should not be considered a complete list, nor should it be considered an endorsement of any vendor.

Diffraction gratings:
Edmund Scientific, **http://www.edmundscientific.com**
Sargent-Welch, **http://www.sargentwelch.com**

Student Spectroscopes:
Learning Technologies, Inc., **http://www.starlab.com**
Sargent-Welch, **http://www.sargentwelch.com**

Spectroscope kits:
Learning Technologies, Inc., **http://www.starlab.com**

Spectrum tube power supply:
Sargent-Welch, **http://www.sargentwelch.com**
Edmund Scientific, **http://www.edmundscientific.com**

Spectrum tubes:
Sargent-Welch, **http://www.sargentwelch.com**
Edmund Scientific, **http://www.edmundscientific.com**

Glass prism, equilateral:
Edmund Scientific, **http://www.edmundscientific.com**
Sargent-Welch, **http://www.sargentwelch.com**

Spectrum glasses:
Educational Innovations, **http://www.teachersource.com**

Alcohol thermometers:
Sargent-Welch, **http://www.sargentwelch.com**
Ward's, **http://www.wardsci.com**

UV Beads:
Educational Innovations, **http://www.teachersource.com**

AtomicMac™: resource software that provides information, including emission spectra, for all of the elements. Mac and Windows versions available for $25.
http://www.blackcatsystems.com/software/atomic.html

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