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FOR THE TEACHER

ACTIVITIES

INQUIRIES

What is *Science, Optics & You*?

Science, Optics and You is a standards-based interdisciplinary science curriculum package for elementary students and teachers through which they can explore light, color, and optics. Activities are designed to engage students in active investigation of the properties of light beginning with lenses, shadows, prisms, and color, leading up to the use of sophisticated instruments that scientists use to help them understand the world.

The materials are presented in ways that encourage the asking and answering of questions related to light and optics and that provide strategies for students and teachers to incorporate questioning into the study of science at the elementary level. *Science, Optics and You* was designed with the premise that elementary classroom science should be an integrated, multidisciplinary core subject that incorporates critical thinking skills, specific performance skills, as well as reading, writing, and communicating skills that transfer easily to other subject areas. For that reason, *Science, Optics and You* has a strong interdisciplinary component that includes language arts, mathematics, social studies, art, and history.

The *Science, Optics and You* Guidebook is made up as follows:

- **Front Materials** to orient teachers to the perspectives from which the package was developed. This section includes instructions and strategies on how to use the materials. Also included in the front section of the Guidebook are general strategies for using visual tools to construct knowledge, constructing graphs and data tables, using historical and artist vignettes to teach science, alternative methods of assessment, and other pedagogical issues.
- **Eight *Science, Optics and You* Modules**. Each of the first six modules includes activities that are grouped by concepts covered. A Student Self-Check of performance skills and concepts is included for Modules 1-6. Modules 7 and 8 are a combination of research and project ideas and activities that will enrich the experience for students who wish to go further into the study of light and optics. Practical applications are explored in Modules 7 and 8 with explanations of technology that is dependent upon an understanding of optics. There are a total of 25 activities (see Table of Contents).
- Accompanying each activity is an artist vignette and a historical vignette. Vignettes are designed to put the concept from the activity into a context that encourages further explorations. Each vignette has activities to help students explore the impact that the study of light and optics has had upon our culture. (For further discussion of using vignettes in the teaching of science, see “Art in Science” and “Using Historical Vignettes in Science.”
- Each activity is cross-referenced to State Standards.
- Each activity is accompanied by Extensions that include enhancement activities in literature, reading, writing, mathematics, social studies, art, music, and history.
- References to web sites and interactive web-based tutorials.
- Reproducible Student Pages written independent or collaborative group use.
- Appendices include transparencies that enhance teachers’ and students’ understanding of basic concepts, an annotated bibliography of literature books recommended throughout the activities, and an annotated reference list of resource books for teachers, and blackline masters.

Using Centers to Teach Science

You are well acquainted with the use of centers, or exploration areas, in the elementary classroom. Centers that enhance the teaching and learning of science are those that encourage students to do science rather than just experience an activity. The use of learning centers to investigate different facets of a particular unit of study is a way to expose students to many different activities over a period of time.

In classrooms where one teacher teaches all subjects, a "science area" can be equipped with objects and materials that can be used all year. Materials such as magnifying glasses, rulers, tape measures, scissors, different types of containers, beakers or graduated cylinders for measuring volume, modeling clay, straws, string and other materials that are inexpensive but are used frequently can be kept in this area. Students can visit the area as time permits. If activities are available that allow students to study a problem, design ways to investigate the problem with the materials provided, and to record their results in a notebook or journal, then students are involved in doing science.

In designing learning centers, it is important that each center be as flexible as possible in allowing manipulation of materials that allow students to pose questions and seek answers. These centers may involve pencil and paper tasks or actual experiments used to test questions students may have.

It is important to remember that students will find science learning meaningful when they are allowed to raise their own questions and try to figure out answers. True inquiry-based science activities provide for this flexibility. Activities or materials and tools themselves do not help students develop their own ideas about the world. Students need to make connections among things in their lives that make sense to them. These connections may not make sense to you, but if you have provided some content, the skills to ask and answer questions, and the materials to conduct research or investigations, then students will be able to interpret knowledge in their own way and at their own pace.

If a series of centers is designed for use with a particular unit of study, the time provided at each center should allow students enough time to complete the activity, but you will need to plan activities so that each center is completed in the same amount of time. Students should be challenged, allowed adequate time to investigate, and some time to make sense of what they have learned. This could come in many different forms, graphing, making observations, or recording data in their notebooks or journals. Sharing what they have experienced at the end of all of the activities is important. By encouraging students to express what they have learned from the experience allows them to emulate the way scientists in the real world conduct their work

Scientific Inquiry

A vision for science education as stated in the national and state standards is that all students become scientifically literate as they enter the 21st Century. The *Science, Optics and You* Guidebook supports teachers as they make this happen. The guidebook contains eight modules and 25, inquiry based and hands on activities.

Inquiry based science instruction in the elementary classroom includes the processes of science: observation, inference, and experimentation combined with scientific knowledge and critical thinking skills. The students use critical thinking and scientific knowledge as they observe the natural world to develop an even deeper understanding of science. *Science, Optics and You* uses inquiry based instruction by encouraging students to develop the ability to think critically, ask questions, develop strategies to answer their questions and communicate their findings in a variety of ways. Inquiry based instruction does require that the learner have opportunities to explore the content. Then students can develop questions about the subject. This means they will have to manipulate equipment, read, use the internet, interview, ask questions of others, and document their observations to gain an understanding so they can develop questions which they can think about. Current research in teaching and learning states more information is retained when students are given opportunities, support and encouragement to explore their own questions. This type of authentic based instruction is reflected in the *Science, Optics and You* modules and activities.

Hands-on instruction is different from inquiry in the following ways:

1. Hands-on instruction does not always have a critical thinking component.

2. Hands-on instruction may not utilize the students ideas for shaping explorations.

3. Hands-on instruction and inquiry based instruction are not mutually exclusive. In other words, hands on instruction does not guarantee inquiry.

4. Hands on activities provide the students with the opportunities for exploration and manipulating equipment so further questions may be generated.

5. They provide the students with the opportunities for observing, documenting those observations, measuring, recording, interviewing or drawing conclusions. These processes may stimulate more authentic questions, which would lead the student to do inquiry type investigations.

Inquiry based instruction and hands on science instruction are opportunities for success in the elementary classroom.

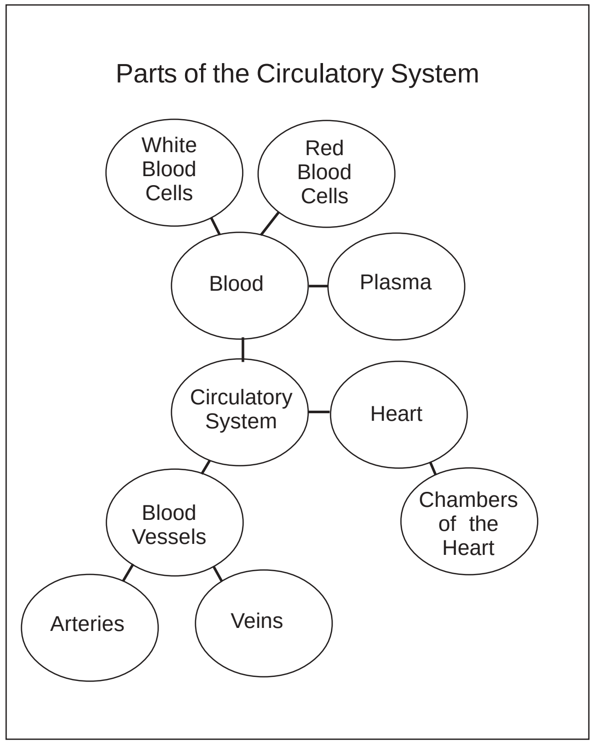
Graphic Organizers

Students and teachers use graphic organizers to help them arrange ideas in ways that make sense to them. Graphic organizers can be powerful tools to create visual pictures of information to help students see patterns and relationships. It has been said that a picture is worth a thousand words. This is especially true for graphic organizers. A good graphic organizer can facilitate a holistic understanding of complex concepts by illustrating at a glance the key parts of the whole and their relationships. Graphic organizers are particularly useful as prewriting tools for students to use for organizing their thoughts.

There are many types of graphic organizers. They include webs, Venn diagrams, matrixes, concept maps, and others. The type of organizer to be used depends on the nature of the relationships that need to be illustrated. The following are some examples of graphic organizers and descriptions of how they can be used.

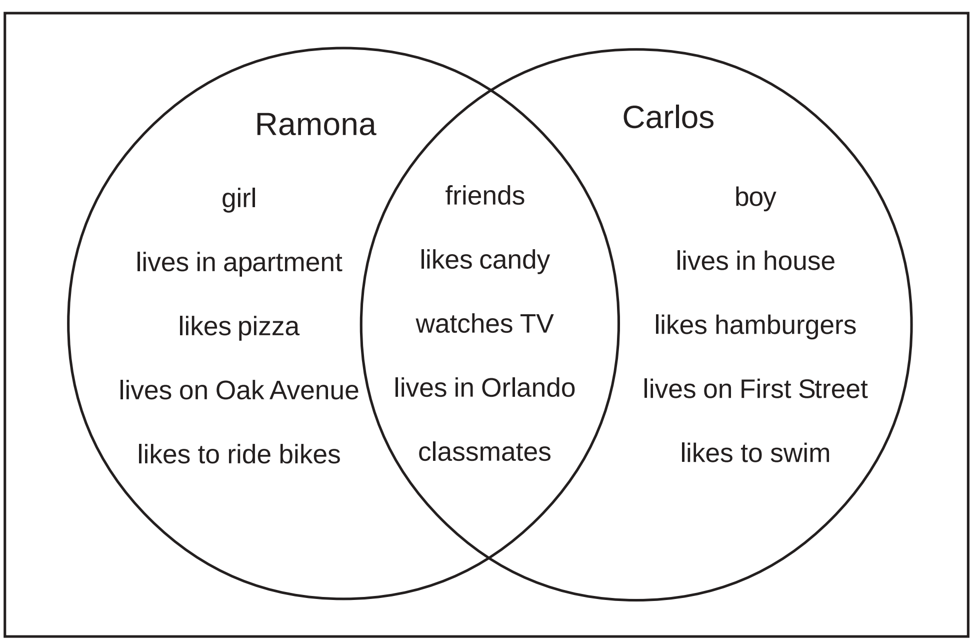
Webs

Webs are used to describe a central idea. It could be a thing, a process, or a concept. Webs are based on the thought process of identifying a main idea then its attributes or functions. In language arts they could be used to analyze the traits of main characters in literature. In mathematics they could be used to identify attributes of geometric shapes. In social studies students can use webs to analyze cultural traits. In science they can be use to identify properties of objects. Webs are particularly effective visual tools for brainstorming sessions with your students.



Venn Diagrams

Venn diagrams, developed by John Venn of Cambridge University, are used to describe and compare two or more things in terms of identifying attributes that are similar and different. Venn diagrams consist of intersecting circles that illustrate how, things, people, places, events, or ideas are alike or different. They identify and isolate those characteristics that are shared and those that are not shared.



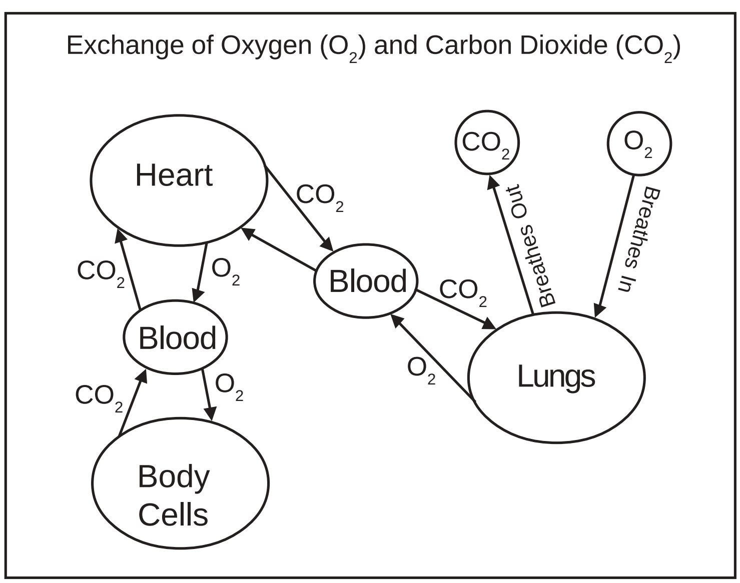
Matrixes

Matrixes are essentially tables with rows and columns that are used to show similarities and differences between two or more things. Matrixes are particularly useful for comparing many things and many attributes at the same time.

Student	Height	Weight in lbs.	Resting Heart Rate Breaths Per Minute	Quiet Breathing Rate Beats Per Minute
Amanda	4'11'	103	85	22
Carlos	4'10"	101	87	24
Ramona	4'8"	94	84	21
Jesse	4'10"	96	86	23
Monica	5' 0"	108	85	22

Concept Maps

Concept maps are special types of webs used to map, organize, or describe the thinking process and complex relationships. Like simple webs, concept maps are used to identify related concepts and subconcepts. However, with a concept map, the links between the various cells are labeled to describe the nature of the relationships. Arrows can be used to describe the direction of the relationships. The relationships between concepts can be read like a sentence. These additional features make concept maps useful and effective in graphing relationships, which are complex.



Graphs

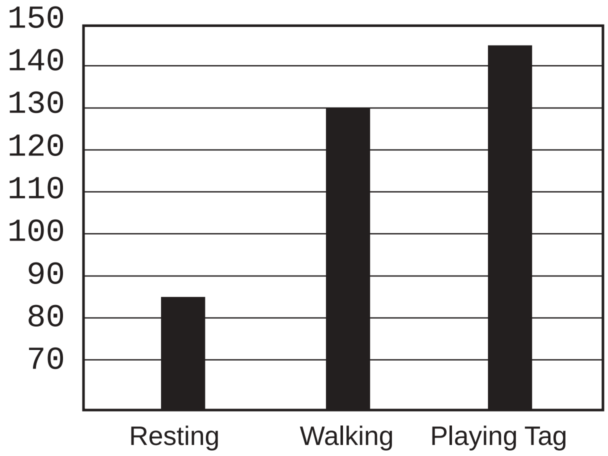
Competence in graphing skills is necessary for a number of SCIENCE-U activities. Students will be asked to use the tools of data analysis for recording, managing and displaying information (MA.E.2.2). They will be given opportunities to learn to use graphs as tools to create pictures of relationships.

One of the skills needed to construct graphs is organizing data in tables. Organizing data into tables helps your students to see patterns in the data and makes it easier to construct graphs.

Constructing Data Tables

When elements of an observation are recorded, the measurements made are called data. Measurements of time, temperature, volume, and rates are examples of data. There are no absolute rules for constructing tables of data. However, the manipulated variable is usually recorded in the left column and the responding variable is recorded in the right column. A manipulated variable is the one the experimenter changes in order to observe a response to the change. For example, the data table below is a record of measured heart rates after a variety of activities. The manipulated variable is an activity and is recorded in the left column. Heart rate is the responding variable and is recorded in the right column.

Activity	Heart Rate (BPM)
Resting	85
Walking	130
Playing Tag	145
Playing Basketball	170
Playing Soccer	180



Constructing Bar Graphs

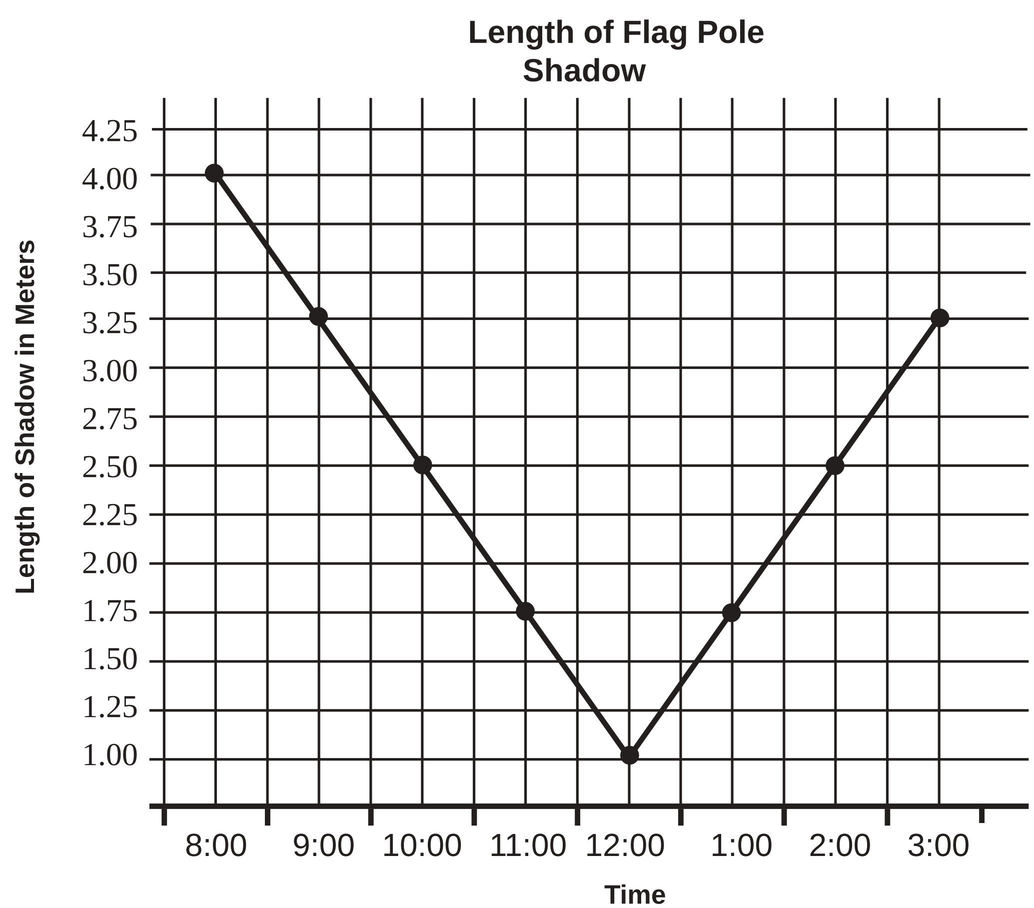
Using a well organized data table makes constructing a bar graph much easier for your students. Students can use the information to construct a bar graph similar to the one below based on our measurement of heart rates data table. Students can use graph paper to construct the bar graph. The first step is to label the axes of the graph. The convention is to use the horizontal axis for the manipulated variable and the vertical axis is used for the responding variable. However, these may be reversed. The FCAT recognizes either way of structuring the graph as acceptable.

The next step is to determine an interval scale that is appropriate for the data to be graphed. In the case of heartbeats per minute, an interval of 20 beats is appropriate for illustrating changes and trends. The final step is to plot and draw bars with the designated lengths.

Constructing Line Graphs

A line graph is the best way to represent a continuous change in data. For example, a line graph might be used to show how the length of a flagpole shadow changed from one hour to the next during the day. Students would construct a data table as shown in the example. Graph paper should be used to construct the line graph. The axes are drawn and labeled and appropriate intervals indicated as in the example. Points are then plotted to represent the two related sets of data, and a line is drawn to connect the points. If measurements of the shadow were made every hour, these points would be plotted and straight lines drawn between the points. There is an assumption with a line graph that even though the only real data points are those that are plotted, the line between points represents implied data. In the example, a shadow did exist at all times, and its length did not jump or drop from one plotted value to the other. It changed continuously and gradually as suggested by the graph. Therefore, a student could use the graph to infer the length of the shadow at times other than when measured.

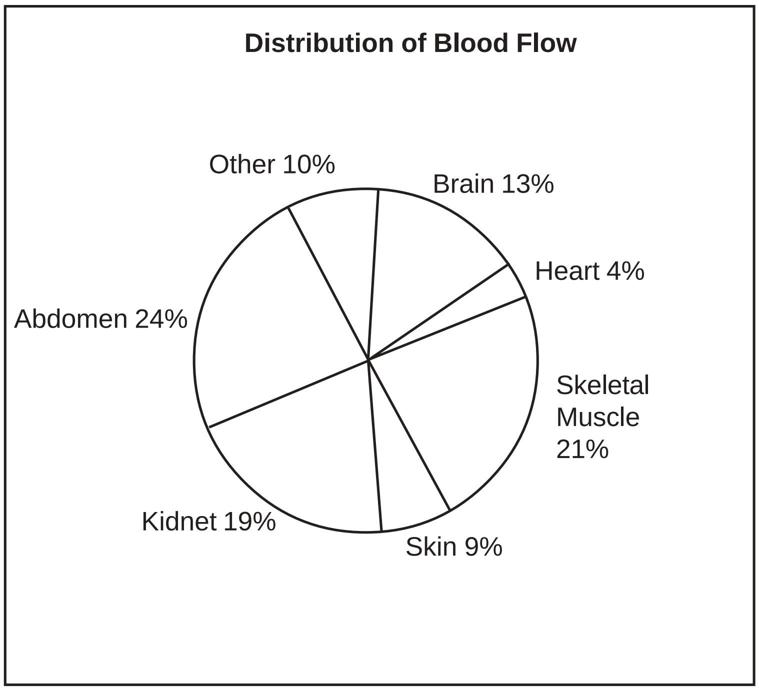
Time	Length of Shadow in Meters
8:00	4
9:00	3.25
10:00	2.50
11:00	1.75
12:00	1
1:00	1.75
2:00	2.50
3:00	4



30.48cm = 1ft

Circle Graphs

Circle or pie graphs are used when a total amount has been divided into parts and the interest is in the ratio of each part to the whole and not so much in the particular quantities. For example, the circle graph below shows a comparison of the amounts of blood flow to various parts of the body. Pie graphs can be made from computed percentages. To do this the numbers in each category are added to form the total or whole. By dividing each of the parts by the whole with a calculator, numbers between zero and one will result. If rounded to hundredths, these numbers are now percentages of the whole. Check that the total is 100 percent since rounding may cause some error. Using a compass, ruler, and protractor a circle graph can be constructed. This requires an understanding of the relationship between percentages and the degrees of a circle. Each 18 degrees of a circle represents 5 percent, 36 degrees represents 10 percent, 90 degrees represents 25 percent, 180 degrees represent 50 percent, and so forth. To facilitate construction, a hundredths disk can be used to construct the graph. It is worth noting that computer software programs are available to produce a variety of graphs. Circle graphs are included in almost every computer spreadsheet and graphing program.



Science in the real world requires communication of research results, dissemination of information, and synthesis of findings. Included in all *Science, Optics and You* modules are opportunities for students to read and write to articulate the concepts covered in the activities. Reading and writing about issues in science stimulates thinking, encourages participation, and motivates students to become responsible consumers of information (Dickson, 1995).

Reading in Science

Reading is not necessarily limited to factual, nonfiction material because it is being done in the context of science. There is a great deal of well-crafted fiction as well as nonfiction material written for children that can enhance any science program by introducing students to alternative ways of thinking about science concepts. Different techniques are necessary for the different types of materials, however, and when reading from technical literature, it may be necessary to guide students' reading until they are comfortable on their own. Learning strategies such as outlining, concept mapping, and highlighting main ideas can be used to help students with expository reading. When in reading fiction books, with a little practice, students will quickly become adept at distinguishing between science facts and fiction. *Science, Optics and You* activities provide suggestions for both fiction and nonfiction books which can be used to enhance activities, extend student thinking, and reinforce concepts. *Science, Optics and You* activities also include reading experiences that are geared to address specific reading benchmarks of the Florida Sunshine State Standards, and to prepare students for the types of challenges found on the FCAT.

Writing in Science

Being able to share results and ideas with others through writing is a dynamic process that happens every day in science. The portrayal of science as a body of information or a collection of facts to be memorized precludes writing understandable research reports, readable biographies, nonfiction accounts of scientists, or fictional stories. Writing of any sort extends students' learning of science as they articulate concepts. Further, presenting results of an experience or knowledge to others requires a great deal of confidence, which can be gained from believing you have accurate information as students expand their reading experiences.

Included in *Science, Optics and You* activities are opportunities for students to write about what they have learned in a variety of ways. While research writing is an important science skill, children often resist when assigned to write reports and respond with sterile and stilted compositions (Matz, 1990). Therefore, *Science, Optics and You* includes writing activities that add the elements of self-reflection and creative imagination. The *Science, Optics and You* writing activities are designed to provide students with experiences that promote the effective use of the writing process consistent with standardized tests.

Journal writing and reflective writing are two ways for students to clarify their thinking and articulate science concepts. These techniques also provide the teacher with unique insights into how students learn and what the are learning. Throughout the *Science, Optics and You* modules students are encouraged to maintain Science Notebooks. The Science Notebook is a vehicle that encourages students to take notes, express themselves, clarify ideas, criticize their own thinking, and reflect on ideas. Science Notebooks also provide a record of data collected, questions to be answered, and serve as a ready reference for subsequent inquiries.

In addition to the Science Notebooks, teachers are encouraged to offer students varied writing opportunities such as:

- Composing letters and/or email to other students in the school or in remote locations to share science-related experiences, to request information from scientists, to write persuasive letters about scientific or social issues, or to contact legislators and public figures who affect public policy.

- Developing picture or easy reading books written and published by students to introduce scientific concepts to younger students.

- Creating poems and skits about the topic being studied, to personalize the information or concept learned through the expressions of the affective domain.

- Writing stories using a variety of techniques and representing a variety of genres; for example, science fiction or fantasy based on scientific ideas, life in the future, life and creatures from prehistoric times, life in a different environment, imaginary creatures and distant worlds.

- Other writing opportunities include creating web pages, fact books, guidebooks, manuals and video productions, writing newspaper or magazine articles, editorials, interviews, dictionaries, technical reports, posters, and advertisements. These writing experiences will draw students into the inquiry process and lead to understanding and internalizing of new ideas.

Assessment

The assessment portion of *Science, Optics and You* is designed to improve teaching and learning rather than supply teachers with assessment for monitoring. However, how you opt to use this section is a decision that only you can make based upon your school and classroom needs and the individual personality of each class.

Each assessment task in *Science, Optics and You* has been designed to conform with National Science Education Assessment Standards. Formative and summative assessments are addressed. It is assumed that you will know best which task to choose for which purpose at different times. *Formative* assessment is used to gather information so that you can plan future work for your students. Formative assessment is a diagnostic tool in that it helps the teacher decide how to proceed. *Summative* assessment, on the other hand, is used to determine where the students are within a certain continuum. Summative assessment answers the question, "How far have my students come?" It is the type of information that you would provide to parents—a summary of the child's progress.

Each task is accompanied by suggestions to help you determine whether the students you teach with their specific and particular needs, abilities and interests, have successfully met the goals for the assignment. What have students learned? How did they learn it? Why did students find it important? What connections have students made with other disciplines? Where can students go from here?

Types of Assessment:

Performance assessment refers to tasks that students engage in for a long period of time and do something that results in a product. Performance assessment is embedded in each activity. Each time you ask a student to solve a problem using the concepts and content in an activity, that student is required to demonstrate a knowledge that goes beyond memorization of facts for a multiple-choice test. If students measure the temperature of water they are demonstrating that they are proficient in using a thermometer. Taking a measurement to show proficiency in measurement is a performance assessment. When you look around your classroom and students are working together simulating real-world decision making situations, this is also performance assessment. Other examples of performance assessment tasks include brainstorming, using content and concepts in unstructured ways, relating science concepts to other areas of study, using multiple methods of communication to present science concepts to others, reading and writing about science, or analyzing data in a coherent way.

Any method of collecting work in an organized fashion as evidence of learning can be considered a "portfolio." Portfolio assessment can take many forms. For example, the Science Notebook that the students maintain for a series of investigations can be considered a portfolio since it will contain most of the information and analysis required for each activity.

Authentic assessment simply means that the students are thinking like and doing tasks like scientists do. In the case of the Science Notebook, keeping a log of information is something scientists do. In addition, since the students know the purpose of the notebook and its role in the activity, keeping the notebook is an authentic task.

Assessment Choice

Current theories about assessment in classrooms encourage teachers to give students choices about how they can best display their newfound knowledge. This is not to say that with each assignment, students should be allowed to do whatever they please; rather, students need a repertoire of resources from which to select the one that allows them to best demonstrate what they have learned. Certainly there are times when you decide what is to be completed, how, and when. By suggesting a variety of ways in which students can display their knowledge, you enable students to select the best assessment tasks and display strategies. By making a conscious selection of one option from an array of tasks, the student frequently takes ownership of that particular assignment

What are your students expected to know?

Science, Optics and You expects that your students will use certain skills or will acquire those skills as they complete each Module. Many students come to the the classroom with a repertoire of problem-solving and critical thinking skills. However, it cannot be assumed that all students have these skills when they enter the science classroom. It is advisable to determine at the beginning of the school year those learning skills that you will want to develop. Using *Science, Optics and You* to develop some of these skills is an option, but you will want to choose your groups carefully and rethink your expectations if these skills are being introduced. Skills listed here are not subject-specific and should increase students' opportunities to be successful in all content areas.

Brainstorm: Students clarify ideas in either small or large groups without judgments being made as to "right" or "wrong" answers. Groups generate a large number of ideas from which to choose. Brainstorming encourages different perspectives and allows each person to contribute without question.

Draw conceptions: If students have never been asked to draw their idea of something, they may need some guidance. In the case of *Science, Optics and You*, students will draw, for example, their idea of how rainbows are formed. The drawing supplies a permanent document that can be revisited at a later time, added to, or subtracted from. In some cases, students are not able to articulate their ideas, but can draw them. When asked to explain their drawings to you or another student, students can often clarify their thoughts more easily.

Group roles: Regardless of how you choose to design your groups (you choose, students choose, same groups for all activities, or rotating roles in static groups, for example), students should have assigned roles. The roles represent tasks that need to be completed but include some discussion of the fact that the defined tasks are not the sole responsibility of one person; rather, the group maintains responsibility for the total product. Examples of group roles are: recorder, spokesperson, materials manager, and timekeeper. These roles could rotate on a regular basis or could be chosen by you based on identified areas in which students excel or based on areas in which you believe students need more practice.

Articulate ideas and reach group consensus: In each *Science, Optics and You* activity, you are asking your students to make decisions as a group. This is a skill that many elementary students may not have. You will need to guide some groups with a discussion of decision making and listening skills. You may need to speak about leadership versus authoritative behavior and leadership versus dominance. Although students may have done groupwork previously, they may be just getting to a point where true collaboration is a possibility.

Critical analysis skills: Some skills that will be necessary to develop through these Modules are distinguishing between similarities and differences, being able to compare and contrast, identifying the main idea in a paragraph or article, and distinguishing between fact and fiction.

Group work/Cooperative Learning

Science, Optics and You is designed to support students working in pairs or groups of four. How groups are chosen is up to you. Students will realize after several experiences working in groups that working in a group is not working *near* other people, but *with* other people.

There are several ways to set up for group work: you choose the groups based on areas of expertise or areas in which students need practice; students choose their own groups for the maximum comfort level; or groups are chosen randomly. Regardless of how you decide to implement the groups, there is some preliminary discussion that is necessary about your expectations, group roles and responsibilities, and ultimately what is expected of the final product. In the case of the Science Notebooks, it is imperative at the start of *Science, Optics and You* that you make it very clear that the Notebooks are individually completed, but based on the collaborative work.

Learning Styles

Each person has a way of learning and presenting evidence of that learning. A learning style should not be confused with multiple intelligences as presented by Howard Gardner. A learning style is a way of approaching learning that is usually applied to all content. Some students learn well by listening and repeating information orally; others demonstrate what they have learned by creating artwork. Still other students can incorporate science concepts into creative writing material, while some students do well with graphic organizers such as charts, graphs and concept maps. There are students who prefer a multiple choice-type test to demonstrate what they have learned. More and more frequently students create multimedia projects to display their learning. It is our intention that these assessment materials provide you and your students with enough choices to accommodate the learning styles of all the students that are in your classroom.

Rubrics

A rubric is part of the process of scoring student work by determining a standard of performance based upon your class. (I refer you here to the National Science Education Standards discussion of assessment.) Setting up a rubric for each assessment task serves several purposes including clarifying teacher expectations and providing students a clear guide to measure how well they are meeting these expectations. There is no question about whether a student is successful if there is a clear understanding of what is required when the task is assigned. An example of a rubric for a diagram about rainbows might be:

A. The diagram includes a prism or a water droplet acting like a prism, has a title, illustrates white light being broken into the colors of the visible spectrum, and has the colors of the spectrum represented in the correct order.

B. The diagram includes all a prism or a water droplet acting like a prism, has a title, and illustrates white light being broken into the colors of the visible spectrum.

C. The diagram includes a prism or a water droplet acting like a prism, a title, and illustrates white light as different colors after it hits the prism or water droplet.

D. The diagram does not include a prism or a water droplet acting like a prism and does not indicate in any way that white light is actually composed of the colors of the visible spectrum.

F. The diagram includes a drawing of a rainbow.

To encourage students to further take part in self-evaluation, you could have the class create the rubric. Discussing the criteria of a certain task helps students clarify what they need to do to be successful. Being certain that your expectations are clearly defined for students is, in many instances, the key to their success or failure. Further, it makes your job easier, since many questions have been addressed ahead of time. Students will not come back to you later with questions about why they got a certain grade.

An excellent resource for further information on assessment in science and mathematics classrooms is *Science Assessment in the Service of Reform* edited by Gerald Kulm and Shirley M. Malcom, American Association for the Advancement of Science, 1992. ISBN 0-87168-426-8.

Current Issues

Any time students make the link between what is happening in the science class and real life it is a victory for the science teacher. A simple comment such as "I saw a rainbow yesterday on my way home and I know how it is made," becomes a teacher's badge of honor. Using magazines, videos, television, and newspapers in the classroom is a valuable technique especially in science. Scientific research and development laboratories announce new discoveries every day. Sometimes in the course of just one school year a discovery or invention is announced and soon thereafter is repudiated or worse rejected as fraudulent. Students are more aware than ever of issues such as AIDS, cloning, space travel, and environmental problems. Tapping into their natural curiosity about such issues can alleviate fears and answer questions. Reading expository material is a skill that is rarely "taught."

Interdisciplinary/Integrated Application

Science, either in the classroom or in a research laboratory, is not done in isolation. Current events, history, literature, art, and music influence even scientists who have a very specific area of interest. To study science in a classroom that is devoid of these other areas of interest is not only artificial but also sends the wrong message to middle level students. Regardless of the science discipline being studied, it is imperative that students begin to make connections between what they are studying and real-world applications. Using the knowledge gained in their science classroom to enhance the study of geography or language arts reinforces the interdisciplinary nature of science. When students find relationships between and among the subjects that they study they are more likely to find intrinsic value in the knowledge they are gaining.

Misconceptions in Science

One of the most difficult jobs a teacher has is determining what students know, what they think they know, and how to use that understanding to facilitate further understanding. Many students come to science classrooms with misconceptions about the world, how the world works, and where we fit in. This is partially due to misinformation, misunderstanding, and attempts to understand concepts that are too big to even contemplate without good models. Using misconceptions as a jumping off place for science exploration can be a good strategy because the student is already comfortable with the idea behind the misconception. Correcting misconceptions requires that students must clarify concepts and then find a replacement for the mistaken idea.

Science Fiction

Distinguishing fact from fiction is a skill previously mentioned as necessary in the science student's repertoire of competencies. As students attempt to determine what parts of a science fiction story could be true and the parts that could not be possible, they begin to describe what they know. In order to identify and defend the factual portions of a science fiction story, students need to find evidence to back up their claims. Science fiction helps students discover the effect that science has on their lives and how science could affect the future. Science becomes much more than a collection of facts. It takes on new meaning as students try to imagine the future. This requires that students take a look at society today in order to imagine how it will be in the future. Current technological advances form the basis for inventing new modes of transportation, new ways of getting information, and ways of understanding new scientific research breakthroughs (for example, cloning).

Using Historical Vignettes in Science

In *Science, Optics and You*, historical vignettes are used to enhance each activity. These vignettes serve to explain some of the scientific contributions that have been made by scientists and how these scientists were either influenced or limited by the culture of the time. All of the historical vignettes have extensions that encourage writing, additional research or serve as springboards for group or class discussions. Historical vignettes may be about the lives of scientists who have increased our understanding of science. They may be used as teacher background information or for "story-telling." Stories told by teachers often capture the imagination and interest of students, and make the learning experience more meaningful.

According to *Science for All Americans* (1990), knowledge of the way science works is an important component of scientific literacy. Science requires creativity, imagination and insight. Students should be encouraged to think about what is going on and use their creativity and imagination to explore concepts in science. The idea of vignettes may be extended so that they tap into the creativity and imagination of students. Instead of using the vignettes provided in *Science, Optics and You*, students may create and present their own vignettes to the class as multimedia presentations or skits, including period costumes. Vignettes could be assigned to different groups in the class, and students in these groups could extend the impact of their historical vignette by producing a bulletin board as a "Scientist of the Week" theme. Students will find a list of scientists to research at http://micro.fsu.edu/optics.

Using Artist Vignettes in Science

Many concepts in science would be difficult to understand if drawings, diagrams and models were not used. For this reason in *Science, Optics and You* there are many activities involving art and science. Included in each of the activities is an Artist Vignette. These vignettes encourage students to make connections that exist between science and art. All of the artists featured in these vignettes have used some of the principles or applications of optics including light, lenses, mirrors, color, photography, shadows, or optical illusions. For example, in Module 3: Activity 7, Mirrors and Multiple Images, the Artist Vignette is about Leonardo da Vinci. In this vignette a discussion of possible reasons for him using "mirror writing" in his notebooks is included. This leads directly to an activity in which students are encouraged to try mirror writing and then use the mirrors in their *Science, Optics and You* package to read their messages.

Another use of art in the *Science, Optics and You* modules involves students drawing or making diagrams as methods of explaining data or as a way of problem solving. For example, in Module 4, Activity 8: Light, Prisms and the Rainbow Connection**,** students are encouraged to draw a picture that illustrates how to produce the color spectrum by using a flashlight and a prism. This technique reinforces what the students have discovered in the laboratory activity. Diagrams can also be used as a form of performance based assessment, or may be placed in students' portfolios as evidence of skills mastered.

Artist Vignettes analyze techniques used by certain artists and encourage students to model those techniques. The use of primary versus secondary colors, Pointillism, Impressionism, and the application of photo micrography are techniques that manipulate color, and light. For students the use of Artist Vignettes helps them realize that science is not an isolated subject, but is interwoven with other areas of study such as art, math, history and language arts.

Researching in Science

By the end of the fifth grade, students should support their statements with facts found in books, articles and databases and be able to identify the sources used (Benchmarks for Scientific Literacy). For this reason, students need to be comfortable with using a variety of media to find information. In *Science, Optics and You*, there are many opportunities for students to research topics about Optics. Whether students use library books, magazines, newspapers, encyclopedias, videos, or the Internet, they may need some assistance with how and when to use each of these forms of media.

Before beginning research on a particular topic, students need to know where to look. Recognizing the type of information they need, whether it is facts, opinions, news reports, or historical information from primary sources, knowing where to look will make their task easier. If students are searching for information on some current event, then a reliable newspaper like the *New York Times* or the *Washington Post* will be a useful source. Checking the date of publication is as important as the choosing which publication to use. It is important for students to be aware of the date that any article was published. Materials, especially science materials, become outdated quickly and may not be current enough to be useful. On the other hand, if a student is looking for an historical perspective, the date may not be of primary importance.

Here are some sample citations taken from the APA Publication Manual:

> Book: Author, I. (date). Title. City, State: Publisher.
>
> Article in a magazine or newspaper. Author, I. (date). Title. Journal, Volume #, page number.

Internet sources can be very timely and very useful, but they should not be the only source of information that the students use. There are several caveats about using the internet with any level students.

- Check all websites before recommending them to students or using them in class. This includes all links from that website.
- Students need to understand that they must cite the website just as they would give credit to an article or book. Here is an example of how to cite on-line information:

  > Author, I. (date). Title of article. [On-line]. Available: Specify path.

- Forms for citing on-line information can be found in Li and Crane's (1993) *Electronic Style: A Guide to Citing Electronic Information.*
- Information and graphics found on a website is usually copyrighted material. It is technically illegal for students to print out material from a website and claim it as their own.
- Material found on websites cannot be used for other purposes unless the creator of the website gives his or her permission.
- The source of information found on websites should be checked carefully. The information is only as reliable as the source. Students should be told that just because they find something on a website does not mean that it is dependable.

How to Design and Use Discovery Centers

You are well acquainted with the use of centers, or exploration areas, in the elementary classroom. Centers that enhance the teaching and learning of science are those that encourage students to do science. The use of learning centers to investigate different facets of a particular unit of study is a way to expose students to many different activities over a period of time.

In classrooms where one teacher teaches all subjects, a "science area" can be equipped with objects and materials that can be used all year. Materials such as magnifying glasses, rulers, tape measures, scissors, different types of containers, beakers or graduated cylinders for measuring volume, modeling clay, straws, string and other materials that are inexpensive but are used frequently can be kept in this area. Students can visit the area as time permits. If activities are available that allow students to study a problem, design ways to investigate the problem with the materials provided, and to record their results in a notebook or journal, then students are involved in doing science.

In designing learning centers, it is important that each center be as flexible as possible in allowing manipulation of materials that lead students to pose questions and seek answers. These centers may involve pencil and paper tasks or actual experiments used to test questions students may have. It is important to remember that students will find science learning meaningful when they are allowed to raise their own questions and try to figure out answers. True inquiry-based science activities provide for this flexibility. Activities or materials and tools can help students develop their own ideas about the world by making connections to things in their lives. These connections may not make sense to you, but if you have provided some content, the skills to ask and answer questions, and the materials to conduct research or investigations, then students will be able to interpret knowledge in their own way and at their own pace.

Students should be challenged, allowed adequate time to investigate, and provided time to make sense of what they have learned. This could come in many different forms: graphing, making observations, or recording data in their notebooks or journals. Sharing what they have experienced at the end of all of the activities is important. By encouraging students to express what they have learned from the experience allows them to emulate the way scientists in the real world conduct their work.

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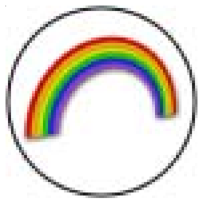
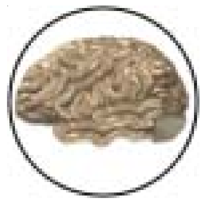
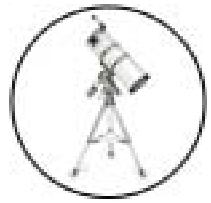
MODULE m1

THINKING ABOUT LIGHT AND OPTICS

INTRODUCTION

Module 1, Thinking about Light and Optics, is made up of three activities that can be used at any time throughout this unit of study.

Activity 1: Perspectives: Powers of 10
Activity 2: K-W-L: What I Know, What I Want to Know, What I Learned
Activity 3: Using Media to Explore Light and Optics

Activity 1, Perspectives: Powers of 10, is an effective way to get students to look at things in new ways; Activities 2 and 3, in particular, can be used any time. These activities can, and should, be used several times while students are asking and answering questions about lenses, color, light, shadows, and optics in general. Use of these activities is enhanced by the Extensions that include ways to incorporate mathematics, literature, history and social studies, art, and reading and writing in science.

Module 1 differs from the other 7 modules in *Science, Optics & You* in that it stands alone and does not rely on one concept building upon another. That feature allows you to use the strategies in Module 1 at any time or with other units of study.

The Powers of Ten interactive web-based tutorial can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: http://micro.magnet.fsu.edu/optics/tutorials/java/powersof10/

ACTIVITY
Perspectives - Powers of 10

Scientists look at things in very particular ways using sophisticated equipment, everyday instruments, and unlikely tools. Some things that scientists want to see are so small that they need a hand lens, or a microscope; other things are so large that they need a powerful telescope, for example, to focus in on one small part. Students will use observational skills, math skills, and their imaginations to complete this activity that was inspired by the video, “Cosmic Voyage” (35 minutes, IMAX Corporation, Cosmic Voyage, Inc.).



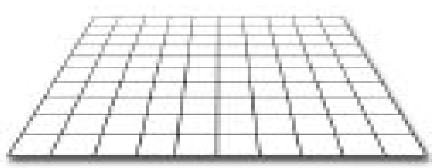
Plan to complete this activity in stages. You could set aside ½ hour or 1 hour each day to complete the steps and stages of the activity. This activity is also appropriate for a weeklong (or more) mini-unit on how things look from different perspectives. The variations are almost endless!

Materials:

- ☐ Pre-cut butcher paper, bulletin board paper, or the end roll of newsprint from a local newspaper (1M square for each group)
- ☐ Meter stick, tape measure, or other measuring device (string cut in equal lengths will do)
- ☐ Science Notebooks
- ☐ Crayons, markers, or pencils
- ☐ Assorted objects, such as leaves, notebook paper, photographs,
- ☐ M. C. Escher print, poster or photocopied image (to complete the artist vignette portion of the activity)
- ☐ Hand lenses
- ☐ Field microscopes

WHAT WILL THE STUDENTS DO?

There are several variations of this activity that become apparent as you read through the directions. You will determine how best to facilitate the students' discovery of how things appear depending upon one's perspective.



Part I

1. Students will work in pairs or small groups. Using their 1M square piece of paper, they can trace one student's outline.

2. Then, students will choose one object for each person in the group (like leaves, pieces of paper, pieces of newspaper, photographs, etc.), and place the items around the "body," and outline them as well.

3. Now, have students go back and put in as much detail as possible on the smaller objects. [The purpose here is not to examine the detail on a human body, but to put the item the students will examine into perspective.]

4. Students should record what they are doing and what they see in their Science Notebooks.

5. Have students divide the paper into 10 equal parts by moving around the paper marking it off in one-tenth of a meter (10 centimeters) increments. Then they can use their tape measures or other straightedge to connect the horizontal marks and the vertical marks. What will be left is a grid with 100 squares on top of their original drawing.

6. In their Science Notebooks, students draw what they see in *one square* of the paper and then answer the following questions:

   How is what you see different from what you saw at first?

   Why are your drawings different?

   Would you have to be larger or smaller to see what you drew?

   What would happen if we divide the paper into smaller boxes?

7. Have each student cut out one square that has something drawn in it.

8. Students should draw themselves in that square so that they are comparing the detail from the larger item originally drawn to their own image. (In other words, they will be looking at the original object as if they were 10cm tall.)

9. Now, take that square and divide *it* into ten equal parts, again marking around the paper, but this time in 1-centimeter increments.

10. *What do you see now?* You can discuss this as a whole group or have students write their observations in their Science Notebooks.

11. Ask students: *Do you have to move away from something or closer to something for it to look bigger?*

12. Tell students to draw a picture of themselves in the smaller box. *Is this what it would be like to be a giant? Or, is this what it would be like to be an ant?*

Part II

1. Students use the 10-cm squares that they cut out and observe the drawings using 10X hand lenses.

2. Students draw what they see through the 10X lens and answer the following questions:

   How is what you see through the lens different from what you can see with your eyes?

   Why would a person want to use a hand lens to look at something?

   What do you think you would see if you could get even closer?

3. Now, students cut out another square. This time they will cut out one of the smaller (1 cm) squares.

4. Discuss with students what they can see. Some students will be able to see great detail depending upon how much detail they put into their work in the first place. Others will say that all they can see is "paper." That is all right because the next step will be to put the square into their field microscope with the 100X attachment.

5. Students place their squares in the field microscopes. Even those who saw "only paper" will be able to see a great deal of detail in the paper fibers or perhaps graphite where they drew lines.

6. Students write or draw (or both) what they see in their Science Notebooks.

♦ ♦ ♦

ENCOURAGE STUDENTS TO WRITE DOWN OR DISCUSS WITH ONE ANOTHER ANY QUESTIONS THAT THEY HAVE AS THEY ARE WORKING ON THIS ACTIVITY.

Use the activity as a jumping off point for a discussion about how scientists study things. Ask students:

What would you do if you wanted to look at something that was very tiny?

What could you use to look at something far away?

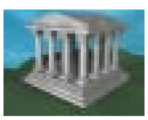
Extensions:

Writing. Choose a person, pet, or thing and ask students: What would you see if you could keep getting closer and closer to it? In the case of a dog, for example, students will probably identify hair and skin, inside their ears or eyes or noses, fleas. Encourage students to go even further with those types of ideas and then write a story about a child with special powers who can see things at the cellular or atomic level.

Reading. Read *The Borrowers* (ISBN: 0-15209-990-5) and have students predict before each chapter or portion of the book some scenarios that they might expect to hear or read about. Then, students can check their predictions and discuss how accurate they were. Students can draw pictures to illustrate the story. They will make the connection between their drawings and the drawings they did in the Perspectives Activity.

Art. Make a class cartoon or comic book based on the way things look to someone or something very small or very large. Each student or group of students could contribute a panel or portion of the book that could be shared with other classes.

Game. Play a game where students each describe an item as seen by an ant. Then, each student reads his or her description to the entire class as the others try to figure out what they are "looking at."



Historical Vignette: Robert Hooke

In 1665, Robert Hooke (1635-1703) improved upon earlier microscopes developed by Anton van Leeuwenhoek and Zacharias Janssen. His compound microscope consisted of an objective lens used to focus light on what he was examining, an eyepiece lens, and a "field lens" that Hooke used to increase the field of view. The light source that he used was either sunlight or an oil lamp that he attached directly to the microscope. By using a microscope, Hooke was able to show people things that were previously invisible. Hooke published a book, *Micrographia*, that contained detailed drawings of plants and insects that he called "minute bodies."

Hooke is not as well known as his contemporary, colleague, and rival, Isaac Newton. However, his contributions to the field of experimental science are well documented. The fact that he had to contend with a contemporary who wanted to discredit him and his work is a subject for class discussion. Students could think about other famous men and women in history who may have had to deal with this type of situation. For example, Rosalind Franklin who worked with Francis Crick and James Watson. Although she was instrumental in the discovery of the structure of DNA, Crick and Watson are credited with the discovery and received a Nobel Prize for it.

Activity. Students research and present their findings on Robert Hooke and Isaac Newton. Presentations include who, what, why, when, and where; in particular, students should note contemporary current events, linking scientific accomplishments with political and social happenings. For example, Isaac Newton's scientific gift emerged during a time that he was self-taught, studying at home for 2 years while Trinity College at Cambridge was closed because of an outbreak of plague.

ARTIST VIGNETTE: M. C. ESCHER

M. C. Escher's graphic work is popular on t-shirts, ties, and other items of apparel, so it may be familiar to some of the students. The images are easily obtainable so Escher would be an appropriate artist to introduce with this activity. The book, *M. C. Escher: The Graphic Work* (Barnes & Noble Books, ISBN 1-56619-789-9), contains an introduction written by the artist and illustrations of many of his most famous works.

Maurits Cornelis Escher (1898-1972) studied graphic arts in the Netherlands and created his works based on different ways of looking at things. In particular, he discovered that drawing figures that were impossible based upon the laws that govern how things work was particularly challenging. Escher was not a good student and lived for the 2 hours each week that he was instructed in art. In fact, Escher never graduated and repeated grades two times. Even the artwork that he submitted for a final grade was not thought of as good enough to receive the highest grade. Escher's father still believed, however, that his son could and should become an architect. In 1919 he entered the School of Architecture and Decorative Arts in Haarlem, The Netherlands. Escher traveled extensively with other artist friends sketching and creating woodcuts for which he would later become famous.

Activity. Although some of Escher's prints are disturbing, particularly for young children, others, like "Dewdrop" fit in very well with the Perspective Activity. His work "Puddle" could be used as a starter for a story about "What happened here?"

Research. There are also several web sites featuring Escher prints where students can access the images directly. As usual, it is recommended that you thoroughly explore any web sites that you recommend to students.

ACTIVITY 1
Perspectives - Powers of 10

In this activity, you will be looking at things in different ways. Scientists look at things using special tools like microscopes, or tools that might surprise you, like eyeglasses or hand lenses. Some things are so small that scientists must use powerful microscopes and some things are so large or so far away that they need a powerful telescope. Imagine what it would be like to be a flea on a dog's back or the giant in Jack and the Beanstalk walking through a normal-sized village. What would things look like to the *Indian in the Cupboard* or *The Borrowers* who live under the floorboards?

Materials:

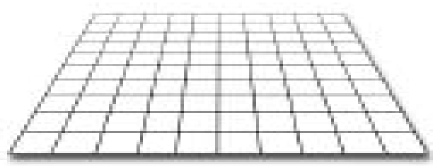
- ❑ Pre-cut butcher paper, bulletin board paper, or the end roll of newsprint from a local newspaper (1M square)
- ❑ Meter stick, tape measure, or other measuring device (even string cut in equal lengths will do)
- ❑ Your Science Notebook
- ❑ Crayons, markers, or pencils
- ❑ Assorted objects, such as leaves, notebook paper, photographs
- ❑ Hand lens
- ❑ Field microscope

1. With a partner, take your piece of paper that has been cut to measure 1 meter square and trace a person's body outline near the edge of the paper.

2. Choose an object for each of you. This could be a large leaf that you bring from home or gather in the schoolyard, an article from a newspaper, a photograph, or a large flower like a sunflower. Trace it on the same paper near the body outline. Put as much detail on the drawings as you can.

3. Now, divide your paper into 10 equal parts by moving around the paper and making a mark every 10 centimeters on the edges of the paper. Use your tape measure or other measuring device to do this.

4. Connect the marks so that you have 10 vertical lines on the page and then 10 horizontal lines. You now have a "grid" with 100 boxes of equal size.



5. Look at *one square* and draw what you see in your Science Notebook.

6. In your Science Notebook, answer these questions:

   How is what you see in the small square different from what you saw in the larger square? Why do you think your drawings are different? What would happen if we divided the paper into even smaller boxes?

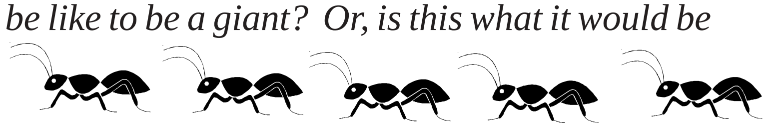
7. Choose 1 square that has something drawn on it and cut it out. Draw a person in that square like you did at the very beginning with the large piece of paper.

   What do you see now? Do you have to move away from or closer to something for it to look bigger?

8. Take your small square (the one you cut out) and divide it into 10 equal parts by making a mark at each centimeter (1cm) all around the paper.

9. Draw a picture of a person in this little box. [You should have a picture of a person and a piece of the object that you had drawn at the beginning.]

   Is this what it would be like to be a giant? Or, is this what it would be like to be an ant?



ACTIVITY 2

K-W-L: WHAT I KNOW, WHAT I WANT TO KNOW, WHAT I LEARNED.

A STRATEGY FOR LEARNING.

The K-W-L chart can be used to help students clarify their ideas about difficult concepts and take responsibility for their own learning. It is also an opportunity for teachers and students to look at possible misconceptions and use them as a vehicle for asking questions and finding ways to answer them. A simple, yet effective strategy, the chart itself is divided into three columns: K – what I know, W – what I would like to know, and L – what I have learned. Students create the charts and keep them accessible so that as they work on light and optics, they can enter new ideas, new information, and new questions at any time.

K W L

In this activity, students will make entries on their K-W-L charts about lenses. Since you have already completed Activity 1, students have probably already discussed microscopes, telescopes, binoculars, and other devices that assist us in seeing things that are very small or very far away. Some students will have quite a large number of entries for their K-W-L charts; others will have fewer, but may have more questions in the W column. Encourage students to make entries in the W column in the form of questions, further emphasizing the process of asking and answering questions in special ways with special tools. Students should be motivated to make additions to their K-W-L charts as the unit progresses.

The K-W-L can be used as a culminating activity, having students enter what they think they have learned at the end of one of the activities or at the end of the entire unit of study. This strategy can be used with other areas of study and is an ongoing assessment of student mastery of difficult concepts. A sample K-W-L chart is included with the student page of this activity.

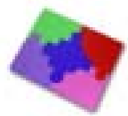
MATERIALS:

- ☐ K-W-L Charts
- ☐ Science Notebook

Assessments. Check K-W-L charts either periodically or at the end of a set period of time. From time to time, however, remind students to write on their charts so that they will not have to try and remember everything at the end when you are ready to assign a grade. If students are filling in their charts in a way that makes sense to them and they can discuss their ideas with you, then they have successfully completed this task.

Students can share K-W-L charts with one another. For younger children, making a K-W-L chart on butcher paper on their table or desk so it is accessible as they are working might be helpful. Completing a class K-W-L with children who cannot write may help some students to articulate their ideas by talking them out with others.

Have students react to each other's K-W-L charts by answering the following questions in their Science Notebooks: (1) How is your K-W-L chart like your classmate's? (2) Are there changes that you wish to make on your chart? What are they and how can you change it? (3) What information is missing from your K-W-L that would help you?



EXTENSIONS:

Expanding the K-W-L. You can add a column to the K-W-L chart in which students identify sources for answering their questions. It then becomes a K-W-W-L, adding "Where I can find the information." For some students, this would be listing books, magazines, people, or places where they could find answers to their questions; it could also be a list of web sites students have accessed to find information.

Research. Have students design a plan for gathering the information that would help them answer their questions. Putting something in the W column that a student wants to learn about serves no purpose unless the student has a strategy with which he or she can find the answer. A research plan or list of possible ways to find the information will help some students begin their search for answers.

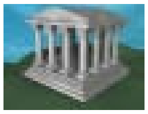
Presentation. Students design a way to present their completed K-W-L chart to the whole class, to a group of students, or as part of a class poster session. If you are doing a class K-W-L, students may wish to present their findings to other classes or to younger students. This will encourage others to ask questions and students will have to explain their findings. When all students have had a chance to see what others have done, brainstorm a class list of questions that remain unanswered. Use this list for students to plan and implement a way to test ideas and answer questions.

Expository writing:

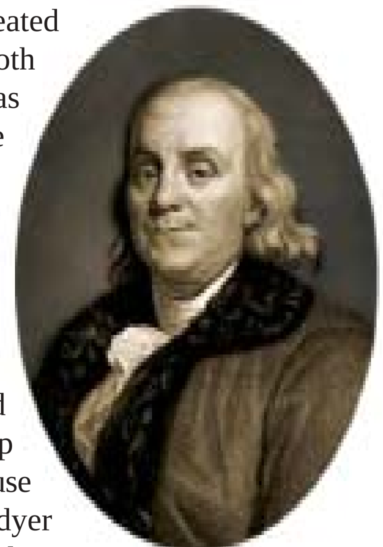
> *Scientists ask and answer questions.*
> *Choose one question from your K-W-L chart and think about how you answered the question.*
> *Write a description of how you discovered the answer to your question.*

Narrative writing:

Lenses are used in many different ways, for example in glasses, contact lenses, or binoculars. Imagine that a person put on the wrong glasses and saw everything much larger than it really is. Write a story about the kinds of adventures this person with the wrong glasses would have.



HISTORICAL VIGNETTE: BENJAMIN FRANKLIN (1706-1790)



Benjamin Franklin is known for many inventions, sayings, and accomplishments. One of his inventions, the bifocal lens, was created because he became frustrated when he discovered that he was both near-sighted and far-sighted. He had two pair or glasses and was constantly switching from one pair to the other until he cut the lenses of both pairs in half and mounted one on top of the other in one frame. Then he could read small print and see objects far away with the same pair of glasses. As is often the case, an inventor created a new product because of a problem that needed to be solved.

Benjamin Franklin was the son of an Englishman who left England for America in 1683. Benjamin's father became a candle and soap maker reacting to a need for these items among the colonists. Because he had to change his occupation to earn a living (he was a textile dyer in England), Benjamin's father insisted that each of his sons learn a marketable trade. Benjamin showed the most promise of the Franklin children and so was enrolled in school at the age of 8. However, he had difficulty in mathematics and had to be withdrawn from school and served as an apprentice in the printing business.

Benjamin's older brother, James, was already in the printing business, so Benjamin's father saw this as a way for him to blend his love of books and reading with a trade. Through his brother's connections with booksellers, Benjamin began reading the classics in literature and philosophy, learning as he apprenticed. His cleverness and talent contributed to his brother's success when he established a new newspaper, the *New England Courant.* When he was only 16, Benjamin wrote stories using the pseudonym Silence Dogood and slipped them under the door of his brother's newspaper. No one knew who the author was, but the articles were published and made the newspaper, and Silence Dogood, famous. Benjamin left Boston and his brother's shop and went to Philadelphia after his brother's jealousy over Benjamin's success led to a fistfight between the two boys.

Franklin used his skill as a printer to find work in Philadelphia and, through a series of events that could only be termed serendipity, Benjamin became a success. Benjamin married and started his own printing business. He had a long and full life as a international diplomat, scientist, printer, statesman, philosopher, musician, and economist. Franklin's experiments with electricity are well documented as are his many inventions that include the Franklin stove, catheter, and the lightening rod.

Activities. Encourage students to read *Ben and Me : A New and Astonishing Life of Benjamin Franklin As Written by His Good Mouse Amos* (ISBN 0316517305) by Robert Lawson. This is the "true" story of Benjamin Franklin and his many adventures and accomplishments as told by his mouse-friend, Amos. Students can discuss the biography genre and how it can be accomplished with humor and fun.

Have students choose a famous person and imagine what pet that person would have. Then, students can write a story about something that happens to that person from the pet's point of view. Encourage students to include events that they have researched to provide a feeling of realism to their writing.

ARTIST VIGNETTE: JACQUES-LOUIS DAVID (1748-1825)

Jacques-Louis David was chosen for this vignette because of the influence of political events upon his work. His art was used for political means, preserving major events and prevailing attitudes at the time of the French Revolution. After being imprisoned for his participation in political rallies and voting for the King's execution, David was released because of his loyalist wife's influence. After his release, David transferred his efforts to painting Napoleon and his exploits. When Napoleon was defeated at Waterloo in 1815, David fled to Brussels, where he died ten years later.

David's work is filled with minute detail of political life in France around 1800. However, his attention to detail did not always portray reality. One famous work, *Napoleon in His Study*, is David's interpretation of Napoleon. The furniture and surrounding accessories are true to the style of that time.

David's works are housed in the Louvre Museum in Paris, in the National Gallery in Washington, DC, and in the Musée Royale des Beaux Arts in Brussels. David combined portraiture with the neoclassical style of painting, contributing to the establishment of what is known as the French Empire style.

Activity. Have students choose a contemporary or historical political person that has commissioned a portrait. Either have students create the portraits *or* have students plan the portrait, determining surroundings, furniture, accessories, or important documents that they may wish to have in the portrait. Then, students should be able to explain to others the importance of each element of the painting and how it characterizes the subject. [In fact, the portrait of Napoleon discussed above was commissioned by an Englishman who was trying to gain Napoleon's favor in hopes of having the Stuarts restored to the British throne.]

Activity 2

K-W-L: What I know, What I want to know, What I learned.

A strategy for learning.

The K-W-L chart is a way for you to put in writing some of your ideas about lenses. You will be using this chart from time to time, so leave yourself plenty of room for adding and taking away ideas, questions, and information. The chart has 3 columns: K – what you already know about lenses; W – what you would like to know about lenses; and L – what you have learned about lenses. The L column gets filled in as you discover new things, so at first, it will have a lot less in it than the other columns.

1. Design your K-W-L chart. If you have already done this, or if your teacher has given you a chart, make sure that you have enough room to use it for a long time. [You can design your K-W-L chart in a variety of ways. Be creative. Ask your teacher or Media Specialist for some suggestions.]

2. In the K part of your chart, write the things that you think you know about lenses. Don't worry about being right or wrong!

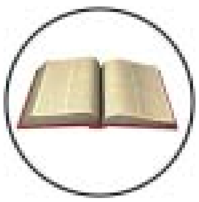
3. Now, under the W section, enter any questions that you have about lenses. Also list types of lenses that you may wish to learn about (for example, contact lenses or wide-angle lenses). In your Science Notebook, list ways that you could answer these questions or find more information.

4. The L column is where you will put things that you have learned. For example, if you asked the question, "How do contact lenses work?" you can put the answer to this question in the L column. As you fill in the L column, you may have even more questions that you will put in the W column.

ACTIVITY 3

Using Media to Explore Light & Optics

As science educators, we ask our students to take the information we provide in the classroom and use it to interpret their world. In the study of light and optics, we are dealing with people and subjects that appear frequently in newspapers, magazines, on radio or on television, as well as online via the internet and e-mail. Add to this the fact that young people are frequently targeted by media because of their buying power. According to Consumer's Union, young people from 6-12 spend nearly $11 billion annually; children 13-17 spend $57 billion *of their own money*, and about $36 billion of their parents' money.



Combine the marketing value with the fact that most of the information that we get about the world is supplied in some form to us by the media and we have an area that is ripe for misinterpretation and misunderstanding. Helping students analyze, evaluate, and interpret the messages to which they are constantly exposed and helping them to create new messages becomes a mandate for teachers. These are skills which are assessed by standardized tests that are used by policy makers and the general public to evaluate school progress.

This activity provides you and your students with some basic information about news reports and advertisements, some suggested strategies for incorporating the newspaper and magazines into the science classroom, and ways to integrate the skills used to analyze and interpret messages into other subject areas. Activities and Extensions can be used throughout the *Science, Optics & You* materials or can stand alone with this or other units of study.

Some information and suggestions were found in *Mastering the Message* and *Messages and Meanings*, publications sponsored by the Newspaper Association of America Foundation, and "Using the Newspaper in Secondary Science," by Dr. John Guenther and Dr. William LaShier, The University of Kansas. How you use this activity will of course depend on the level of your students, but even the youngest students can benefit from discussing how to interpret the great variety of messages to which they are exposed.

News Reports are reports, columns, and features found in newspapers that inform, entertain, and persuade. Students cannot, of course, control the content or the tone of news reports, so they need strategies to help them analyze and interpret what they read and hear. The three main types of news reports are described below.

Informational news reports:
- Address the 5 W's and the H (who, what, why, when, where, and how)
- Present interesting details in an organized way
- Identify sources
- Support the main idea with quotes and information
- Include commonly-used words to help explain technical or subject-specific terms
- Utilize a consistent style

Articles written for entertainment:
- Address a specific audience
- Support the main idea in an interesting or entertaining way
- Use entertaining vocabulary
- Present an organized piece of writing in an creative way
- Present unusual stories or information

Articles written to persuade:
- Capture the reader's attention by using persuasive words
- Identify a specific topic, opinion, theory or idea
- Include strong arguments
- Combine facts with personal opinion
- Present a well-organized sequence of ideas

News reports differ from advertisements although advertising uses persuasive writing in ways that sometimes makes us think they are really news reports. Children need to be aware of the fact that an advertisement is *always* there to convince them to buy something. Advertisements have the following easily-identifiable features:
- Capture your attention by presenting a product in a desirable way
- Present information
- Encourage you to take action
- Make you feel positive about a specific product or activity

Materials:

- ☐ Newspapers, magazines, or predetermined newspaper articles and advertisements
- ☐ Science Notebook
- ☐ Supplies for creating presentations

WHAT WILL THE STUDENTS DO?

Students will be doing one or more of the suggested activities. The Student Page provides alternative activities for students to complete. Some activities are best suited to individual work and others, for example creating a public relations campaign, are better suited to collaborative groupwork. The Student Page gives students choices so that issues of not receiving newspapers or magazines, or not having a television at home will *not* dictate the way you use this activity, nor will it exclude students for those reasons. Regardless of the nature of the work that students are assigned, it is important that they continue to ask and answer questions, and relate what they are reading and experiencing with their study of light and optics. Some of the activities refer to specific inventors, artists, or historical figures. Most of these are included in the artist and historical vignettes that accompany each of the activities.

EXTENSIONS:

<u>Research.</u> Have students identify and investigate people who have had an influence on mass media *or* people who either invented an optical device or developed a technique or theory that relates to light and optics. Then, students can look at how mass media would have affected the development and marketing of that device. For example, when Galileo built and tested his telescope, only men of science or those of great wealth could own an instrument like that. His discoveries and observations led to a controversial way of viewing our world. If there were newspapers that could publish word of his great invention, how would this affect the public acceptance or rejection of his ideas?

<u>Writing.</u> Students create their own light and optics newspaper or magazine that explains some of the major concepts in this unit. For example, a headline might read, "Scientist Discovers How Rainbows are Formed!" The story that follows would include the students' explanation of how water droplets act like prisms and separate the colors of sunlight.

<u>Art.</u> Have students create a cartoon that represents one of the concepts they have learned about in studying light and optics. The cartoon could be a cartoon strip, a comic book, or single frame (like *Dennis the Menace*). You may wish to have the students exchange cartoons or have an exhibition of work that is viewed by all. Encourage students to explain how they created their cartoon and why they chose the concept to represent.

<u>Current Issue.</u> Students identify an issue related to one of the activities (for example, moving lighthouses that are in danger of falling into the ocean because of coastline erosion) and learn more about it, report it to their classmates, and discuss how it relates to the study of light and optics. Along with the reporting, students should identify *why* it is a newsworthy event or issue.

Activity 3

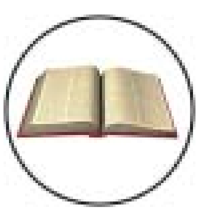
Using Media to Explore Light & Optics

Much of the information that you get comes from the media — newspapers, magazines, radio, and television. You are the focus of the media because of your "buying power." Young people from ages 6-12 spend nearly $11 billion each year. Children between the ages of 13 and 17 spend $57 billion of their own money and about $36 billion of their parents' money. Because you are the focus of so much media attention, you need to become a good consumer of information, just like you would be a consumer of toys, food, or games.

Since you are studying light and optics (for example, light, lenses, color, shadows, mirrors, and rainbows), this will be the main thing that you will think about when you use newspapers, magazines, television, or radio to complete these activities. You will choose one or more ways to look for how the topic of light and optics is found in the media.

Remember: If you choose an activity that requires you to watch a *news program*, that does *not* mean a talk show like Rosie O'Donnell or Oprah Winfrey. It is *not* a news magazine show like *Dateline* or *20/20.*

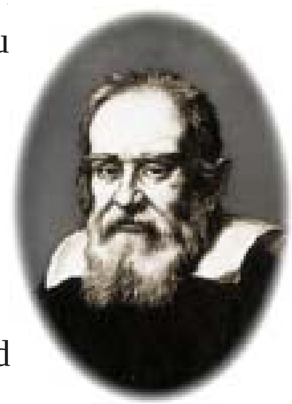
1. Use the newspaper to find ads for instruments or electronic equipment that use lenses or optical tools to work. For example, DVD players, video recorders, optical scanners, or digital cameras. Cut out the ads and glue them in your science notebook. Answer these questions: Do the ads say anything about light, color, lenses, or optics? Why do you think information about light, lenses, color, or optics is needed or not needed for people to want to buy this product? How would you write the ad?

2. Find all the ads that you can about one type of instrument or piece of electronic equipment that use lenses or optical tools to work. For each of the ads or articles, answer the following:

   - Who are these ads designed for?
   - Would this ad be used anywhere, or just in your community?
   - How does the company get your interest?
   - Would you buy the product? Why or why not?

3. Design an advertisement for Galileo's telescope. Before you begin, think about these questions and write your answers in your Science Notebook. If Galileo had a newspaper or magazine in his town in Italy, how do you think he would advertise his new invention? Would he want *everyone* to have one, or would Galileo want only a few people to be able to have a telescope? What features of the telescope would Galileo want to show off? What kinds of things would people expect to see if they bought a telescope?



Galileo

4. Look in the newspaper for articles or advertisements about new kinds of eye surgery. Radial keratotomy and lasix surgery are two ways to correct vision and laser surgery is used to remove cataracts so that people can see clearly. Think about how these new types of surgery have changed to way people think about glasses and contact lenses. Underline or highlight parts of the articles or advertisements that you think are hard to understand. Answer the following question in your Science Notebook: What kinds of things about light and lenses should a person know when he or she is trying to understand about the choices for correcting vision?

5. Each day in newspapers, in magazines, on television, and on the radio, people are talking about our planet, the stars, our universe. One of the reasons that this is so interesting for a lot of people is that we have very good equipment that helps us look at stars, planets, moons, rings, and distant galaxies. For example, almost every day since it was launched and placed in space, the Hubble Telescope has been in the news. Find as many articles as you can that discuss new ways of looking at our universe. Cut out the articles, put them in your Science Notebook, and answer the following questions:

- Why is this article interesting enough to be in the newspaper?
- Why is it so important for us to learn about what is happening in space?
- How do lenses, light, and colors help us learn about the universe? [To answer this question, you may have to look up information about colors of stars, distances between stars and planets, and how fast or slow things are moving in the universe.]

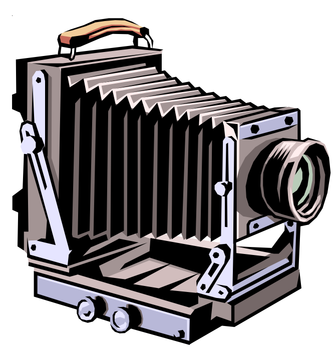
6. Write a newspaper or magazine story about a person who has used light, color, or optical instruments to change the world around us. Remember to use the 5 W's and the H (who, what, when, where, why, and how). You can choose a famous inventor, like Thomas Edison or Benjamin Franklin, or an artist who used color and light in new ways, like Leonardo da Vinci. Or, you can write about a style of painting, like pointillism or impressionism.

7. Develop a public relations campaign for an optical invention that has changed our world. It could be an invention from a long time ago, like the microscope, or it could be a recent invention, like fiber optics. A public relations campaign does the following:

   - always says positive things about the client
   - stands for a certain point of view
   - uses many different media to get the message out: bumper stickers, radio and television messages, brochures, stickers, buttons, debates, town meetings, videos, etc.
   - usually has a slogan, song, or jingle

   When you have chosen the product, theory, or point of view that you wish to support with your campaign, plan your strategy and remember, you will be presenting this to your classmates.

8. Photographs are a major feature of newspapers and magazines. Sometimes people read articles because a photograph has caught their attention. The art and technology of photography continues to grow and change based on new ways to use lenses and new technology for cameras. Look at a newspaper or magazine and think the following questions (you may have to do some research). Answer them in your Science Notebook.



- Before cameras, were there newspapers?
- Did newspapers have illustrations before photographs were used?
- How do photographs change the way people read and understand news articles?
- How would newspapers be different is photographs were not used?
- What kinds of photographs do *you* like looking at in the newspaper?

9. Many photographs that are used in newspapers are prepared on computers. Computers “digitize” images that are sent to newspapers all over the world via satellite. Local photographs can be scanned into computers and can be changed by the person at the newspaper in charge of getting pictures ready to be printed. Sometimes the images are changed, words or parts of pictures taken out, colors changed to bring out a certain part of the photograph, or even taking out words that appear in the photograph on clothing or pieces of paper that someone is holding. When you read the newspaper, do you think you should be told if the photograph has been changed? With your classmates, discuss whether you think photographs used in news stories should be changed, if they are changed, should the reader be told, and who should be in charge of deciding whether photographs are changed? When you have brainstormed this with your classmates, write three paragraphs in your Science Notebook about how you feel about each of the three questions: (1) should photographs be changed? (2) who should change them? And (3) should the reader be told?

10. Contact your local newspaper. Find out how newspapers use color. When you look at a color photo or advertisement in a newspaper, sometimes the color seem to separate. (Be sure to get a newspaper so that you can observe first hand what it looks like before you write your questions.) Find out why this happens. In your Science Notebook, write down questions that you want to ask about using color in newspaper stories. After you interview someone at your local newspaper, write the responses in your Science Notebook also. Then, write what you think about the use of color in newspapers.

Student SELF-CHECK

MODULE 1: Thinking About Light & Objects

Now that you have completed Module 1, follow the directions below as a self-check to see if you need more practice.

1. Draw a horizontal line 4 cm long.

2. Draw a vertical line 5 cm long.

3. How many centimeters are on a meter stick?

4. If you wanted the biggest view of the eye of a bug, which instrument would you use, a hand lens or the field microscope?

5. If your hand lens is marked 10X, what does that mean?

6. Draw a square that is 2cm on all sides.

7. A field microscope can magnify things 100X. What does that mean?

MODULE m2

LIGHT AND LENSES



INTRODUCTION

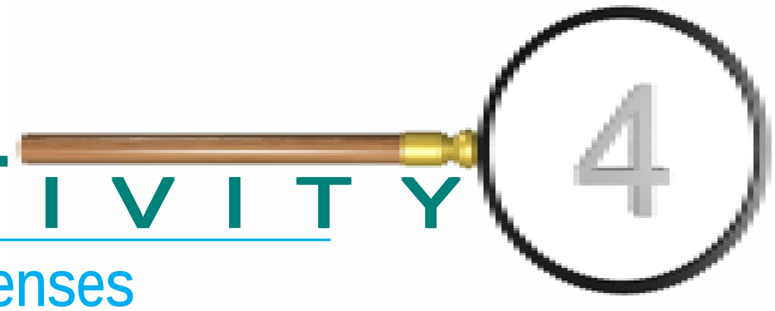
Module 2, Light and Lenses, is made up of two activities that introduce students to types of lenses and how light is focused in different ways when they use different lenses.

Activity 4: Exploring with Lenses
Activity 5: Looking Through Lenses

In Activity 4, Exploring with Lenses, students will be encouraged to use each of the lenses supplied in the Science, Optics and You package. Students will look at different images, use flashlights to see how light reacts with each of the lenses, and will be asked to draw and write about what they are observing.

Activity 5, Looking Through Lenses, allows students to explore the surface of the lens, focal point, and images that lenses produce. This is a good introduction to concepts of focal point and focal length and allows students to experiment with lenses before moving onto more complex manipulations.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Optical Light Bench, Simple Magnification, Magnifying with a Bi-Convex Lens, http://micro.magnet.fsu.edu/optics/tutorials/index.html



ACTIVITY

Exploring with Lenses

Using the sets of lenses in your package, students will be looking at each of the lenses, observing their similarities and differences, and experimenting with light as it passes through each of the lenses. Allowing students to find out for themselves the characteristics of differently-shaped lenses will help them in Activity 5, Looking through Lenses, when they work with only the convex and concave lenses.

Materials:

- ☐ Sets of lenses
- ☐ Science Notebooks
- ☐ Flashlights

What will the students do?

1. In pairs or small groups, students will look at various lenses.
2. In their Science Notebooks, students will write a description of what each lens looks like, what objects look like when viewed through the lens, and other information that they decide is necessary to enhance their understanding of how lenses change the way we look at objects.
3. Students will brainstorm with classmates about uses for the various lenses, answering the question, "How would a scientist use each lens?" and "What instruments can you think of that might use the lenses you looked at?"

EXTENSIONS:

Research. Have students use a variety of media to list scientific instruments and tools that use lenses. Students should list the types of lenses used in each and compare them to the lenses they looked at in this activity.

Research. There are hundreds of American women who kept the lamps burning in lighthouses. Most of these women served in the nineteenth century, when the keeper lit a number of lamps in the tower at dusk, replenished their fuel or replaced them at midnight, and every morning polished the lamps and lanterns to keep their lights shining brightly. Several of these women were commended for their courage in remaining at their posts through severe storms and hurricanes. A few went to the rescue of seamen when ships capsized or were wrecked. Their varied stories provide a unique picture of this profession in maritime history. Students can research and explore the lives of some of the more important women during this time, or excerpts from the book, *Women Who Kept the Lights: An Illustrated History of Female Lighthouse Keepers* by Mary Louise Clifford and Candace Clifford (ISBN: 0-963-64120-4) could be read to the students. After learning about these women, students could write a diary entry describing the daily life of a lighthouse keeper during this time.

Narrative writing. Use the following expository writing prompt.

> *Key West, Florida, has a Wreckers' Museum that tells about how early residents of Key West purposely tried to wreck ships.*
>
> *Think about reasons why someone who lived in an isolated area would want to wreck a ship.*
>
> *Now write a description of what you imagine life as a child of a "wrecker" would be like.*

Writing. Have students determine how life as a lighthouse keeper could be enhanced by technological developments of the last decade (for example, e-mail and the internet). How might life have been different for "wreckers?" Would lighthouse keeping be a more popular career choice if keepers had access to these technological advances?

HISTORICAL VIGNETTE: IDA LEWIS

Idawalley Zorada Lewis, called Ida, was born in Newport, Rhode Island, in 1842. Her father, Captain Hosea Lewis, was a coast pilot and became the first keeper of nearby Lime Rock beacon on a tiny island near Newport. Shortly after he started this job he had a stroke. Ida became responsible for the care of her father and of the light. She filled the lamp with oil at sundown and again at midnight, trimmed the wick, polished the carbon off the reflectors, and extinguished the light at dawn. After her father died, she received official appointment as lighthouse keeper and continued at that post until she died in 1911.

Schuyler Colvax

Because of the many rescues for which she was responsible, Ida became the most famous lighthouse keeper of her day. During her 39 years on Lime Rock, Ida is credited with saving 18 lives, although unofficial reports suggests that the number may have been as high as 25. Many of the newspapers and magazines of the day wrote stories about some of her rescues. President Ulysses S. Grant and Vice President Schuyler Colvax even went to visit her in 1869.

In 1881 the Annual Report of the U.S. Life Saving Service reported that the highest medal awarded by the Life Saving Service had been presented to Mrs. Ida Lewis-Wilson. Her last recorded rescue occurred when she was 63 years old.

In 1924 the Rhode Island legislature officially changed the name of Lime Rock to Ida Lewis Rock. The lighthouse service changed the name of the Lime Rock Lighthouse to the Ida Lewis Lighthouse, the only such honor ever paid to a keeper.

Activity. Research lighthouses and, if possible, take a field trip to a nearby lighthouse. Have students record similarities and differences among lighthouses that are found in different areas. Lighthouses in southern coastal states can be compared with lighthouses on New England's rocky coast. European lighthouses can be compared with American ones..

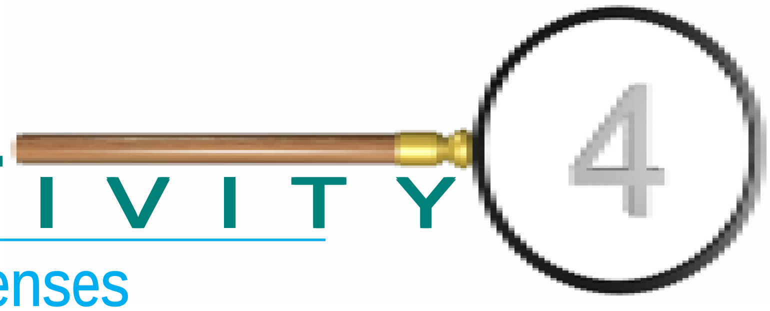
ARTIST VIGNETTE: WINSLOW HOMER

Winslow Homer (1836-1910) was an American artist most remembered for his New England seascapes. Homer worked in a variety of media. He created oil paintings of rural early America, was a magazine illustrator of Civil War scenes, and used watercolors to produce his heroic scenes of the sea. He created hundreds of works that are admired for their beauty and depiction of rural American life. Lesser known than his seascapes is a series of tropical watercolors that reflected his winter stays in Florida, the Bahamas, and Cuba.

Homer had a robust sense of humor that is well documented. When visitors came to his studio, he often made his own illustrations the butt of his jokes. Once he put a tin tag on one of his sketches as a hog's nose; when his visitor was not looking, the "nose" became a setting sun. At the beginning of a path that led to one of Homer's favorite spots to paint, Cannon Rock, he place a sign that said "SNAKES! MICE!" so that he would not be disturbed.

Homer's scenes of the sea can serve as a complement for a study of lighthouses as is recommended in this Activity.

Activity. Recently Bill Gates, Chairman of Microsoft, paid a record $30 million for Winslow Homer's last seascape still in a private collection, *Lost on the Grand Banks.* The sale was a private one and was kept a secret until the deal was struck. Have students debate the issue of private versus public art collections and the value of each. You may wish to divide your class into two groups and have them brainstorm the points that they will make in order to defend their position.



ACTIVITY
Exploring with Lenses

Each of the lenses that you will use in this activity is different. Observe how each lens is different from the others.

MATERIALS:

- ☐ Sets of lenses
- ☐ Science Notebooks
- ☐ Flashlight

1. With a partner, examine each of the lenses in your package, one at a time.
2. Look at different things around you with each of the lenses. Shine the flashlight on each of the lenses. Compare how things look when you look through each lens.
3. In your Science Notebook list each lens. Then, as you make your observations, write about each of the lenses.

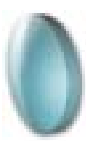
    How do things look through the lens?
    What happens to the light when you shine it through the lens?

4. Draw each of the lenses and label your drawing. Be sure to include a side (profile) view.
5. Write 5 sentences about lenses.
6. List any questions you have about lenses in your Science Notebook.

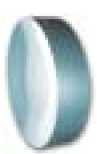
ACTIVITY

Looking through Lenses

A lens is a piece of transparent material with at least one curved surface. The curved surfaces refract, or bend, light rays coming from an object. There are two basic kinds of lenses: convex and concave. Lenses are important in optical devices that use light (including our eyes). Cameras, telescopes, binoculars, microscopes and projectors all use lenses.



Convex lenses are thicker in the middle than on the edges and cause light rays to converge or come together. Things look bigger through a convex lens. A convex lens will concentrate a beam of light on a surface causing it to appear brighter. Convex lenses can focus light and project an image. The point where light rays converge after passing through a lens is called the *focal point*. The distance from the lens to focal point is called the *focal length*.



Concave lenses are thicker on the edges than in the middle. They cave in toward the center. Things look smaller through a concave lens. Concave lenses make light rays bend outward or diverge. A concave lens will spread a beam of light on a surface.

MATERIALS:

- ☐ Plano-convex lens
- ☐ Plano-concave
- ☐ Flashlight
- ☐ White paper
- ☐ Science Notebook

WHAT WILL THE STUDENTS DO?

In this activity students will explore and discover the properties of the two basic types of lenses. Students can work individually, in pairs, or in small groups. This can be an activity guided by the teacher or students can work independently using the Student Page as a guide. After distributing the materials, allow students ample time to explore the materials freely.

Ask students to look closely at the lenses and describe how the lenses are shaped. Introduce the terms *convex* and *concave* for the two different types of lenses. As students discover new things about how we look at objects, have them write their discoveries in their Science Notebooks. Encourage students to do the following:

1. Look through the lenses at the pages of a book, a picture, their hands and other objects.

2. Shine a flashlight through the lenses onto a white piece of paper.

3. Repeat steps 1 and 2 above after combining the lenses.

Have students explain the differences in what they see. Introduce the terms *focus*, *converge*, and *diverge* for describing the properties of the lenses.

Students will demonstrate how a convex lens can focus light and project an image. Step #5 on the Student Page has students hold a convex lens between an upright piece of paper and the window in a darkened room with a sunlit window. Students place the lens close to the piece of paper and slowly move the lens away from the paper until a sharp inverted (upside down) image of the window appears on the paper. If a sunlit window is not available, students can use a flashlight and any object. Explain that the light causes the inversion of the image from the top of the object being bent and projected to the bottom of image and light from the bottom of the object being bent and projected to the top of the image.

Facilitate a discussion about the uses of lenses. Students should be able to identify a variety of uses including magnifying glasses, eyeglasses, microscopes, binoculars, telescopes, cameras and projectors.

Have students draw and label cross-sectional diagrams of the two types of lenses in their Science Notebooks. Have them describe in writing and with diagrams the projection of an image using a convex lens.

EXTENSIONS:

Research. Using a variety of print and electronic media students can research and write about the different types of lenses and why they have different effects on images that are seen through them. This could include answering the question, "Why do some people need to wear glasses?" and "What is the difference between being near-sighted and far-sighted?"

Activity. After researching how various optical devices work, students can make simple telescopes and microscopes using the lenses. Telescopes and microscopes can be made by using the convex and concave lenses, and cardboard tubes (an empty paper towel tube and a plastic wrap tube work well since one will fit inside the other). Rather than supplying step-by-step instructions, after students have completed this activity, see if they can design their own instruments. Books such as *The Optics Book* (ISBN 0-8069-9947-0) contain many activities that can be done using everyday items.

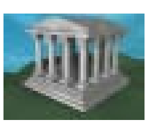
Activity. Students can study how the lenses of our eyes enable us to see. Students can be challenged to determine what causes near and far-sightedness. Invite an optician to be guest speaker so students can learn how lenses in eyeglasses are used to correct vision. Making a model of the eye and how it works would be an appropriate activity.

Expository writing. Use the following as an expository writing prompt.

> *Movie and slide projectors use lenses to project images on a screen. Think about your experiences with the lenses and how the shapes of lenses bend light in different ways. Now write a description of how lenses are used to project images on a screen.*

Narrative writing. Use the following as a narrative writing prompt.

Magnifying glasses and microscopes are sometimes used to investigate crime scenes. Pretend that an unknown thief has burglarized your classroom. Think of an unusual piece of evidence that could be discovered using a magnifying glass that would identify the thief. Now write a short mystery story about how the evidence helped catch the thief.



HISTORICAL VIGNETTE: AUGUSTIN FRESNEL

In 1822, a French scientist named Augustin Fresnel invented a lens that is now used in lighthouses around the world. The lens looks like a giant glass beehive with a lamp in the center. The lens is made out of rings of glass prisms above and below the lamp that bend and concentrate the light into a bright beam. The Fresnel lighthouse lens work so well that the light can be seen from a distance of 20 or more miles. Before Fresnel's invention, lighthouses used mirrors to reflect the light. These lights could be seen at only short distances and hardly at all during foggy or stormy days. Lighthouses with Fresnel's lenses have saved many ships from going aground or crashing into rocky coasts.

Activities. Lighthouses have always fascinated people. There are a number of books depicting the colorful history of lighthouses. Students can research the history of nearby lighthouses or historic lighthouses. Students can also research other uses of Fresnel lenses (for example, in stage lighting).

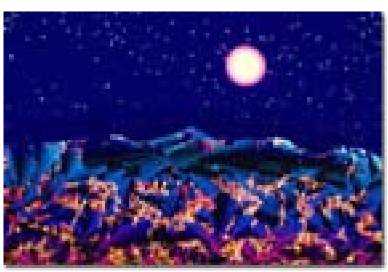
Reading. Students can read *Women of the Lights* by Candace Fleming (ISBN 0-8075-9165-3). This book is a compilation of the adventures of some of the 250 women who have served as lighthouse keepers in America.

Reading. Students will also enjoy *The Wreckers* by Iain Lawrence (ISBN 0-440-41545-4). This fast-paced adventure tells a story about shipwrecks, pirates, kidnapping, mystery and ghosts and courage. The story is historically based upon a community on the coast of Cornwall, England during the early 19th century. Wreckers used lights to lure ships to crash on their rocky shores and lived on the loot salvaged from the wreckage.

Florida History. Key West, Florida, was settled originally by "wreckers." A wreckers' museum exists there and there are many documented stories about how the area was settled. This is an opportunity to work Florida history and culture into your science curriculum.

ARTIST VIGNETTE: MICHAEL DAVIDSON

Microscapes: The Art of Photomicrography

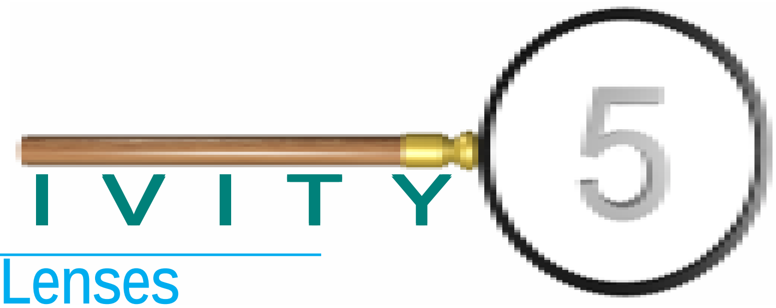


Michael Davidson is a scientist at the National High Magnetic Field Laboratory in Tallahassee, Florida, who has developed techniques for creating art photographs by taking pictures through a microscope. This is called photomicrography. Using polarizers, multiple exposures, and other techniques, Davidson has created unusual and colorful pictures that look like dream landscapes or alien worlds. He calls his creations microscapes.

Davidson uses microscopic images of real moon rock slices, vitamin C recrystalized crystals, proteins, DNA and other substances to create his microscapes. He combines these images into artistic creations with titles such as Black Hole in Space, Crystal Forest, Macdonald's on Mars, Mount Meatloaf, and Star Wars. You can see Davidson's creations on the Internet at: http://micro.magnet.fsu.edu/micro/gallery/microscapes/microscapes.html

Activity. After viewing Davidson's microscapes on the Internet, students can create their own microscapes using school microscopes or convex magnifying lenses. Have students examine everyday items such as fingerprints, leaves, a basketball, bark, or food items through the lens. If available, students can view the items through polarizers or a diffraction grating. They can then draw and color various patterns and textures that they see using crayons, markers or paints. Encourage students to be creative in the use of color and names for their microscapes.

ACTIVITY

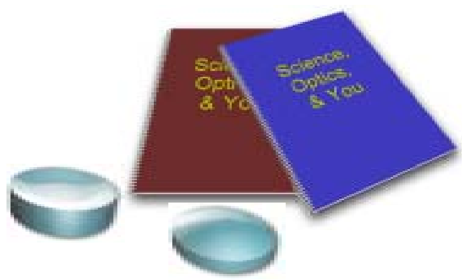


Looking through Lenses

A lens is a piece of transparent (see-through) material. Lenses are usually made out of glass or plastic and they have special characteristics some of which you explored in Activity 4, Exploring with Lenses. Now you will look at only two kinds of lenses and observe the similarities and differences.

MATERIALS:

- ☐ 2 Convex Lenses
- ☐ 2 Concave Lenses
- ☐ Flashlight
- ☐ White paper
- ☐ Science Notebook



1. Look closely at the lenses and answer these questions in your Science Notebook:

   How are they shaped?
   How are the lenses alike? How are the lenses different?

2. Look through the lenses at different things. Look at the pages of a book, your hands, a hair, and other things. Draw what you see in your Science Notebook and answer these questions. Label each picture with the type of lens with which you observed the object.

   How does a convex lens make things look?
   How does a concave lens make things look?

3. Lenses bend light in different directions. Shine a flashlight through the lenses onto a piece of white paper.

   In what direction do convex lenses bend light?
   In what direction do concave lenses bend light?

4. Shine the flashlight through different combinations of lenses: two convex lenses, two concave lenses, one concave and one convex lens. Draw a picture of what you see in your Science Notebook and answer these questions:

   What happens? Can you use two different lenses to make things far away appear closer?

5. If you can, darken the room and place a convex lens between a sunlit window and a white piece of paper. Place the lens close to the paper then slowly move the lens towards the window. Draw a picture of what you see in your Science Notebook.

6. Design an activity for a younger student that would help you explain to them the difference between a convex lens and a concave lens.

Student SELF-CHECK

MODULE 2: Light and Lenses

Now that you have completed Module 2, follow the directions below as a self-check to see if you need more practice.

1. A window is transparent. What does that mean?

2. Which type of lens has a surface that is curved outward?

3. Which type of lens has a surface that is curved inward?

4. Name three instruments that use lenses?

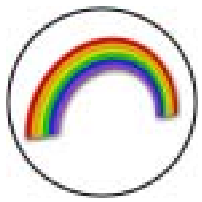
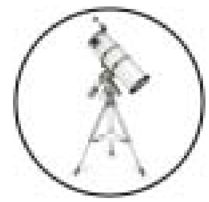
5. A magnifying lens is a convex lens; does it spread light out or bring light rays together to a point?

6. If you place a convex lens between a window and a white piece of paper, what happens to the image?

7. How do you bring an image into focus using a lens?

MODULE m3

MIRRORS AND IMAGES

INTRODUCTION

Module 3, Mirrors and Images, consists of two activities that facilitate students' discovery of the Law of Reflection and how light reflects off different surfaces.

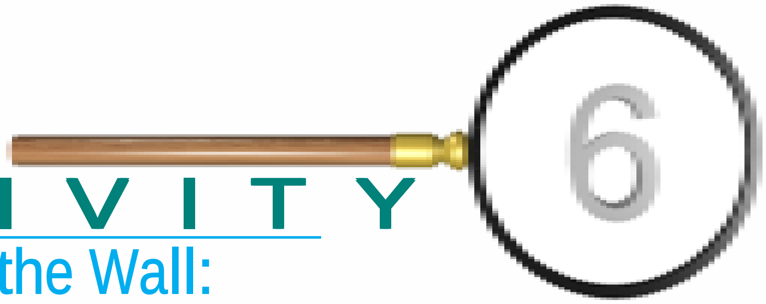
Activity 6: Mirror, Mirror on the Wall
Activity 7: Mirrors and Multiple Images

Activity 6, Mirror, Mirror on the Wall, will point students to Snell's Law (the angle of incidence equals the angle of reflection) in words that they can understand. Students will study how light reflects off mirrors to produce images. This incorporates math if you have students measure the angles using protractors.

Activity 7, Mirrors and Multiple Images, has students explore the relationship between the angle of a hinged mirror and the number of images produced.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Angles of Reflection, Refraction of Light, and Multiple Images, http://micro.magnet.fsu.edu/optics/tutorials/index.html

ACTIVITY



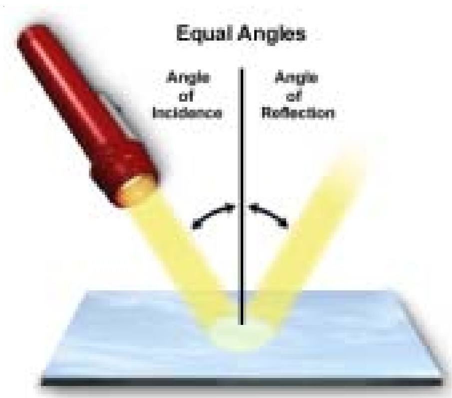
Mirror, Mirror on the Wall: Angles of Reflection

When light strikes a mirror it bounces off. This is called reflection of light. When you look at an object in a mirror, you are seeing the reflection of light from the object. Reflection involves two types of rays: the incoming or incident ray, and the outgoing or reflected ray. The angle between the incident ray and an imaginary perpendicular line drawn to the surface of the mirror is called the angle of incidence. The angle between the reflected ray and the perpendicular is called the angle of reflection. Light is reflected at the same angle that it strikes the mirror. The angle of reflection is always exactly equal to the angle of incidence. This is called the *Law of Reflection*.

In this activity, students will explore the law of reflection by trying to guess where two people must stand so each can see the other's reflection in a mirror.

MATERIALS:

- ☐ Mirror
- ☐ Masking tape
- ☐ Paper
- ☐ Science Notebook



What will the students do?

1. Students mount the mirror flat on a wall with masking tape. The mirror should be at eye level covered with a piece of paper.

2. Tape a 2-3 meter length of masking tape on the floor extending out from and perpendicular to the wall and centered on the mirror.

3. Students will work in pairs using the Student Page as a guide.

4. Students will be challenged to predict where **two people** must stand so each can see the other's reflection in the mirror.

5. Each pair will discuss and agree on the places where they think they must stand.

6. They will draw diagrams in their Science Notebooks to show the places they have selected.

7. Once students have determined where they will stand, they remove the paper from the mirror and test their predictions.

8. Pairs of students will continue doing this until they have found and marked the places where they must stand to see both reflections in the mirror.

Extensions:

<u>Measurement.</u> Show students how to use protractors to measure angles. Then have students design and construct large protractors out of cardboard to measure their angles of incidence and reflection. Draw and record results in student Science Notebooks. Each team of students should be able to explain to another group how they constructed the protractors and how they used the tools to measure the angles.

<u>Reading.</u> Either read aloud or have students read the fairy tale, *Sleeping Beauty*, or the story of *Alice in Wonderland* before they go onto the narrative writing prompt. Discuss ahead of time how mirrors are used in both stories and how the use of mirrors allows characters to see and do things they could not do in a real world.

<u>Writing.</u> Use the following as a narrative writing prompt.

In the fairy tale Sleeping Beauty and in the story of Alice in Wonderland, mirrors are magical.

Use your imagination and think about how mirrors could be used in magical ways.

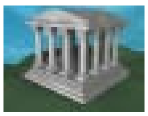
Now write a short story about your magical mirror.

Writing. Use the following as an expository writing prompt.

We know that light reflects off a mirror like a ball bounces off a surface. Think about how a basketball bounces off the backboard of a basketball goal.

Make up a game in which you use flashlights to reflect light off of a mirror onto a goal or target.

Now describe in writing how the game should be played. Include diagrams to help explain the game.



HISTORICAL VIGNETTE: EUCLID

Euclid and His Students

The ancient Greek scientist and mathematician Euclid was one of the first to explain how light reflects off a mirror. He lived 2300 years ago in Alexandria, Egypt. Euclid was very interested in learning about how light works, but he is most famous for his work in geometry.

Euclid started a school in Alexandria and worked hard to help his students learn. The young King of Egypt was one of his students. One day, the King asked Euclid if there was an easier way for him to learn geometry than by studying. Euclid answered, "There is no royal road to geometry" and sent the young King off to study.

There is another story about Euclid in which a student wanted to know what he was going to get for learning geometry. Euclid was concerned that this student felt that he needed to receive something for learning. So Euclid called his assistant and told him to give the student just a penny, since "he must make gain out of what he learns."

Research. Euclid was not the only scientist that contributed to our understanding of light and reflections. In the 1100s the Arab scientist Alhazen studied the reflection of light and came up with the law that describes exactly what happens to a ray of light when it strikes a surface and then bounces off of it. Using a variety of print and electronic media, students can research and write about the discoveries of Euclid and Alhazen.

ARTIST VIGNETTE: LEONARDO DA VINCI

This vignette is designed to be read aloud to the class. It can be used to introduce an activity on mirror writing or as a jumping off point for further research on Leonardo da Vinci. Although da Vinci was a prolific artist, inventor, architect, and engineer, little is known about Leonardo the person. This fact alone may pique students' curiosity and encourage them to further research.

Leonardo da Vinci was a great artist and scientist that lived from 1452 to 1519, during a time called the Renaissance. He was one of the greatest painters of the Renaissance. The Last Supper and the Mona Lisa are two of his best known paintings.

Leonardo was also a great engineer and inventor. He designed buildings, bridges, canals, forts and war machines. He was fascinated by birds and flying and drew designs of fantastic flying machines. Leonardo kept huge notebooks of his designs and ideas.

In his notebooks, Leonardo wrote using mirror writing, writing backwards from right to left, instead of from left to right. In order to read his writing, you can place a mirror beside the writing and read the reversed image in the mirror. No one knows why Leonardo wrote this way. Some people believe he was trying to keep people from stealing his ideas. Others point out that he was left handed which made it easier for him to write from right to left.

To this day, people enjoy looking through the fantastic notebooks of Leonardo da Vinci. You can find many books in libraries with pictures of his notebooks and paintings. There are also many Internet sites with more information about Leonardo, his art, his inventions and his mirror writing.

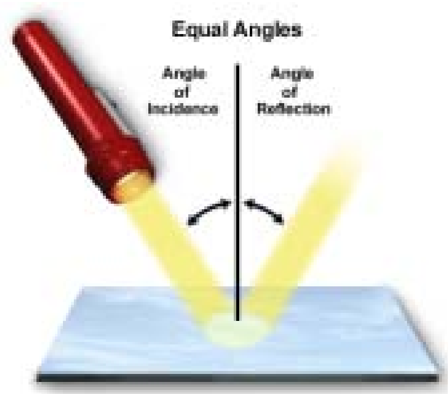
Activity. After reading aloud the vignette, challenge students to write their names backwards. Have students use mirrors to check to see if they correctly reversed the letters. Students can also use the mirrors as they are writing and write messages to their parents or friends. After looking at reproductions of da Vinci's notebook pages, challenge students to draw designs of fantastic flying machines or space ships. Have them label their designs using mirror writing.

Activity 6

Mirror, Mirror on the Wall: Angles of Reflection

Have you ever wondered why you can see your face in a mirror? Mirrors are very smooth and shiny. Light bounces, or reflects, off of the smooth and shiny surface of mirrors. When you see your face in a mirror you are seeing light from your face reflecting off the mirror.

Light bounces off mirrors very much like a bouncing ball. You can throw a ball straight down, and it will bounce straight back at you. Or you can bounce a ball at an angle and it will bounce off the floor at the same angle away from you. Light reflects the same way off a mirror. Light reflects from a mirror at the same angle as it arrives.



Materials:

- ☐ Mirror
- ☐ Masking tape
- ☐ Paper
- ☐ Science Notebook

1. Work with a partner to do this activity. Find a place where there is a wall with plenty of space around it. Attach the mirror flat on a wall with masking tape. The mirror should be at eye level. Cover the mirror with a piece of paper.

2. Now both you and your partner try to predict where you both need to stand to see each other's reflection on the mirror. When you both agree on the places, mark them on the floor with pieces of masking tape. Draw a diagram in your Science Notebook.

3. Now remove the paper from the mirror. Stand at your chosen places. Can you see each other in the mirror? Write several sentences in your Science Notebook about what you discovered.

4. If you cannot see each other, try different places until you can. Mark the places that work with the pieces of masking tape.

5. Now place long pieces of masking tape on the floor from the center of your place markers from step 2 to the wall straight under the center of the mirror.

6. Look at the angles made by the taped lines on the floor and the wall. Measure the angles with a protractor. Draw a diagram in your Science Notebook that shows the angles.

7. In your Science Notebook, write a description of what you did in this activity.

8. Compare your results with other students in your class and write down any questions that you still have about mirrors and reflections in mirrors.

9. With your partner, design a *different* way to show this same idea to a parent or friend. Record this in your Science Notebook.

ACTIVITY 7

Mirrors and Multiple Images

What is it that lets us see objects? If an object does not emit its own light, then it must reflect light in order to be seen. The walls in the room do not emit their own light; they simply reflect light from overhead lights or from window light. Polished metal surfaces reflect light quite similar to the silvering on the back of a mirror.



The reflection of light involves two rays, the incoming or incident ray and the outgoing or reflected ray. The law of reflection requires that two rays are at identical angles but on opposite sides of the normal which is an imaginary line at right angles to the mirror located at the point where two rays meet. Reflected light follows the relationship known as Snell's Law, which states that the angle of incidence equals the angle of reflection, as you and your students discovered in Activity 6.

Reflection of light from a smooth mirror-like surface, such as water, results in a clear image and is called specular. When the surface of a lake or pond is wind-blown, the incident rays strike the surface of the water at many different angles. As a result, the reflected rays produce an unclear image. The reflection of light from such a surface is called diffuse reflection.

Activity. To illustrate this concept, have students, take a piece of aluminum foil that is smooth and observe the clarity of the image. Then they roll the aluminum foil into a tight ball, open it back up, and observe the image. Have students record their observations in their Science Notebooks.

Brainstorming activity. Before beginning this activity, place students in small groups and have them list uses of mirrors, types of mirrors, or places they have seen mirrors. This is a good warm-up activity to encourage students to clarify what they learned in Activity 6 and to further extend their thinking about mirrors. You may want to have students create a K-W-L chart (See Activity 2).

MATERIALS:

- ☐ 2 mirrors
- ☐ Masking tape
- ☐ Paper
- ☐ Protractor
- ☐ Science Notebook
- ☐ Tape measure

Before you begin this activity, have your students "hinge" two mirrors using masking tape on the back or clear tape on the front.

WHAT WILL THE STUDENTS DO?

This activity builds on Activity 6: Mirror, Mirror on the Wall: Angles of Reflection.

1. Students will observe the relationship between the angles of two hinged mirrors and the number of images produced. On a piece of paper or cardboard, have students mark angles of 180 degrees, 90 degrees, 60 degrees, 45 degrees, 36 degrees, 30 degrees and 20 degrees.
2. Students will open the hinged mirrors to each of the above angles and place an object (for example, a paper clip or a coin) between the two mirrors. Students will then count and record the number of images they see at each of the seven angles.

WHAT IS HAPPENING?

When you put an object between the two hinged mirrors, light from the object bounces back and forth between the mirrors before it reaches your eyes. An image is formed each time the light bounces off a mirror. The number of images that you see in the mirrors depends on the angle that the mirrors form. As you make the angle between the mirrors smaller, the light bounces back and forth more times and you see more images.

EXTENSIONS:

<u>Activity.</u> A spoon is a good example of both a concave mirror and a convex mirror. Have students look at one side of the spoon. Have them write down in their Science Notebook what they see. (For example, they might say that the reflection upside down or right side up or that it is smaller or larger than their face?)

Turn the spoon around and make the same observations. The side of the spoon that caves in is called a **concave mirror**, and the side that curves outward is called a **convex mirror**.

Writing. Have students create a science fiction story that addresses the following:

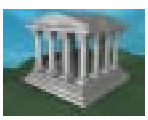
- science facts about mirrors, reflection, or lenses
- strange or unusual happenings
- human nature

For example, an alien lands on Earth and sees its reflection for the first time when it lands near a clear pool of water. Or, a young person finds a "magic mirror" that shows what it was like at different eras in history. The variations are endless!

Reading. Suggest the following books for students to read.

- *The Face in the Mirror* (ISBN 0688153941) by Stephanie Tolan. This book for young adults blends Shakespeare, a ghost story, and life in the theater. About a 15-year-old boy who is sent to live with his father who works in the theater.
- *The Secret of Mirror Bay* (ISBN 0448095491) by Carolyn Keene. A Nancy Drew mystery where Nancy and her friends investigate reports of a mystery woman gliding over the water at Mirror Bay.

Poetry. Copy the poem *I Am Your Mirror Image*, from *A Pizza the Size of the Sun* by Jack Prelutsky (ISBN 0-590-14963-6). The entire poem is written so it can be read when held up to a mirror. Have students use their mirrors to read the poem to one another.



HISTORICAL VIGNETTE: CAROLINE HERSCHEL

Caroline Herschel was born in 1750 to a working class family in Germany. When she was ten she became sick with Typhus and, from that time on, she thought her only option would be to become a servant. Typhus stunted Herschel's growth, and she never grew past four feet three inches. Her father was sure she would never marry because he considered her to be so ugly. Herschel's family was sure she would not amount to anything other than being a maid, and so she became one.

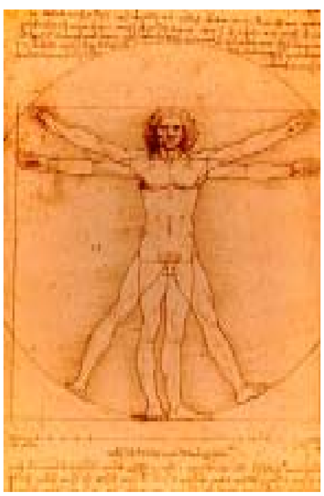
After a few years of being a maid, Herschel went to live with her brother, William. He felt sorry for her and needed a housekeeper. William was a musician but had developed a deep love of astronomy. William had the desire to see deep into space and the only way he could do this was by constructing powerful telescopes. After receiving a pension from King George III, William quit music to devote all of his time to making and selling telescopes. In time Herschel began to help him in his business. She spent long hours grinding and polishing the mirrors they used to collect light from distant objects. At the age of 32, she became an apprentice to her brother. As Herschel gained confidence, she became more and more of a help to her brother. Frequently when he would leave on business, Herschel would take over in his place. Visitors began to recognize her authority, and King George III gave her an annual pension of fifty pounds. This was the first time that a woman was recognized for a scientific position.

While Herschel lived and worked with her brother, she discovered eight comets, which was a great accomplishment in the late 1700's. Herschel received the Gold Medal of Science for her life's work from the King of Prussia and became an honorary member of the Royal Astronomical Society and the Royal Irish Academy.

Writing. Have students imagine a letter that Caroline Herschel would have written to her brother after she took over his work. What kinds of things would Caroline write about? Would she discuss household matters? Would she want to share her latest news about looking for comets? As an extension to this have students imagine that Caroline and William had e-mail and could communicate regularly. How would their correspondence be different?

ARTIST VIGNETTE: LEONARDO DA VINCI

Leonardo da Vinci (1452-1519), known as a genius of the Renaissance, was an artist, inventor, engineer, theatre designer, and architect. He is well known for his many notebooks and sketchbooks that continue to be used for study today. Leonardo's notebooks are significant because he did not only record his observations of natural phenomena, he attempted to figure out how things work. To explain his work, Leonardo wrote long descriptions that included diagrams of his scientific and mechanical projects.



Leonardo da Vinci wrote in Italian using a special kind of shorthand that he invented himself. People have long been puzzled by his use of "mirror writing" in his notebooks. His notes started at the right side of the page and moved to the left. Only when he was writing something intended for other people to read did he write left to right. Contemporaries of Leonardo recorded that they saw him write and paint left-handed. He also made sketches showing his own left hand at work. Being a lefty was highly unusual in Leonardo's time. Because people were superstitious, children who naturally started using their left hands to write and draw were forced to use their right hands. No one knows the true reason Leonardo used mirror writing, though several possibilities have been suggested:

- He was trying to make it harder for people to read his notes and steal his ideas.
- He was hiding his scientific ideas from the powerful Roman Catholic Church, whose teachings sometimes disagreed with what Leonardo observed.
- Writing left handed from left to right was messy because the ink just put down would smear as his hand moved across it. Leonardo chose to write in reverse because it prevented smudging.

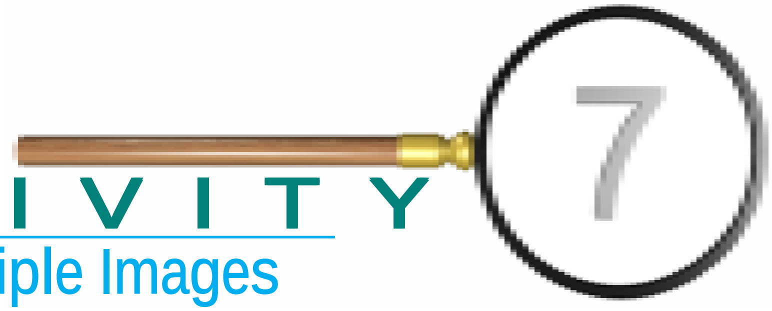
Mirror Writing Activity

Materials: paper, pencils, pens, markers and mirrors.

Procedure: Distribute paper and pencils and encourage students to try writing their signatures in cursive from right to left. If students have difficulty forming these letters in reverse, have them try the following: Hold a pencil in each hand. Write backwards with the usual writing hand while writing forwards with the opposite hand.

Have students write backward with pens and markers to make comparisons. Is one kind of writing tool easier to use this way than another? Distribute mirrors and show students how to position them to one side of there backwards writing to read it normally. A mirror also lets them check to see if they actually reversed all letters. Have students try writing reverse messages to a partner who can then decipher them with a mirror.

Follow-up discussion. Ask students if the type of writing implement made a difference in the ease of mirror writing. You may also see if anyone was left handed in the class and whether it was easier or harder for them to do the mirror writing. Have students hypothesize why they think that Leonardo used this technique in his notebooks.



ACTIVITY

Mirrors and Multiple Images

What is it that lets us see objects? If an object does not put out its own light, then it must reflect light in order to be seen. The walls in the room do not put out their own light; they simply reflect light from overhead lights or from window light. Polished metal surfaces reflect light like the silvering on the back of a mirror.

When you put an object between two hinged mirrors, light from the object bounces back and forth between the mirrors before it reaches your eyes. An image is formed each time the light bounces off a mirror.

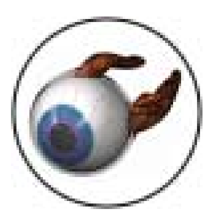
In this activity you are going to be investigating how the angle between two hinged mirrors determines the number of images you see.

MATERIALS:

- ❑ Mirrors
- ❑ Masking tape
- ❑ Paper
- ❑ Protractor
- ❑ Pencil or some other object such as a coin or paper clip
- ❑ Science Notebook

1. Work with a partner. Take two mirrors; place them together with the shiny sides facing one another. Tape them along one side to form a hinged door. The mirrors should be able to open freely like a book.





2. Take a piece of paper or cardboard. Using a protractor, measure and mark angles (by drawing a line) of 180 degrees, 90 degrees, 60 degrees, 45 degrees, 36 degrees, 30 degrees and 20 degrees.

3. Place the hinged mirrors at each of these angles and put an object (it could be a coin, a pencil, an eraser, or some other item you may have at your desk) between them as close to the mirrors as possible.

4. Count the number of images you see and record your observations in the chart below.

Angle between mirrors	Number of images	Observations

Answer the following questions in your Science Notebook:

1. What happened to the number of images you saw as you changed the angle from 60 to 45 degrees between the mirrors?

2. What happened to the number of images you saw as you changed the angle from 30 degrees to 60 degrees?

3. What can you say about the angle of the mirrors and the images that are produced?

4. Compare your chart with the charts of other groups. How were they alike? How were they different?

5. If you were to do this experiment again, would you change anything? What did you discover from doing this activity?

Student SELF-CHECK

Module 3: Mirrors and Images

Now that you have completed Module 3, follow the directions below as a self-check to see if you need more practice.

1. When light strikes a shiny surface such as mirror, what happens to the light?

2. What instrument would you use to measure angles?

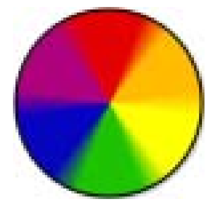
3. Light hitting a mirror behaves like a ball hitting a wall. Explain what this means.

4. If you had two hinged mirrors with a paper clip in front of them, would you see more paper clips with 45 degrees between the two mirrors or would you see more paper clips with 20 degrees between the mirrors?

5. Name 3 uses of mirrors.

MODULE m4

LIGHT AND COLORS



INTRODUCTION

Module 4, Light and Colors, encompasses three activities that help students explore, investigate and understand the relationships between visible light and color. Visible light as a form of energy is addressed in Activity 10.

Activity 8: Light, Prisms, and the Rainbow Connection
Activity 9: Investigating the World of Colors
Activity 10: Using Centers to Investigate Special Properties of Light

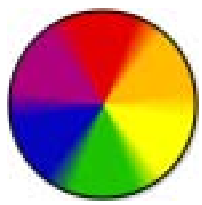
In Activity 8, students use prisms to separate visible light into its component colors. Using Activity 9 students study the primary colors of pigments and use a color wheel to help them understand the relationship between the primary colors and secondary colors. Students will also do an experiment to discover how their eyes see color. Activity 10, Discovery Centers, provides you with an outline of 6 different classroom centers to help students learn about the special properties of light, including visible light as a form of energy.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Newton's Prism Experiments, Light and Color, Moire Images, Optical Illusions, Color Separation, and Polarization of Light, http://micro.magnet.fsu.edu/optics/tutorials/index.html

ACTIVITY 8

Light, Prisms and the Rainbow Connection

White light is made up of all the visible colors in the electromagnetic spectrum. It is possible to separate the colors of white light with a prism. As light passes through a prism, its speed changes and it is bent, or refracted. Because of the angles and plane faces of the prism, each frequency of light is refracted by a different amount. Violet has the highest frequency and is refracted the most. Red has the lowest frequency and is refracted the least. Because each color is refracted a different amount, each bends at a different angle resulting in a fanning out and separation of white light into the colors of the spectrum.


The color spectrum is actually a continuum of color from red to violet, but the following colors are conventionally identified in the order that they appear: red, orange, yellow, green, blue, indigo, and violet. A way to remember the order of the colors of the spectrum is with the mnemonic name: ROY G. BIV.

How are rainbows made? Water droplets in the air can act like prisms and separate the colors of sunlight producing a spectrum known as a rainbow. To see a rainbow, you have to be standing with the sun behind you. The sunlight shines into water droplets in the air, bending as it moves from the air into the water, reflecting off the sides the drops, and bending again as it exists the drops separating the sunlight into the colors of the spectrum.

In this activity, students will observe white light passing through a prism and separating into the color spectrum. They will also make the connection between light passing through a prism and how rainbows are formed. As with the other activities, how much time you spend on this activity is up to you. However, it is recommended that you complete the activity in stages. The topic "rainbows" can be the basis for an entire unit of study if you use this activity and the accompanying extensions as a jumping off point.

MATERIALS:

- ☐ Prism
- ☐ Flashlight
- ☐ White paper
- ☐ Science Notebook
- ☐ Transparency of visible spectrum

WHAT WILL THE STUDENTS DO?

As an introduction to this Activity, read the Historical Vignette aloud to students while they explore the prisms. Students will be attempting to "make a rainbow" by producing the spectrum using a flashlight, prism, and white paper. Encourage students to explore the prisms and articulate some ideas about rainbows and how they form.

1. Students working in pairs or in small groups predict how to best make a rainbow using the materials from the *Science, Optics and You* package. Darken the classroom as much as possible. The most brilliant spectrums are produced when the room is very dark and the flashlights very bright.
2. Students will compare the rainbows that they produce with other groups of students and identify the colors that they see in their Science Notebooks. This is a good time to introduce the term color spectrum to help students describe what they see. Have students compare their earlier predictions with what they observe.
3. Students write about their observations and draw diagrams in their Science Notebooks. Drawings should show how a prism separates the colors of light.

More Prism and Rainbow Demonstrations

Depending on the amount of light in the classroom and the intensity of the flashlights, students will have varying degrees of success in projecting color spectrums. The following are alternative methods to demonstrate the separation of white light into the color spectrum.

- On a bright sunny day, students can go outside and use sunlight through a prism to project a color spectrum on a piece of white paper.
- Cut a slit 1 cm wide and 15 cm long in a piece of black construction paper. Place the paper over the glass of an overhead projector so that just a slit of light is projected in a darkened room. Position a prism close to the projector and within the light beam and allow students to experiment to find the best placement for projecting a color spectrum.
- Students can spray a fine mist of water in bright sunlight to produce a rainbow. This is an excellent rainbow demonstration since, as with natural rainbows, water droplets are used. Or, this can also be done in the classroom using an overhead projector projecting a slit of light. Spray a fine mist in front of the projector across the light beam. A color spectrum can be seen within the mist.

Extensions:

Writing. Have students write a poem about rainbows with lines for each color of the rainbow: ROY G BIV.

Music. Play recordings of songs about rainbows such as *Somewhere Over the Rainbow* or *The Rainbow Connection*. Have students write their own verses for the songs or make up songs of their own.

Research. Isaac Newton and Rene Descartes discovered much of what we know today about rainbows. Using a variety of print and electronic media, students can research and write about the discoveries of Newton and Descartes. Older children can write stories about Newton and other scientists for younger ones and younger students can write for other classes.

Expository writing. Use the following as an expository writing prompt.

> *We learned that raindrops can be like prisms and make a rainbow in the sky.*
> *Think about how sunlight moves through a raindrop and separates into the color spectrum.*
> *Now write a description of how rainbows are made.*

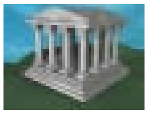
Narrative writing. Use the following as a narrative writing prompt.

> *We have all heard the myth that at the end of the rainbow you can find a pot of gold. Use your imagination and think of something else that you can find at the end of the rainbow. Now write a story about how you can reach the end of the rainbow and what you will find there.*

Reading. Choose poems (there are 70) from *Rainbows are Made* by Carl Sandburg (ISBN 015265481X) that relate to natural phenomena. Have students react to the poems and then write their own about rainbows, rain, or water.

Water by Ken Robbins (ISBN 0-8050-2257-0) is one of four photographic essays about the elements that combines geography, weather science, photography, optics, and art to learn about water. The beautiful hand-colored photographs combine black and white photography with an artist's interpretation of natural phenomena.

Share with students *A Drop of Water* by Walter Wick (ISBN 0-590-22197-3). Another photographic essay, this investigates the three states in which water is commonly found and its properties in each state.



HISTORICAL VIGNETTE: ISAAC NEWTON

This vignette was written to be read aloud. You may choose to read this *before* completing the activity, allowing students to handle the prisms as you are reading to them about Isaac Newton.

Young Isaac Newton and the Color Spectrum

In 1665, Isaac Newton was a young scientist studying at Cambridge University in England. He was very interested in learning all about light and colors. One bright sunny day, Newton darkened his room and made a hole in his window shutter, allowing just one beam of sunlight to enter the room. He then took a glass prism and placed it in the sunbeam. The result was a spectacular multicolored band of light just like a rainbow.

Newton believed that all the colors he saw were in the sunlight shining into his room. He thought he then should be able to combine the colors and make the light white again. To test this, he placed another prism upside-down in front of the first prism. He was right. The band of colors combined again into white sunlight.

Newton needed to prove that the colors came from the sunlight and not from the prism. Newton placed a card with a hole in it between two prisms allowing only red light from the first prism to go through the second prism. The red light going through the second prism did not split into *different colors, or turn white again; it remained red. Newton repeated this with all the colors with the same result. Newton proved that the colors came from the sunlight and were not in the prism.*

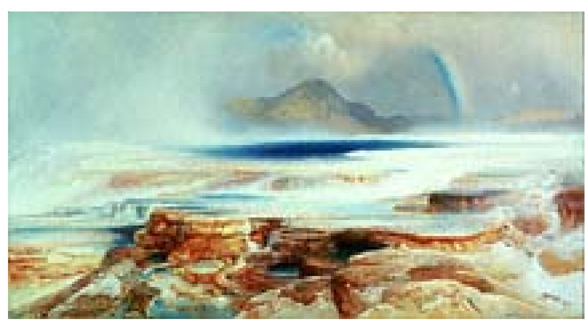
Newton was the first to prove that white light is made up all the colors that we can see. Newton wrote about his discoveries in his book, Opticks, in 1704. His book has become one of the most important scientific books ever written. The following is a description of his experiment in his own words:

> *In a very dark chamber, at a round hole, about one-third part of an inch broad, made in the shut of a window, I placed a glass prism, whereby the beam of the Sun's light, which came in that hole, might be refracted upwards toward the opposite wall of the chamber, and there form a colored image of the sun.*

Role Play. After reading aloud the vignette, have students research Newton's experiments and discoveries. Students can then write a skit depicting the day that Newton made his discovery about the properties of sunlight. Students will include imagined dialogue of Newton talking to his friends and family about his discovery.

Writing/Art. Students draw and write a comic book version of the story of Newton's discovery. Each step of Newton's experiment should be depicted in the frames of the comic book. Students then share the comic book with other students and other classes.

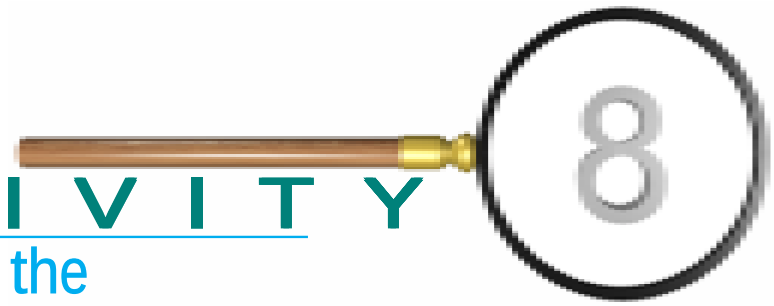
ARTIST VIGNETTE: THOMAS MORAN



During the 1800s, painters often joined government expeditions to the western wilderness of America. They painted and brought back to the cities in the east exciting and beautiful paintings of the Rocky Mountains, Yellowstone and Yosemite. In 1871, the painter Thomas Moran joined an expedition to Yellowstone in Wyoming. Yellowstone is now well known for its waterfalls, hot springs, and geysers. Moran painted pictures of the beautiful scenes that he saw. These paintings were reproduced and became very popular. Moran's paintings helped make Americans aware of the natural wonders of the western wilderness. This awareness helped establish Yellowstone as the first national park in 1872. Hot Springs of Yellowstone is one of his paintings and shows a rainbow forming in the mist and steam of a hot spring.

Moran's *Hot Springs of Yellowstone* can be viewed on the Internet. After viewing Moran's painting or other landscapes from the same period discuss with students how pictures can help communicate strong feelings about places.

Writing/Art/Current Issues. Students select a natural or historical location in their neighborhood or city that is at risk or that they feel needs to be preserved. Students then draw and color pictures of the site. They may choose to write letters to send to community leaders to encourage them to support its preservation. Students as a group can also paint a mural of the location. This is an opportunity to let students either choose an activity that they wish to complete or to create their own activity based on Moran or other artist.



Activity
Light, Prisms and the Rainbow Connection

Did you know that the light from the sun or from white electric lights is made up of all the colors we can see? In this activity you will use a prism to investigate colors.

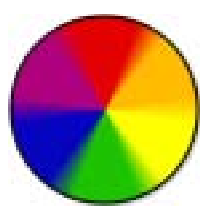
You see a rainbow when sunlight shines on raindrops in just the right way. The sunlight is bent as it moves through the drops. It spreads out and is reflected back to us as a colorful rainbow in the sky. The group of colors that we can see with a prism or in a rainbow is called the color spectrum.

Materials:

- ☐ 2 Prisms
- ☐ Flashlight
- ☐ White paper

1. Before you begin, try to guess how you could make a color spectrum with a flashlight, prism, and a piece of white paper. In your Science Notebook, write down (or draw) your ideas about how to make a rainbow and share your ideas with your group.

2. Use your materials to try and make the color spectrum appear on a piece of white paper, like Isaac Newton did. This works best when the room is very dark and the flashlight very bright.


3. Can you identify colors in the spectrum you created?

4. Compare your color spectrum with the spectra other students have made. In your Science Notebook, write how they are alike and how they are different.

5. In your Science Notebook, draw a picture showing the flashlight, prism, paper and the color spectrum.

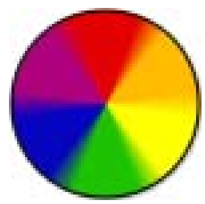
6. Compare how you made the spectrum appear on a piece of paper with how light moving through raindrops can make a rainbow. In your Science Notebook include a diagram that supports your idea about how a rainbow is made.

7. In your Science Notebook, write down any questions you still have about rainbows and how rainbows are formed. With each question, suggest a way that you could find the answer.

ACTIVITY

Investigating the World of Colors

What we notice most about light is color. However, the way we see colors has to do with how light is reflected or absorbed. The reason something appears red is that all of the colors in white light are absorbed except red. The red light is reflected to our eyes and therefore we see the color red. If an object *absorbs* all of the colors found in white light then it appears black. If all of the colors are *reflected* an object appears white.



Color comes from the visible spectrum of light. The colors that make up white light from longest to shortest wavelengths are red, orange, yellow, green, blue, indigo and violet. Scientists measure the wavelength of light in a unit called a nanometer (one billionth of a meter). In any system of colors, those that cannot be mixed from any of the others are called primary colors. The primary colors of *light* are red, green and blue. From these three colors, every other color of light can be made. Televisions, movies, and computer screens all project red, green and blue dots called pixels; these pixels create the variation in shades and images that are formed on the screen.

In the human eye, the retina, which is the inner lining of the eye, is composed of cells known as rods and cones. The rods allow our eyes to pick up small bits of light and are the type of cells that are the most numerous on the retina. Cones are the other kind of cells making up the retina. The cones are responsible for the color and clarity of an object. The heaviest concentration of cones is found in the center part of the retina. For that reason the best color and clarity of an object can be seen when the object is directly in front of the eye. As the object moves more to the side of our eyes, the clarity and the amount of color we can see is diminished. However this side vision or peripheral vision allows us to see the smallest amount of light and motion.

Paint pigments mix differently than light. The type of color mixing familiar to most artists is that done not with lights but with paints or pigments. Each color of paint can be thought of as a filter that removes all of the light frequencies except the one meeting the eye. Red, yellow and blue are the most common ones primary colors of paints. For example, a red paint reflects only the wavelengths that create a sensation of red; the rest are absorbed. Mixing primary pigments with other colors results in darker colors as more of the light energy is absorbed. The absorbed energy becomes heat and that is why, for instance, white cars are cooler than black ones.

SOME OF THE MATERIALS LISTED ARE NOT FOUND IN YOUR OPTICS PACKAGE. CHECK THE LIST CAREFULLY BEFORE YOU BEGIN THE ACTIVITY.

BEFORE YOU BEGIN, MAKE A COPY OF THE COLOR WHEEL, FOUND IN APPENDIX C, FOR EACH STUDENT.

MATERIALS:

- ☐ White unlined paper
- ☐ Science Notebook
- ☐ Water
- ☐ Watercolor paints
- ☐ Paintbrush
- ☐ Container for holding water
- ☐ Blank color wheel (in the Appendix)
- ☐ 3 markers of the same size but different colors

This activity consists of two investigations: the first investigation encourages students to experiment with color vision. In the second investigation, students experiment with mixing primary colors of pigment to produce secondary colors, work with color wheels and explore the effects of combining colors.

WHAT WILL THE STUDENTS DO?

Investigation I

1. Working in pairs, students test their ability to see color peripherally. They will take turns testing one another by using different color markers.

2. Each student will view 3 different objects and record what they experience in their Science Notebooks.

Investigation II

In the second investigation, students will be mixing watercolors. In mixing colored pigments, the three colors that combine in various proportions to give all the other colors of the spectrum are red, yellow, and blue. Because this phenomenon depends on the ability of the pigments to absorb the various wavelengths of white light, red, yellow and blue are called subtractive primary colors.

EXTENSIONS

Art and Nature. Another way of introducing students to the art of color mixing and pigments is to have them produce certain colors by using materials that are found in nature. Students could bring in materials they think will produce a color when rubbed on paper, for example seeds, fruit peels, leaves, berries, soil, and rocks. Students then can use these materials to produce paintings or other art..

History. Have students use the natural materials gathered in "Art and Nature" above to create cave drawings. With a little research about the kinds of drawings that exist in many parts of the world, students can discuss reasons that prehistoric man created art, ways the art was created, and the difference between pictographs and petroglyphs. Students can create their own "caves" complete with artwork. Further research can be done on dating techniques used in the caves as Lascaux, France, for example, or rock paintings in Australia and India.

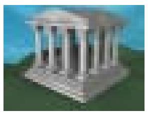
Reading. Read aloud *The Legend of the Indian Paintbrush* by Tomie dePaola (ISBN 0-698-11360-8). This is a wonderful accompaniment to the "Art and Nature" activity above since it deals with a Plains Indian boy who creates beautiful paintings on animal hide. While he creates colors from natural materials such as berries and flowers, he is unable to mimic the bright and vibrant colors of the sunset.

Mathematics. Depending on the experience of your students, it would be an excellent math extension to have them construct their own blank color wheel by drawing a line across the diameter of the circle, identifying the radii, measuring the angles, and then comparing their color wheels to pie graphs. Materials needed are white paper, a drawing compass, and a protractor.

Narrative writing:

> *Each of us has seen how grass can leave a green stain on clothes.*
>
> *Before you begin writing, think about some materials found in nature that could produce other colors.*
>
> *Now tell a story about how you would go about finding materials to produce paint and create some artwork to produce a record of your trip through the forest.*

Careers. To answer the question, "Why produce a color wheel?" or, "Who uses a color wheel?" have students research careers that involve the use of color. For example, interior designers carry color samples with them as they investigate new and creative ways to combine colors for their clients. Artists combine colors to create certain effects to fool the eye or to represent things in a realistic way. Men and women in the textile industry combine colors in special ways so that certain fabrics reflect light to enhance the color combinations. Students could choose a career or a technique used in one of the careers, investigate how colors are used, and present their findings to the class.



HISTORICAL VIGNETTE: THE HISTORY OF TEMPERA PAINTING

Painting as an art medium has a tradition that extends far back into prehistory. It was used to show images, religious symbols, and to record events about every day life. Many of the works of art that still survive from the Stone Age were painted on the walls of caves in Spain and France. Most of these paintings were animal forms with bold lines and colors. The color was limited to red, red-brown and black pigments. When man eventually turned to settled communities, the practice of wall painting continued and was used for decorating the interiors of houses and shrines.

For painters of ancient Egypt and the Near East the paintings were devoted mainly to the decoration of ceilings and the walls of royal tombs, temples, and palaces. Non-religious paintings centered on the events surrounding the life of the Pharaoh while others had themes of religious significance.
The painting medium used throughout the ancient world consisted of tempera, a mixture composed of color pigments extracted from minerals, egg yolk used as an adhesive, and water to liquefy the paint. The surface to be painted upon was often prepared with a thin coating of plaster. The easiest method of working was to apply the paints to the dry surface. As use of the medium progressed, tempera was applied to the plaster while the surface was still wet. This method was known as true fresco. Decorating wall surfaces with fresco paintings became more prominent throughout the Roman, Byzantine, Romanesque, and Renaissance periods. Perhaps one of the most important artists during the Renaissance was Michelangelo who painted a fresco on the ceiling of the Sistine Chapel.

Art History. Students research the use of tempera painting and frescoes by various artists during different periods of art history. Information to be discovered in researching would be how these artists prepared their paints and the type and sources of pigments used in their paintings.

Art and History. A variation on this activity could be for students to create their own "cave paintings." In this way, students would be using tempera (albeit a modern version) while at the same time depicting life of cave dwellers. This requires some research into how cave dwellers survived and what they ate. Students could discuss how the light in the cave might determine how much paint was used. Encourage students to discuss whether the light in the cave, the availability of light, or a combination of both would make a difference.

ARTIST VIGNETTE: ROMARE BEARDEN

Romare Bearden is considered to be America's premier collagist, and has often been referred to as on of the most notable African American artists of the twentieth century. Bearden's career began in the early 1940's. He later turned to collage in 1963 as his primary art medium. Born in Charlotte, North Carolina, much of Bearden's childhood was spent in Harlem, New York. While in New York, he was exposed to many artists and jazz musicians by his father. It was due to this early exposure that he constantly incorporated his love of music into his art. Bearden received his formal education at Columbia University in New York, where he earned his degree in mathematics. Although he later studied philosophy and art history in Paris, he never had formal training in making art. This did not stop him from following his heart and pursuing something that he truly loved to do.

Emerging at the height of the civil rights struggle in the 1960's as a major artist, he created "photomontage projections" which were made of images snipped from newspapers and magazines, then enlarged photographically. Considered by many to be a daring innovator, he used art-making processes that could be considered primitive. Among these were paste-up, photographic copying and enlargement. However primitive these techniques appeared, their impact was great.

Activity

Photomontage is a type of art that can be used by students to produce a group project with a theme. For example students can create a photomontage with the theme "The Impact of Color". Students can look through old magazines and newspapers and cut and paste pictures of colorful objects that may attract a person's attention and perhaps persuade them to buy an object. It may be clothing, furniture, or automobiles. Members of the group would then give a title to their artwork, such as "Color and Cars".

Students choose a current issue and represent it with a photomontage. Encourage students to share their projects and explain how it represents their vision of a particular issue. For example, students might choose to represent animal rights, endangered species, or something happening at school.

ACTIVITY 9

Investigating the World of Colors

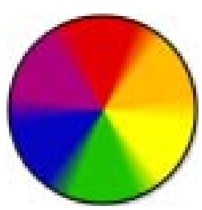
What we notice most about light is color. We see colors the way we do because of the way light is reflected or absorbed. The reason something appears red is because all of the colors in white light are absorbed except red. The red light is reflected to our eyes and so we see the color red.

The human eye is sometimes compared to a camera. It collects information and sends it to the brain. The retina acts like the “film” of the eye. It is made of two types of cells, rods and cones. Rods are the cells that let us see light and motion, and cones are cells that allow us to see an object clearly and in color.

Color comes from the visible spectrum of light. In any system of colors, those that cannot be mixed from any of the others are called primary colors**.** The primary colors of light are red, green and blue. From these three colors every other color of light can be made.

Paint pigments mix differently than light. The type of color mixing familiar to artists is done with paints or pigments, not lights. Primary pigments in paint can vary, however red, yellow and blue are the most common ones.

In two investigations you will be exploring how our eyes see color, how artists mix the primary colors of pigment to produce secondary colors, and how we use color wheels to observe the relationship between primary colors, secondary colors and complementary colors.


Materials:

- ☐ White unlined paper
- ☐ Science Notebook
- ☐ Water
- ☐ Watercolor paints
- ☐ Paintbrush
- ☐ Container for holding water
- ☐ Blank color wheel
- ☐ 3 different colored markers or other objects that are the same size and shape

Investigation I

1. In this activity you will need a partner, 3 different colored objects such as markers or pencils, and your Science Notebook.

2. One partner sits down and faces forward while the other partner stands behind.

3. The person that is standing chooses one of the three colored objects and moves the object slowly around the right side of their partner's head.

[The partner that is sitting should be looking straight ahead and should not shift his or her eyes during this experiment.]

4. The seated partner should say "Stop!" at the very first moment he sees the object, and writes in his or her Science Notebook the color of the object.

5. In your Science Notebooks describe what happened. Where was the marker when the person sitting said "Stop?" Was the color of the marker identified?

6. Repeat until all three objects are tested and then change jobs.

7. Record in your Science Notebooks the following:

    - What was the first thing that you saw once your partner started moving the object?
    - Where were you able to see the best color?
    - Of the three colored objects that were tested, how many of them were you able to identify? Why do you think this is so? Can you explain what happened?
    - If you were to go home and tell your parents what you did in this activity, how would you explain to them how and when you see colors?

8. Use books, websites, or other resources to find out how we see color. Identify the structures in the eye that allow us to see color.

Investigation II

You are going to experiment with mixing colored pigments. You will need your blank color wheel and your Science Notebook to answer questions as you do this activity. You will also need the three primary colors of either tempera paint or watercolors. They are red, yellow, and blue.

1. Color the red, yellow and blue sections of the color wheel.

2. On a piece of paper mix the primary colors to get the secondary colors to fill in the blanks on the color chart. Answer the questions below in your Science Notebook.

    - Identify the color you added to the color chart.
    - What colors did you mix to get each of the secondary colors?
    - Explain how you decided which colors to mix and how much of each color you used.

The colors opposite each other on the color wheel, such as blue and orange, are called complementary colors. In you Science Notebook, write a statement about how you can use compementary colors. What happens when you mix complementary colors?

Collect magazines and cut out pictures that show complementary colors. Create a collage and then describe any new ideas you have about complementary colors in your Science Notebook. You can create a painting using primary colors or secondary colors. Many artists chose to either paint works of art emphasizing primary colors or secondary colors. Artists such as Henri Matisse, Pablo Picasso, Piet Mondrian, Katsushika Hokusai, and Frieda Kahlo emphasized primary colors in their work; Paul Cezanne, VictorVasarely, and Georgia O'Keefe emphasized secondary colors.

ACTIVITY 10

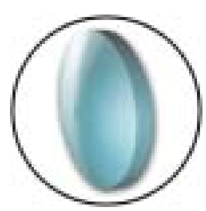
Using Learning Centers to Investigate Special Properties of Light

The Activity consists of four parts:

1. A general description with teacher background for each center,
2. A materials list for each center,
3. “What will the students do?” described for each center,
4. Student Pages.

Many unique properties of light can be investigated in the classroom by using learning centers. The length of time needed to complete these activities varies depending on the number of students in the classroom and the available time for study. Suggestions for how to design and use discovery centers can be found in the Introduction of this Guidebook.

This activity supports the inquiry-based classroom if you encourage students to ask and answer questions. Experiences at the centers can provide data for students to record, analyze and use to learn more about the world around them.



WHAT DO I NEED TO THINK ABOUT AHEAD OF TIME?

1. Through large group and small group discussion, encourage students to form questions that can be answered using materials at the centers.

2. Familiarize yourself with each center and gather materials as indicated for each center.

3. Decide how you want to set up your room and make a plan so students can move around the room easily.

4. Make a rotation plan. For example, if a student begins at Center 1, she moves to Center 2. If a student begins at Center 6, she moves to Center 1. Each Center should take approximately the same amount of time so that students are not ready to change Centers before those ahead of them are finished.

5. Students should take their Science Notebooks to each Center to record their questions, answers, information, or data.

WHICH PROPERTY OF LIGHT ARE STUDENTS INVESTIGATING AT EACH LEARNING CENTER?

LEARNING CENTER 1: DIFFRACTION ACTION

Diffraction Action uses diffraction gratings to look at various types of lights. A diffraction grating acts like a prism, spreading visible light into its component colors. The light that you see from a light source is the sum of all these colors. Each color corresponds to a different frequency of light. The diffraction grating sorts light by frequency, with violet light (the highest frequency of visible light) at one end of the spectrum and red light (the lowest frequency of visible light) at the other.

LEARNING CENTER 2: DID YOU SEE THE LIGHT?

Did You See the Light investigates transparent, translucent and opaque objects. Many students understand that different objects allow more or less light to pass through them. This activity will allow them to investigate many common items and determine whether they are transparent, translucent or opaque. A *transparent* material allows light to pass through it and a clear image to form. A piece of glass would be an example of a transparent material. A sheet of waxed paper is *translucent*. Some light does pass through translucent materials, but most of the light is scattered. As a result images cannot be seen clearly through them. A piece of cardboard is *opaque*. Light cannot pass through it and no image can be seen through this material.

LEARNING CENTER 3: CD RAINBOWS

CD Rainbow uses a compact disk (CD) as a diffraction grating to look at different types of lights. The lines or grooves on a compact disk are equally spaced over the flat surface of the disk. As a result when light strikes the disk it is separated into its component colors. Depending on the type of light, the colors seen may vary from one type of light source to another.

LEARNING CENTER 4: SPINNING COLORS

Spinning Color investigates the additive properties of color using spinning disks. When two or more colors are quickly spun together, our eyes may perceive a different color altogether. This is because the brain has the ability to retain or remember individual colors and adds them together, creating a new color.

LEARNING CENTER 5: BENDING LIGHT

Bending Light investigates the refraction of light. Many students have seen mirages on the highway in which a puddle of water appears on the road on a dry day. As they approached the "puddle" it disappeared, but soon another imaginary puddle may have been seen in the distance. This disappearing puddle is called a mirage and is an example of the refraction of light. Mirages are tricks of the atmosphere, optical illusions caused when a layer of air next to the ground becomes superheated from heat stored in the soil or in dark pavement. The boundary between this hot, and therefore less dense air, and the cooler denser air above it bends the light rays that strike it, acting like a giant mirror or lens held parallel to the ground. Whenever light rays travel from one medium to another like from air to water, or water to air, refraction or bending of light occurs.

LEARNING CENTER 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

Many students may not understand that light is not matter because it does not take up space, has no mass, and is not made of atoms. Visible light is one form of electromagnetic radiation, which is a form of energy. Since energy cannot be created or destroyed under ordinary conditions, light energy is often converted into heat energy. This center will investigate the connection between light and heat energy. Students will also be investigating how and why light colors are cooler than dark colors.

MATERIALS:

LEARNING CENTER 1: DIFFRACTION ACTION

- ❑ Diffraction grating

- ❑ Candle
- ❑ Lamp with a 60 W bulb
- ❑ Flashlight
- ❑ 2 Strings of tiny Christmas lights (1- colored and 1-white)
- ❑ Other types of lighting available in the classroom (e.g., sunlight, fluorescent lights, computer screen)
- ❑ Science Notebooks

Learning Center 2: DID YOU SEE THE LIGHT?

- ❑ Different materials, such as wax paper, brown paper, plastic milk container, construction paper, cardboard, aluminum foil, plastic wrap, foam meat tray, paper towel, or paper plate to be used to investigate transparent, opaque, and translucent materials
- ❑ Lamp with a 60 W bulb as the light source or a small high intensity lamp
- ❑ Science Notebooks

Learning Center 3: CD RAINBOWS

- ❑ Used CD's
- ❑ Flashlight
- ❑ Lamp with a 60 W bulb
- ❑ Sunlight
- ❑ Candle
- ❑ Science Notebooks

Learning Center 4: SPINNING COLORS

- ❑ 2 sharpened pencils
- ❑ Red, blue, yellow, green permanent markers
- ❑ Drawing compass
- ❑ Two 3x5 cards
- ❑ Scissors
- ❑ Science Notebooks

Learning Center 5: BENDING LIGHT

- ❑ Styrofoam cup
- ❑ Penny
- ❑ A container of water
- ❑ Scissors
- ❑ Transparent tape
- ❑ Science Notebooks

Learning Center 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

- ❑ 3 containers of water
- ❑ 3 thermometers
- ❑ A sunny day
- ❑ A sheet of black construction paper and a sheet of white construction paper
- ❑ Tape
- ❑ Science Notebooks

WHAT WILL THE STUDENTS DO?

Students use any or all of the centers to answer the questions they developed before beginning the investigation. Be sure that questions are focused and well-articulated so that students can collect information at the centers.

LEARNING CENTER 1: DIFFRACTION ACTION

Students will use diffraction gratings to view the colors or spectrum produced by visible light.

- Students hold the diffraction grating in front of different light sources.
- They will record on their student page or in their Science Notebook the colors that they see when they view different types of light using the color chart that you provide or that they copy.
- Students may notice the intensity of the colors and the width of the color band produced.

LEARNING CENTER 2: DID YOU SEE THE LIGHT?

Students will be testing various materials to determine whether they are transparent, translucent or opaque.

- Students hold the different materials in front of a light bulb.
- They will then record the name of the material under the appropriate column on their student page or in their Science Notebook.
- Students will think of practical applications for the materials that they have observed.

LEARNING CENTER 3: CD RAINBOWS

- Students will observe features of the surface of a CD in different types of light: candle light, sunlight, light from a 60 W lamp, and a flashlight
- They will then describe any similarities or differences observed in the color spectrum with that observed at the DIFFRACTION ACTION Center.

LEARNING CENTER 4: SPINNING COLORS

- Students will use a compass to draw two circles 8 centimeters (cm) in diameter on the blank side of each of the 3x5 cards and divide it into 8 equal wedges
- On the first circle, color every other section red and blue. On the second circle, color every other section yellow and green.
- Students will push a pencil point through the center of each disk so that the colored sides are facing the pencils' erasers. For better balance they can keep the disk down near the point end of the pencil.
- Students will hold the pencil upright and spin it on the floor like a top and observe and record the color that the disk appears to be.

LEARNING CENTER 5: BENDING LIGHT

- Students work in partners and place a penny at the bottom of a foam cup that has been cut in half.
- One partner will slowly slide the cup away from the other just until they can no longer see the penny.
- Without disturbing the penny, one partner will slowly pour water into the cup until the penny can be seen again.
- Remind the students that they should not be moving or changing position during this activity.
- They will record what happened and why in their Science Notebooks.

LEARNING CENTER 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

- Students observe how dark surfaces absorb light, and light colored surfaces reflect light by making two different colored holders for their thermometers, one that is made of black construction paper and one that is made of white construction paper. Students will place the two covered thermometers outside in full sun for 2-3 minutes, and then read and record the temperatures in their Science Notebooks.
- Students will go outside and measure the temperature of three containers of water that they placed outside at least 1 hour prior to the activity. Place one container in full sun, one in part sun/part shade, and a third container in full shade.
- Students will place the thermometer in the container for at least 1 minute without moving the cups and measure the temperature of the water in each container.
- Students will then record the temperature in their Science Notebooks.

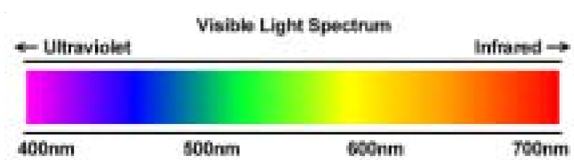
ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 1: DIFFRACTION ACTION

At this center you will be using a diffraction grating to look at different types of light. A diffraction grating works kind of like a prism in that it will separate light we can see into the colors that make it up.

Each color has a certain wavelength with violet being the shortest wavelength, and red being the longest wavelength. The other colors that you might see in the spectrum are usually in this order: red, orange, yellow, green, blue, indigo and violet.



As you look at each type of light with the diffraction grating record what you seee in your Science Notebook. You can use a chart like the one below to record your data if you wish.

violet	indigo	blue	green	yellow	orange	red

Describe the diffraction grating.

What do you think is happening to the light?

Activity 10

Using Learning Centers to Investigate Special Properties of Light

Learning Center 2: DID YOU SEE THE LIGHT?

At this center you will place different objects up to a light and decide whether the object is transparent, translucent or opaque. If it is *transparent* then the light will pass through it and a clear image will form. If an object is *translucent*, it will allow some of the light to come through, but most of the light is scattered. In a translucent material you can see an object through the material, but it will not be clear. In an *opaque* material, all the light is blocked and you will not be able to see through this material.

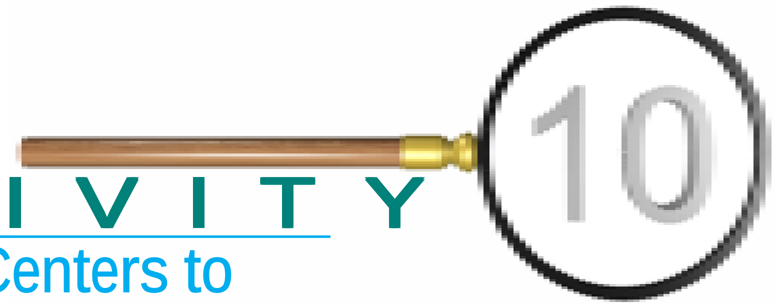
As you hold the objects up to the light, record your answers in a chart like the one below. For example if you held a piece of glass up to the light, you could see through it and what you would see would be clear. You would write the word "YES" in the transparent column.

Object	Transparent	Translucent	Opaque	General Observations

Now, answer the following questions in your Science Notebook:

1. What type of material would you want a computer screen to be made of: translucent, transparent or opaque? Explain your choice.
2. Why would you want a flashlight bulb to be made of a transparent material?
3. Why would you want your sunglasses to be made of a translucent material?
4. What type of object, a transparent, translucent or opaque one, would you use to make a shadow?

Activity



Using Learning Centers to Investigate Special Properties of Light

Learning Center 3: CD RAINBOWS

At this center you will be using a compact disk (CD) to look at light from several different sources. Look at the surface of a CD. In your Science Notebook describe what the surface looks like.

Move the CD and try to allow some of the light from overhead to hit its surface. Record what you see in your Science Notebook, or create a chart like you did at Learning Center 1: Diffraction Action.

Use the CD to look at light from a flashlight, a lamp with a 60 W bulb, sunlight from a window, and a candle. Record the colors that you were able to see in your Science Notebook.

In your Science Notebook explain what happened and why you think it happened. Compare your answer with another student. Write your "theory" about what happened.

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 4: SPINNING COLORS

At this center you will create and observe a spinning color disk .

1. Use the compass to draw 2 circles 8 centimeter in diameter on the blank side of each of the two 3x5 index cards.

2. Divide each circle into 8 equal wedges. On the first circle use the red and blue markers. Color every other section red and blue.

3. On the second circle use yellow and green markers and color every other section yellow and green.

4. Cut out each of the circles. Push a pencil point through the center of the red and blue circle, and take another pencil and push the point through the center of the yellow and green circle with the colored side facing the pencil's eraser. For better balance, keep the disk down near the point end of the pencil. Put the point of the pencil on the floor and spin it like a top. Do this several times and record what happens in your Science Notebook.

5. In your Science Notebook, draw what you see. Then, describe in words what happens as the top slows down. Compare your drawing and results with another student. How can you explain what is happening?

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 5: BENDING LIGHT

At this center you will observe how light bends, or refracts, to form an image. Work with a partner.

1. Place a penny at the bottom of a styrofoam cup that you have cut in half.

2. Have your partner slowly slide the cup away from you until you can no longer see the penny. **Do not move. Stay in this position until your partner has completed Step 3 below.**

3. Without disturbing the penny, your partner will slowly pour water into the cup until you can see the penny again. Record what happened in your Science Notebook and switch jobs.

4. In your Science Notebook answer the following questions:

   What did you observe?

   Can you explain what is happening when you add the water?

5. In your Science Notebook, draw the path that light takes from the penny to your eye before and after the water was added. You may use arrows to show what happens to the light.

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

Are light and heat related? In your Science Notebook, write any ideas or questions you have about the relationship of light and heat. Before you begin, go outside with 3 cups of water. Put one in full sun, one in part sun/part shade, and one in full shade.

1. Use a piece of black construction paper and tape to make a cover for a thermometer. Seal one end of the cover so that the thermometer does not fall out.

2. Do the same thing with a white piece of construction paper for a second thermometer. Take the two covered thermometers outside and place them in full sun.

3. Predict what you think will happen if you leave these two covered thermometers outside in full sun. Write your predictions in your Science Noterbook.

4. Wait 2-3 minutes and read the temperature on each of the two thermometers by gently sliding them out of the cover. Record the temperature.

    Thermometer covered with black paper ____________degrees Celsius.

    Thermometer covered with white paper ____________degrees Celsius.

How did your predictions compare to your measurements? Explain what you think happened.

5. Think about the 3 containers of water you placed outside. Predict the temperature of the water in each. Record your predictions in your Science Notebook.

6. Take three thermometers outside, and without moving the cups, measure the temperature of the water in each cup. Record the temperatures in your Science Notebook.

Full sun _________degrees Celsius

Part sun/ Part shade ________degrees Celsius

Shady _______degrees Celsius

Were your predictions correct?

Compare your predictions with your results. Write about this in your Science Notebook. What can you say about the relationship between light and heat?

Are you thirsty yet?
Some people make "sun tea" You can do this by placing a tea bag in cold water in a clear jar and covering it with plastic wrap. After the water sits for awhile in the sun, it will turn from a clear color to a dark brown. Remove the tea bag, add sugar to taste, a couple of ice cubes, and you have delicious iced tea.

Student SELF-CHECK

Module 4: Light & Colors

Now that you have completed Module 4, answer the questions below in your Science Notebook.

1. Draw what happens as light passes through a prism.

2. Many people remember the colors of the rainbow or visible light spectrum by the initials ROY G. BIV. What are the colors?

3. How are rainbows made?

4. What are the three primary paint pigments?

5. Orange is a secondary color. What two primary colors do you mix to get this color?

6. If you looked on a color wheel, where would you find the complementary color for blue?

7. Give an example of an opaque object.

8. A friend asks you to hand him two objects, one that is translucent and one that is transparent. What items would you hand him?

9. A compact disk and a diffraction grating do the same thing to light. What happens when you reflect light off a compact disk? What is it about compact disks that create this effect?

10. What color shirt would you want to wear if you were outside on a sunny day? Why?

MODULE m5

SHADOWS

INTRODUCTION

Module 5, Shadows, contains two activities. Students will be exploring how shadows are made and how to manipulate light to create shadows. These activities build upon the activities in previous modules particularly drawing upon the concepts of transparent, translucent, and opaque materials.

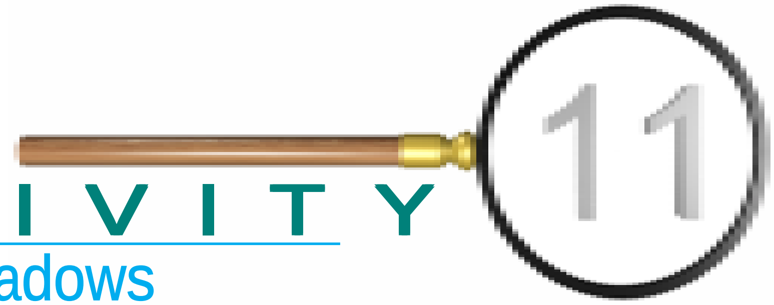
Activity 11: Investigating Shadows
Activity 12: Shadows in Action: The Shadowbox Theater

In Activity 11, Investigating Shadows, students will study the relationship between the size of a shadow and the size of an object as well as how distances between the light, the object and the screen affect the shadow that is produced.

For Activity 12, students will be making shadowboxes and manipulating light and shadow to create special effects. The Shadowbox Theater is a device that can be used at any time with any unit of study. Students can incorporate what they are learning as they study light and optics with other content areas.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: The Shadowbox Theatre, Measuring With Shadows, Eclipse of the Moon, and Solar Eclipse,
http://micro.magnet.fsu.edu/optics/tutorials/index.html

ACTIVITY



Investigating Shadows

In this activity students will be exploring some of the features of shadows and shadow making. The concepts of transparent, translucent and opaque were introduced to the students in Module 4, Activity 10, but it would be a worthwhile activity for students to create a KWL chart about shadows (see Module 1, Activity 2). Students can create this chart in their Science Notebook as individuals or on butcher or chart paper as a group. Some of the students may know more about shadows than others, and the KWL chart enables them to examine what they already know, what they are curious about and, finally, what they have learned.

A shadow is a dark outline or image cast by an object that blocks light. A shadow forms when light hits an opaque object (anything that does not let light through). When light strikes opaque objects it is blocked. Everywhere else, the light continues in a straight path until it bounces off the ground or wall behind the object. The result is a dark patch, or shadow, with the same outline as the object surrounded by light.

Students will investigate the relationship between the size of a shadow and the size of an object and also how the distances between the light, the object and the screen (or ground or wall) affect the shadow that is produced. They will also investigate why an object can produce several differently shaped shadows. Students will be asked to record information in their Science Notebooks about what they observe.

Materials:

- ❑ Flashlight
- ❑ Scissors
- ❑ White paper or poster board
- ❑ Ruler or measuring tape
- ❑ Objects to use to produce shadows (some that are translucent, some that are opaque, and some that are transparent).
- ❑ Science Notebooks
- ❑ Graph paper

What will the students do?

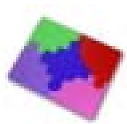
Students will be doing a lot of exploring in this activity. They will use the Student Page to guide them while they are exploring and their Science Notebook to record answers to questions that are asked while doing these manipulations.

Students begin by creating a KWL chart, either individually or in groups. Encourage students to write down anything that they want to know about shadows in the W (What I Want To Learn) column of their KWL charts, and if they find the answer to their question while experimenting, to write the answer down in L (What I Learned) column of their KWL chart.

1. The first part of the activity involves a brief trip outside. Working in pairs, one student will stand in the sunlight and the other will draw a sketch of the shadow that is formed. Have students make two shadows shadows and sketch them, one with the person facing the sun, and the other with the person's shoulder facing the sun. Students will then discuss how the shadows are alike and how they are different.

2. Returning to the classroom, students will take an object and use it to make a shadow by illuminating it with a flashlight. They will follow the directions on the student page and discover how to change the length or direction of the shadow.

3. Students will now choose a 2-dimensional object and a 3-dimensional object and compare the shape of the shadow with the shape of the object and the size of the object with the size of the shadow.



Extensions:

Narrative writing.

Each of us has studied how light produces shadows.

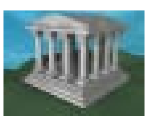
Before you begin writing, think about a time when the shadow of an object might have frightened you.

Now write a story about this experience and why the shadow frightened you.

Reading and Writing. Read aloud *Shadow* by Marcia Brown (ISBN 0-689-71875-6). Based on stories told by African storytellers and tribal leaders, *Shadow* is a rich story of how shadows can become part of our cultural heritage. Use this book to encourage students to write their own stories about shadows. It can also be a starting point for looking for other stories about shadows that are specific to certain cultures.

Art and Reading. Show students *William and the Magic Ring* (Museum of Fine Arts, Boston, Catalog 1-800-225-5592, ISBN 0-87846-467-0). This is an excellent demonstration to use before completing Activity 12, by projecting paper cutouts to produce shadows. It also is a good way to start a writing activity since it is a story about a boy who imagines an animal battle just by looking at his window shade.

Photo Fakery. The camera was invented in 1839 and as early as the 1840s and 1850s, photographers were manipulating images. Photographs were a new way to convey messages to family and friends. This new medium also became a way for people to get firsthand looks at historical figures and events. Sometimes photographs were "faked" by inserting one image onto another photograph to communicate a certain message. In order to determine whether a photo has been manipulated, experts look first at light and shadows. With your students, look at photographs and determine where the light is coming from. If you can, find photographs that have been changed (for example, putting one person's image on another person's body) and have students look at the light and shadows and figure out if the photo has been changed. A good source of information on this subject is *Photo Fakery: The History and Techniques of Photographic Deception and Manipulation* by Dino A. Brugioni (ISBN 1574881663).



HISTORICAL VIGNETTE: LEWIS H. LATIMER (1848-1928)

Lewis H. Latimer was born in Chelsea, Massachusetts in 1848. As a young man, Lewis Latimer learned mechanical drawing while working for a Boston patent office. In 1880 Hiram Maxim of the U.S. Electric Lighting Company hired him to help develop a commercial electric lamp. In 1882, Latimer invented a device for efficiently manufacturing the carbon filaments used in electric lamps and shared a patent for the "Maxim electric lamp." He also patented a threaded wooden socket for light bulbs and supervised the installation of electric streetlights in New York City, Philadelphia, Montreal and London.

Lewis Latimer assisted Alexander Graham Bell in preparing the application for his telephone patent. In 1918 he became one of the 28 charter members of Thomas Edison's elite research team, "Edison's Pioneers." While working for Edison, Latimer wrote *Incandescent Electric Lighting,* the first engineering handbook on lighting systems. He was the only African-American in this prestigious, highly selective group.

Cooperative Learning Research Activity. Divide students into groups of three or four and give each group a different type of light to research. In groups each member could have a certain responsibility such as researching how the particular light works, researching the inventor and the year the light was patented, researching the use of their particular type of light, and illustrating or making a model of the of light. Groups could present their information to the rest of the class. Types of lights could include incandescent, fluorescent, neon, halogen, mercury vapor, sodium vapor or infrared lights.

Florida History. Thomas Edison made his home for part of his life in Ft. Myers, Florida. He originally came to Florida because he believed that carbonized bamboo would make a good filament for his newly-invented light bulb. He became a very good friend of Henry Ford and they lived in Ft. Myers in adjoining homes. Have students imagine what a conversation between Henry Ford and Thomas Edison might have sounded like. They often sat together, joking and laughing and visiting with other famous men and women of their time. Students could role-play using a written script and share their ideas with the class.

Art and History. Thomas Edison and his wife, Mina, constructed a walkway of stepping-stones, each one placed in the garden after someone visited their Florida home. Have students design a walkway. Each stone should have on it the name of the person who visited, the date of the visit, and a word or two to describe the visit. Students can either use the time period in which Thomas Edison constructed his walkway or choose another time period. For example, another historical vignette in the *Science, Optics and You* materials is one that features Galileo Galilei. Have students imagine who Galileo might have spoken with to discuss his astronomical theories and have them create a walkway based on those famous scientific figures.

ARTIST VIGNETTE: JOHN MIERS (1758-1821)

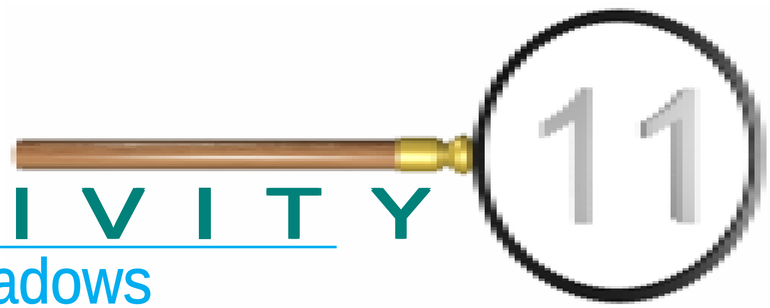
One form of preserving images is the creation of silhouettes. The development of silhouettes has been linked to that of outline drawing and shadow painting. It is said that this art form first appeared in France and Spain in the cave murals of Stone Age people. Tracing the outline of an object's shadow and then filling the drawing in with a flat color made the drawings realistic. Ancient Greek and Roman painters drew silhouette outlines of a person's shadow cast by sunlight as well as by candlelight or lamplight.

Silhouette techniques became popular in Europe during the eighteenth century. Many people collected silhouettes, especially well known people. These shadow portraits were painted on different materials such as plaster, wax, and paper and were elaborately framed.

One of the most famous silhouette artists was John Miers. He has been called one of the finest and most widely known profilists in the history of art, and was one of the few artists that painted silhouettes on plaster. A native of Leeds in northern England, Miers sold paints as did his father, but by 1781 he expanded his business to include painting coaches, gilding, and making profiles. He was so successful in making silhouettes that in 1791 he opened a studio, employed several artists and had a very good business. He continued making silhouettes of famous people until 1800.

Activity. Students create a silhouette of a friend in the classroom. There are several ways to create one. One is to paste dark paper cut to a person's profile on a light background. Then there is hollow-cut, which involves the opposite color combinations. The student will cut out the likeness from the center of white paper and place it on a background of black paper or black fabric. Materials needed are paper, pen and a light source. Seat the student sideways in a chair positioned against a blank wall. Position a light a few feet from the wall so that it creates a shadow. Tape tracing paper on the wall and trace the outline. Place the profile on black paper and use scissors to cut it out of both sheets. Mount the black silhouette on light-colored paper.

ACTIVITY



Investigating Shadows

A shadow is a dark outline or image cast by an object that blocks light. It is formed when light hits an opaque object (anything that does not let light through). Everywhere else, the light continues in a straight path until it bounces off the ground or wall behind the object. The result is a dark patch, or shadow, with the same outline as the object surrounded by light.

In this activity you will explore some of the features of shadows and how to make shadows. You will also be investigating how the size of a shadow and the size of the object that produced the shadow are related. You will find answers to some questions such as: Why can an object produce several differently-shaped shadows? You will also be investigating how the distances between the light, the object, and the screen (wall or ground) affect the shadow that is produced. Record all of your observations and data in your Science Notebook.

MATERIALS:

- ❑ Flashlight
- ❑ Scissors
- ❑ White paper or poster board
- ❑ Ruler or measuring tape
- ❑ Objects that will produce shadows
- ❑ Science Notebook
- ❑ Graph paper

Prepare a K-W-L chart in your Science Notebook. Use the first column (K) to place things that you already know about shadows. In the second column (W) write down any questions that you want to find out about shadows during this activity. In the final column (L) write down what you learned about shadows after doing this activity.

Keep your Science Notebook open and answer questions as you can or record any data that you may collect.

Investigation # 1: Outdoor Shadow Activity

1. Find a partner, go outside and measure his or her height. One of you will make the shadow and the other will draw what the shadow looks like.

2. Have your partner stand facing the sun and draw the shadow that is created. Then answer the following questions in your Science Notebook.

   How was the shadow made?

   What is the length of the shadow?

   How does this compare with the height of your partner?

   What affects the height and position of the shadow?

   Does the shadow give an accurate picture of the shape of your partner's body? Explain why or why not.

3. Draw your partner's shadow again, but this time have your partner turn with his or her shoulder facing the sun. Compare the two drawings you made and write a paragraph about how they are alike and how they are different.

Investigation #2: Changing the length of shadows

1. Choose several objects from around the room (books, papers, or items that your teacher has provided). Choose one thing that you can see through and one object that you cannot see through.

2. Darken the classroom so that you can use your flashlight to create shadows. Take the object you can see through and your flashlight and produce a shadow.

   What does the shadow look like?

   Can you change the length of the shadow? How?

3. Use your flashlight to form a shadow using the object that you cannot see through.

   What does the shadow look like?

   How is it similar to the shadow you made in #2 above? How is it different?

Investigation #3: Comparing Shapes and Shadows.

1. Choose a two-dimensional (flat) object and use your flashlight to produce a shadow.

2. Then choose an object that is three-dimensional and use your flashlight to produce a shadow. Answer the following questions in your Science Notebook.

   How are the shadows produced by these objects alike?

   How are the shadows produced by these objects different?

3. Find a three-dimensional object and try to create three different shadows from the same object. Draw them in your Science Notebook.

4. List any questions you still have about shadows in your Science Notebook and suggest ways that you can answer the question.

INVESTIGATION #4: WHAT AFFECTS THE SIZE OF A SHADOW?

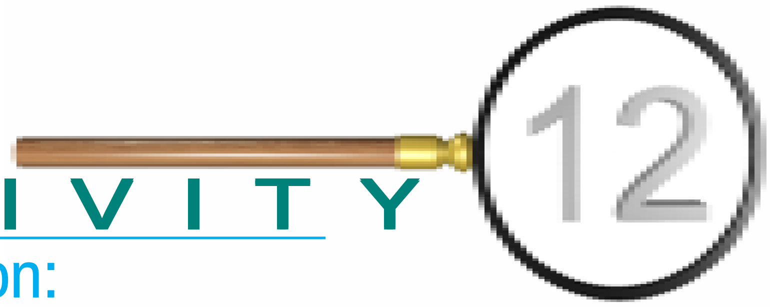
1. Use the materials in *Science, Optics & You* to answer the question, "What affects the size of a shadow?"

2. In your Science Notebook, write your plan for answering the question. Then, share your plan with a classmate and then put your plan into action!

3. Write a description of how your plan worked in your Science Notebook and answer your original question, "What affects the size of a shadow?"



Activity 12



Shadows in Action: The Shadowbox Theater

A shadowbox theater can be used with any unit of study that you are conducting in your classroom, not just with light and optics. However, once students reach a level of understanding of how the theater works and how light and shadows can be manipulated, the shadowbox theater (and its variations) can be an alternative way for students to share what they have learned. Students will discover that making and using their theaters is easier if they identify a few variables and how to manipulate them. [A variable is something being changed in an experiment.] Some variables are: the type of material or paper that is used as a screen for the shadowbox; how far away or close the puppet is; how carefully students cut out the puppets; how dark or light the room is; and what kind of light source students are using (a broad beam of light or a concentrated beam of light).

Although you do not have to use the word "variable," the concept of manipulating parts of an experiment one at a time is consistent with how science is done in real-world situations. Part of the scientific process of asking and answering questions is learning to manipulate one variable at a time. This ensures that students will be able to analyze their data and draw viable conclusions. They will quickly discover that manipulating more than one variable at a time leads to confusion and questionable results.

The more students experiment with the shadowbox and puppets, the more variables they will identify and the more questions they will have. Encourage students to write down all their questions in their Science Notebooks. Have them compare ideas with other students and present their ideas to one another.

MATERIALS:

- ☐ Shoeboxes or other small cardboard boxes
- ☐ Craft or Popsicle sticks
- ☐ Scissors
- ☐ Construction paper
- ☐ Flashlights or other light sources
- ☐ White paper
- ☐ Transparent tape
- ☐ Various art supplies to decorate the boxes

This could be a teacher-guided activity or students could work independently using the student page as a guide. It is helpful to have a previously made shadowbox to serve as a model for your students.

Ahead of time: If you wish to have your students perform for other classes, you will need to schedule classroom visits ahead of time. Older students could perform for younger students while explaining to them how the shadow puppets work.

Ahead of time: you will also need to accumulate a collection of boxes so that you will have all of your materials ready when you want to begin the activity.

WHAT WILL THE STUDENTS DO?

Students will construct shadowboxes and demonstrate that they can perform a play by manipulating light, shadows, and puppets. After creating their shadowbox theaters, students will answer questions in their science notebooks about the science of shadow making.

1. Students cut a hole about 13 centimeters square in the bottom of a shoebox. The square hole should be close to the short end of the box. This will provide an area to conceal the hands of the puppeteer.

2. Tape a piece of translucent white paper over the hole to serve as the screen. Copy paper, butcher paper, newsprint, or wax paper will work. Encourage students to try a variety of papers to determine which make the best screen.

3. Students decorate their boxes using crayons, markers, paint, or paper cutouts.

4. Students make up a story or choose a story that they are reading to perform, deciding on the characters for their story and cutting out silhouette puppets from construction paper. Students tape craft sticks to the puppets to serve as handles.

5. To perform, students shine a flashlight into the box in a darkened room and manipulate the puppets so that their shadows are cast on the screen.

6. Students will experiment with the effects of placing the puppets at different distances from the screen and of turning the puppets at different angles to the light source.

EXTENSIONS:

Poetry. Read aloud the poem, *My Shadow,* by Robert Louis Stevenson. Discuss the poem with students. Encourage them to propose some scenarios as to what Stevenson was doing when he got the idea for the poem.

I have a little shadow that goes in and out with me,
And what can be the use of him is more that I can see.
He is very, very like me from the heels up to the head;
And I see him jump before me, when I jump into my bed.

The funniest thing about him is the way he likes to grow –
Not at all like proper children, which is always very slow;
For he sometimes shoots up taller like an india-rubber ball.
And he sometimes goes so little that there's none of him at all.

Writing. Have students write a poem about their shadows. Students can use a word that starts with each letter of the word shadow to start each line of the poem, for example:

Skinny is my shadow when the sun is low,
Happy is my shadow when I run and play,
Angry is my shadow when I go away.

Narrative writing.

In the story of Peter Pan, Peter loses his shadow. Pretend that your shadow runs away from you.

Think about the adventures that your shadow has.

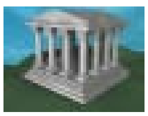
Now write a short story telling what happened to your shadow.

Mathematics. Have students measure their shadows outside at different times of the day. Students can compare differences between their heights and the lengths of their shadows. Then have students graph the data that they collect. Students should be able to explain why the type of graph that they chose was most suited to displaying their data. Challenge students to explain why the lengths of their shadows vary. If your students are ready for a discussion about the rotation of the earth, have them model how the earth's rotation affects the length of their shadows.

Earth science. During a lunar eclipse, the round shadow of the Earth slowly covers the moon. Using a light source and various sized balls, challenge students to discover and demonstrate how a lunar eclipse occurs. This activity can lead to a study of the moon and the discoveries of Galileo Galilei (see the Historical Vignette & Activity: Galileo Galilei & the Moon). It would also be a source for a shadowbox theater play.

Reading. Read aloud *Henry in Shadowland* by Laszlo Varvasovzsky (ISBN 0-87923-785-6). This story about a boy who becomes involved with the characters that he has created for a shadowbox theater could spark the imagination of students before they begin this activity.

Geography. Have students research the shadow puppet theatres of Java, Bali and Thailand. Shadow puppet theatres have been part of the folk culture for centuries. The shadow puppet theatre is considered the strongest traditional theatre form in Southeast Asia and thousands of puppeteers are still active producing elaborate shows.



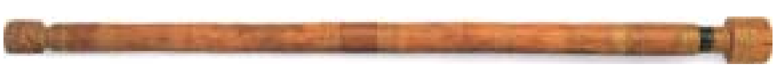
HISTORICAL VIGNETTE: GALILEO GALILEI

This vignette is written to be read aloud to students:

Galileo Galilei was a very famous scientist, mathematician, astronomer, philosopher and physicist. He lived from 1564 to 1642 in Italy. He was the first to use a telescope to explore and map the stars, planets and the moon. Galileo kept careful notes and made beautiful drawings of his observations. The moon particularly fascinated Galileo. Using a telescope (shown below), he was the first to discover what the surface of the moon looks like. Here is a description of the moon in Galileo's own words:

> *It is a beautiful thing and most gratifying to the sight to behold the body of the moon. The moon is not robed in a smooth and polished surface but is in fact rough and uneven covered everywhere, just like the earth's surface with huge prominences, deep valleys, and chasms.*

Galileo collected all of his writings and published them in a book called *The Starry Messenger.* His book became the most famous and important source of information for many years about the moon, planets, sun and stars.



Activity. Read aloud the Caldecott Award-winning book, *Starry Messenger, Galileo Galilei* by Peter Sís (ISBN #0-374-37191-1), a fascinating and beautifully illustrated book. Descriptions are given of the many and varied discoveries of Galileo and excerpts of his writing are included.

ARTIST VIGNETTE: ETIENNE DE SILHOUETTE

A silhouette is an outline or profile drawing of a person or thing filled with a solid color. A silhouette looks very much like a shadow. During the 1700s in Europe, a French government official named Etienne de Silhouette started cutting paper shadow portraits of his friends and family. He would cast a shadow of his subject on a piece of paper using a candle. He would then trace the shadow profile and then cut it out using black paper. Soon shadow portraits became very popular and were named after him.

Silhouette portraits became popular in America during the 1800s. George Washington's granddaughter made a silhouette portrait of her grandfather that still exists. She made it by tracing his shadow cast on the wall of his home using sunlight.

Silhouette portraits continued to be popular until the early 1900s. Many famous people including most of the first presidents of the United States have had their silhouette portraits made. Because of silhouette portraits, we are still able to see what men and women who were important to American history looked like. Silhouette portraits have helped us remember those who have lived long ago.

<u>Activity.</u> After reading aloud the vignette, ask students to think about why George Washington's granddaughter made a silhouette portrait of her grandfather. The discussion will certainly touch on having something to remember him by. Ask students to think about a favorite family member, friend, or pet that they would like to always remember. Suggest that they make a silhouette portrait. Students can practice making portraits in class. Students can even make albums containing portraits of several persons. For each portrait, students can write biographical information and a story about the person or pet.

Activity 12

Shadows in Action: The Shadowbox Theater

When the sun shines, shadows can be seen on the ground or a wall, creating an outline of any object that blocks the light. Shadows are so common that you probably do not pay much attention to them. However, there is much to discover if you observe shadows and experiment with making your own. A fun way to learn about shadows is to make a shadowbox theater and shadow puppets.

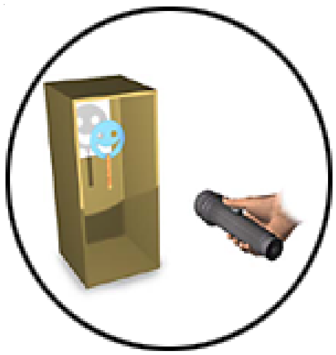
Shadowbox theaters were very popular in Europe during the 1800s and early 1900s. They are still popular in the Indonesian Islands of Bali and Java where very elaborate shadow puppet shows are performed. Follow these directions to make your own shadowbox theater.

Materials:

- ☐ Shoeboxes or other small cardboard boxes
- ☐ Craft or Popsicle sticks
- ☐ Scissors
- ☐ Construction paper
- ☐ Flashlights or other light sources
- ☐ Different types of translucent paper
- ☐ Transparent tape
- ☐ Various art supplies to decorate the boxes

1. Stand the shoebox on its end. Cut a square hole at the top end of the bottom of





the box. This is where the screen will be. The hole should be about 13 centimeters square (13 cm X 13 cm).

2. Cut out a piece of translucent paper just a little bit bigger than the hole you made. Tape or glue the paper on the inside of the box covering the hole. This will be the screen for your theater. Your theater is ready. If you like, use paint, crayons, markers, or paper cutouts to decorate your theater.

3. Now you need a story and puppets. You can make up a story or choose a story that you know. Decide on the characters and what you want the characters to do and say. Draw an outline of the characters on construction paper, making sure that your puppets are small enough to fit on your screen.

4. Carefully cut out your shadow puppets. Tape the puppets to craft or Popsicle sticks so that you have a handle.

5. Shine a flashlight into the box in a darkened room. (You may want to place the flashlight on a pile of books or work with a partner.) Move your puppets in the box between the light and the screen. The puppets will appear as shadows to your audience.

6. Experiment with placing the puppets at different distances from the screen. Turn the puppets in different directions to get interesting effects. For example, can you make the shadows darker, sharper, bigger, or smaller?

Now, on with the show!

After you have performed a show and watched a show, answer the following questions in your Science Notebook.

What did you do to produce the sharpest image on the screen?

What was the most difficult thing about making your shadowbox theater?

How could you improve upon your design?

Which type of translucent paper would you use to design a new screen for a shadowbox theater?

Student SELF-CHECK

Module 2: Light and Lenses

Now that you have completed Module 5, answer the questions below in your Science Notebook as a self-check to see if you need more practice.

1. Which type of object would produce the best shadow, a transparent, translucent or opaque one?

2. Will a shadow look the same size at different times of the day? Why or why not.

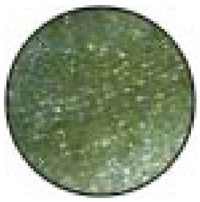
3. What happens to the size of a shadow as the object is brought closer to a flashlight?

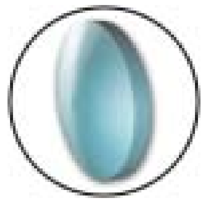
4. Which instrument would you use to see stars?

5. Explain how you can make a shadow darker and sharper if you are using a flat object and a flashlight.

MODULE m6

Microscopes and Crystals





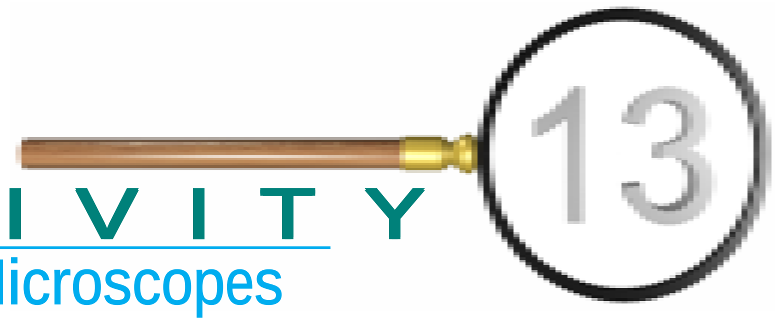
INTRODUCTION

Module 6, Microscopes and Crystals, contains four activities. Students will discover the parts of a microscope and will use the microscope to observe crystals that they create.

Activity 13: Exploring With Microscopes
Activity 14: Crystal Making
Activity 15: What Variables Affect Crystal Growth?
Activity 16: Using Microscopes to Investigate Birefringence in Crystals.

In Activity 13, students are comparing images formed by a water drop magnifier, a hand lens (magnifying glass), and the field microscope. (The hand lens and field microscope are in your *Science*, *Optics and You* package.) Activity 14 provides instructions for making different kinds of crystals. In Activity 15, students design their own experiment to test how variables affect crystal growth. In Activity 16, students use polarizers and the crystals they have made to explore some of the special properties of crystals.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Double Refraction, Polarized Light Microscopy, Microscope Magnification, Translational Microscopy, and Birefringent Crystals in Polarized Light, http://micro.magnet.fsu.edu/optics/tutorials/index.html



ACTIVITY 13
Exploring With Microscopes

The compound microscope was invented in about 1595 by Zacharias Janssen. Robert Hooke (1635-1703) made compound microscopes containing two or sometimes three lenses, which he began using in the 1660's.

In 1665 Robert Hooke published a remarkable book called *Micrographia*, which contained detailed drawings and descriptions of small objects from flies to fleas. With the help of a recent invention, the microscope, Hooke showed things that once had been invisible. Two types of microscopes were in use, the "simple" microscope that had just one lens, and the "compound" microscope which had two or more lenses. Hooke used a compound microscope, while Anton van Leeuwenhoek, another pioneer of microscopy, used simple microscopes made with very good lenses. His great care in grinding these lenses produced excellent results. Van Leeuwenhoek made detailed studies of many tiny "animalcules," and was the first person to ever see bacteria. The magnifying power of his simple microscopes ranged from about 70 times (70X) to more than 250 times (250X). A wonderful source for the history of microscopes can be found at http://micro.magnet.fsu.edu

At its simplest, a compound microscope needs just two lenses, a small but powerful objective lens, and a larger eyepiece lens. [The field microscope found in your *Science, Optics and You* package is a simple microscope until you use the eyepiece attachment which makes it a compound microscope.] Light from the specimen is focused by the objective lens so that it forms a magnified image. The eyepiece lens then enlarges this just like a magnifying glass, so that the observer's eye traces the light back to see a much bigger image. A compound (two-lens) microscope produces an image that is inverted, or back-to-front.

In *Exploring with Microscopes*, students should see the relationship between magnifying lenses and microscopes and realize that the same principle used in finding the focal point of a lens is used in focusing a microscope. In the following activities the students will be exploring some simple microscopes and the field microscope which can be found in the *Science Optics and You* package.

MATERIALS:

- Slide
- Grease marking pencil
- Dropper
- Small container of Water
- Hand lens
- Field Microscope
- Source of light, flashlight or good room light
- Newsprint, and comics from the newspaper
- Science Notebook

WHAT WILL THE STUDENTS DO?

In this activity students will be doing comparative observations of objects using a simple water drop magnifier, a hands lens and a field microscope which is an example of a basic compound microscope. Students can work individually or in pairs, depending on the number of students in the class. This can be a teacher-guided activity or students can work independently using the student page as a guide. There will be three different explorations in this activity.

Part 1

1. Part 1 involves the construction of a water drop magnifier, a type of simple microscope. The students will use a plastic slide, their Science Notebook, a grease pencil, an eyedropper, a small container of water and some newsprint, both black and white, and colored print from the comics section of the newspaper.

2. Students will take the plastic slide and draw a circle in the center of the slide with the grease pencil. The circle should be a little smaller than the diameter of a dime.

3. Using a newspaper, magazine, or book students find a lower case "e" to observe with their water drop magnifier.

4. Students will add one drop of water to the circle, observe the "e," add a second drop of water, observe again, and a third drop of water to the circle and observe and record differences in their Science Notebooks.

5. Students take a piece of the comics or a comic book (this also works with pictures in magazines) and observe the dots that form the images. There are three colors of dots to form all of these images.

6. Students will observe differences in the dots using a 1-drop magnifier, a 2-drop magnifier and a 3-drop magnifier.

WHAT'S GOING ON HERE?

Students have actually formed a plano-convex lens. The more water that is added to the circle, the thicker the "lens" is going to be; consequently, the focal point and the magnification will change. As students first begin to move the "lens" further away from the newsprint, the image grows larger. If they continue to move the lens away from the page it will become fuzzy and when it comes back into focus the image will appear upside down. This is because of the way the lens bends the light traveling from the page to your eye. When the lens is close to the page, you see what is known as a virtual image. This is an upright image that is larger than the image on the page. As you move the hand lens closer to your eye and away from the page, you see what is called a real image, which is upside down.

Part 2

1. Students look at the letter "e" through the hand lens provided in the package.

2. Recording their observations, students will compare what they see through the hand lens with what they saw using the water drop magnifier.

3. Students will look at the colored paper from the comics (like they did with the water drop magnifier). Students should notice and record any similarities and differences they may see in these images in their Science Notebooks. They might comment on the focal length, the clarity of the image or colors they are able to see.

Part 3

1. Students will be using the field microscope included in the package for the last part of this activity. They will be looking at the newsprint and the colored paper from the comics using this microscope.

2. If the paper is too thick for light to pass through the paper from the mirror, then another student can shine the flashlight on the slide so that a good image will be seen. It is suggested that students be made aware of the functions of the parts of these field microscopes, how to focus, and how to place the specimens on the stage of the microscope.

*The field microscope magnifies 50 times (50X) and when using the compound eyepiece it increases the magnification of the microscope 2-4 times. Most of the time students will be using the microscopes without the compound eyepiece.

Basic Operation of the Field Microscope

1. Place the field microscope on a level surface.
2. Insert the specimen slide under the stage clips.
3. Rotate the mirror, using gentle pressure on one or both of the mirror hubs until the maximum amount of light is reflected from the mirror into the eyepiece. This is called the field of view.
4. Focus slowly by turning the focus wheel with your thumb.

Tips for Successful Viewing

- To get a good image, light must pass through transparent or translucent specimens, or bounce off the top of an opaque specimen.
- The higher the power of magnification, the greater the intensity of light needed. A lamp or brightly-lit window should be sufficient.
- Light from fluorescent bulbs generally yields better images than incandescent bulbs.
- If the students are working as partners, one of them could shine the flashlight down on the specimen so that enough light would be produced to see an image.

Extensions:

Expository writing.

Microscopes and telescopes both use lenses.

Before you begin writing, think about the similarities and differences in how microscopes and telescopes work.

Now write how you could make a telescope from materials in the classroom that would allow you to see things at a distance.

Narrative writing.

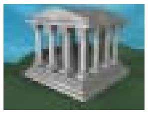
Microscopes are often used to study small plants and animals in ponds.

Pretend that you are investigating a neighboring pond, which suddenly changed color from a light brown to a bright green.

Now write a short story about how you would investigate this problem using a microscope.

Reading. Read aloud (or have available) *A Drop of Water* by Walter Wick (ISBN 0-590-22197-3). This book uses illustrations and some text to describe the properties of a drop of water. This relates directly to the first Exploration in Activity 13, making a water drop magnifier.

Reading. The book, *Looking for Atlantis* by Colin Thompson (ISBN 0-679-85648-X) is rich with images that challenge the reader to identify the thousands of objects "hidden" in the pictures. Beneath each illustration is another illustration of an imaginary world. Have students use their powers of observation to identify as many items as they can and then compare with classmates to develop a complete list.



HISTORICAL VIGNETTE: ZACHARIAS JANSSEN

The origin of the optical microscope is a matter of debate. However, most scholars agree that the invention of the compound microscope can be credited to Zacharias Janssen in the late sixteenth century. At that time eyeglasses were beginning to enjoy widespread use and this focused a great deal of attention on optics and lenses. This first microscope was made in the year 1595 probably with the help of his father Hans Janssen. Part of the confusion about who actually invented the first compound microscope is due to the fact that no early Janssen microscope has survived. A microscope that can be found in a Middleburg, Holland, museum is reported to be an early Janssen-made microscope.

Luckily, there was one true Janssen microscope that survived long enough to be studied. As was customary at the time, the Janssens made several examples of their microscope to give to royalty. One of those was sent to Prince Maurice of Orange, and one was given to Archduke Albert of Austria. Neither of these microscopes survived to modern times, but in the early 1600's a childhood friend of Zacharias Janssen examined it and recorded his observations. He described the royal instrument as being made of three sliding tubes, measuring 18 inches long when fully extended, and two inches in diameter. It was very ornate, with 3 brass dolphins at the end forming the feet of a tripod. This early microscope was different from modern microscopes in that it only contained 2 lenses, and magnified objects nine times.

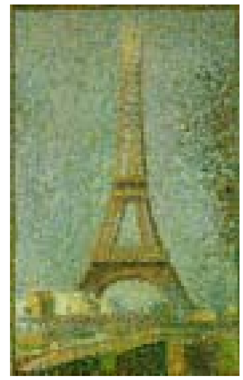
After the invention of this microscope, many other scientists began to experiment with ways of improving this early microscope. Most of them made improvements by grinding the lenses more carefully, and by having more than two lenses to magnify objects.

Activity. Robert Hooke was the first scientist to use the term *cell* for the individual units of living things. Encourage students to research how Hooke decided on this name, and to draw what he first saw.

Writing. The only way that we know that Zacharias Janssen invented an improved microscope was because someone else documented his invention. Discuss with students the importance of keeping accurate and detailed records in both words and drawings. Use the field microscope from your package and have students draw the instrument and write a description of how it

works as if no model of the microscope existed.

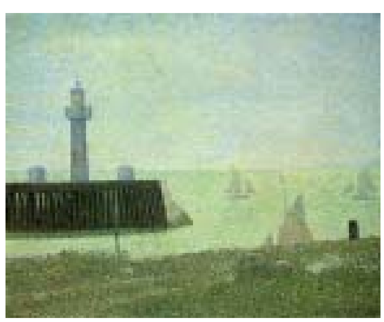
ARTIST VIGNETTE: GEORGES SEURAT (1859-1891)



During his short life, Georges-Pierre Seurat was an innovator in the field of art. This French painter was a leader in a movement called neo-impressionism in the late 19th century. While searching for a way to represent nature, he developed a technique called pointillism. Pointillism is the term given to creating an illusion of depth and light and dark values by grouping dots of ink. By changing the space between the dots, one can achieve an illusion of varying hues. Dots of ink placed close together will create a dark value. The further apart the dots are placed, the lighter the value will appear. A gradient from light to dark can be created by gradually varying the space between the dots.

Seurat was an art scientist in that he spent much of his life searching for how different colors and lines would change the look or texture of a canvas. His experiments with color led him to paint in small dots of color that were arranged in such a combination that they seem to vibrate. Individual colors tended to interact with those around them and fuse in the eye of the viewer. This concept is similar to the dots or pixels in a computer image. If you magnify any computer image enough, you will see individual colors that when set together produce an image. Seurat was interested in the way that colors worked together to create a particular tone. This technique of pointillism took much longer to produce a work of art, however during his life he produced over 500 pieces of artwork.

Activity. Students can produce a drawing using pointillism by following these directions. Students will create a light pencil sketch of their object. This will act as a reference and will be erased once the drawing is complete. They will create the darkest values first by placing dots very close together. Next they will create the illusion of a lighter value by extending the distance between the dots. Then they will gradually extend the distance between the dots as they capture the natural shading of the object. Once they have completed this, have them step back and take a look at the drawing. They will then make any changes needed. This is a time-consuming project but can be a fun way for students to try this art form.



ACTIVITY 13

Exploring With Microscopes

Janssen Microscope

The compound microscope was invented in about 1595 by Zacharias Janssen and his father Hans Janssen. Their early microscope only had two lenses that only allowed them to see objects about nine times larger than normal. Their invention however allowed other scientists to make changes in their initial design until some microscopes even as early as 1665 were able to magnify up to 250 times.

In this activity you are going to make a simple microscope by making a water drop magnifier, and then compare the images produced by this magnifier to images produced by using a hand lens and the field microscope.

MATERIALS:

- ❑ Slide
- ❑ Grease pencil
- ❑ Dropper
- ❑ Small container of water
- ❑ Hand lens
- ❑ Field microscope
- ❑ Source of light, flashlight or good room light.
- ❑ Newsprint and comics from the newspaper
- ❑ Science Notebook

Using the materials above and the procedure below, you are going to make a water drop magnifier. For each trial, draw a circle in your Science Notebook to represent your field of view (the area you can see through your magnifier or microscope) and then draw the images you see. Describe what you see next to your drawings.

1. Draw a circle in the center of the slide with the grease pencil. It should be a little smaller than the diameter of a dime.

2. Add one drop of water to the circle and observe a lower case “e” in a piece of newspaper by looking through the drop. In your Science Notebook, draw and describe what you see.

3. Add two drops of water to the circle and observe the “e” again. In your Science Notebook, draw and describe what you see.

4. Add three drops of water to the circle and observe the “e” again. In your Science Notebook, draw and describe what you see.

5. Now start over with a water drop magnifier using one drop of water and observe a piece of colored paper from the comics. In your Science Notebook, draw and describe what you see.

6. Observe the same piece of paper using a two-drop and a three-drop magnifier. In your Science Notebook, draw and describe what you see.

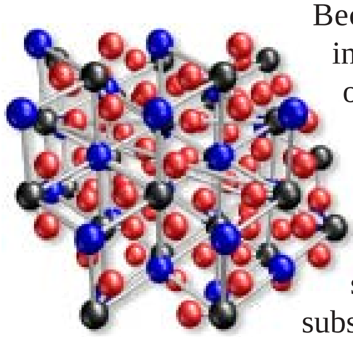
7. Look at the newspaper “e” and the colored picture from the comics with the hand lens provided in the package.

8. Now use the field microscope to view the newsprint and the colored paper from the comics.

9. In your Science Notebook, compare how the objects looked under the different magnifying tools.

ACTIVITY 14
Making Crystals

What is a crystal? Crystals are solids that form when there is a regular repeated pattern of molecules. In some solids, the arrangements of the atoms and molecules can be random throughout the material. In crystals, however, a collection of atoms is repeated in exactly the same arrangement over and over throughout the entire material.



Because of their repetitive nature, crystals can take on strange and interesting shapes naturally. When we grow crystals, in the laboratory or in the classroom, the atoms and molecules are separated into an individual collection of atoms, and as the water evaporates, they fall naturally into their appropriate place in the repetitive structure.

When making crystals in the classroom, you first need to create a saturated solution. When you reach the point that no more solute (the substance that you are trying to dissolve) will dissolve (regardless of what you do to the solution), then you have made a saturated solution. For example, when adding sugar to water you can increase the amount of solute (sugar) the water (solvent) will hold by stirring and heating the solution.

Below are some tips for making crystals and diagnosing some problems that students may experience when doing the activity for the first time.

CRYSTAL MAKING TIPS

1. Measure according to the directions. More of a chemical does not always make better crystals.

2. When heating your saturated solution, use saucepans that are glass or enamel. Metal containers may react with your chemicals.

3. It is preferable to use distilled or filtered water, but tap water works very well. To determine whether tap water will affect the crystals you are making, perform the "ice cube test." (If ice cubes appear cloudy, tap water will probably produce cloudy crystals so use distilled or filtered water. If ice cubes are clear, use tap water.)

4. Try to keep the crystal growing experiment in an area with constant humidity and temperature, as much as possible.
5. Once you prepare solutions, place them where they will not be disturbed.

WHERE TO FIND COMMON MATERIALS FOR CRYSTAL MAKING.

Alum: A common ingredient for making pickles, alum can be found in the spice and herb section of the grocery store, or purchased at some drug stores.

Copper sulfate: Found at hardware stores or nurseries and sold as a product that kills tree roots in septic or sewer lines, copper sulfate ($CuSO_4$) can also be ordered through most science catalogs.

Borax: A laundry product that can be found at the grocery store, borax will make-easy-to observe crystals.

Epsom salts: A product that can be easily found in drug stores or in grocery stores, epsom salts is commonly used in many households.

Granulated sugar and table salt also create interesting crystals crystals.

TROUBLE-SHOOTING:

If crystals do not form:

You may be using too much water, not enough of the chemical, or the temperature or humidity may be unfavorable.

If crystals form but are tiny:

You may have too much of the chemical in proportion to the water, or evaporation is happening too quickly.

If crystals grow but then disappear:

If your crystals get smaller or disappear over time, then add more chemicals to the solution and begin again.

If crystals are cloudy:

You may have impurities in the water or in the chemical. Distilled water is recommended.

MATERIALS:

- ❑ Tap water or distilled or filtered water
- ❑ Slides
- ❑ Baby food jars, clear film canisters, or other clear container
- ❑ Copper sulfate ($CuSO_4$), Epsom salts, table salt, sugar or borax
- ❑ Droppers or straws to dispense and/or stir solutions
- ❑ Teaspoon (a teaspoon holds 5 ml of liquid)
- ❑ Field Microscopes
- ❑ Science Notebooks

WHAT WILL THE STUDENTS DO?

The purpose of this activity is to provide students with the opportunity to make crystals using materials and instructions provided. This is a structured activity, and is intended to introduce students to crystal making. In Activity 15, students will extend this experience by investigating variables that affect crystal growth.

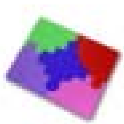
Procedure:

Students will make crystals using one or all of the solutes listed in the materials section.

For example, if students are making a copper sulfate solution, they will follow these instructions.

1. Place 10 ml (2 tsp.) of warm water in a jar, or other container.
2. Add 7 g (1 tsp.) of copper sulfate to the water.
3. Shake or stir until the copper sulfate is dissolved.
4. Take a dropper, or a straw, and put one or two drops of the liquid in the center of a slide.
5. Place the slide where it will not be disturbed.
6. Students will examine the slide the next day. and record observations in their Science Notebooks. These may be in the form of written observations and drawings.

EXTENSIONS:

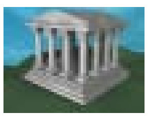


Art. Before photography was widely used, geologists, astronomers, naturalists and other scientists used words and drawings to inform each other about their discoveries. Have students pretend they are geologists and have them draw pictures of crystals as carefully as they can, including all details. Then, encourage students to color the drawings. The more detail they have included, the more colors they can incorporate. Students can compare these drawings to the actual drawings of birefringent crystals in Activity 16.

Writing. Have students imagine that they are spelunkers (cave explorers). What kinds of patterns, shapes, or formations would they see? Students can include stories about stalactites and stalagmites. If any students have visited caves (such as the Marianna Caverns, Luray Caverns, or Carlsbad Caverns), encourage them to share what they have seen to help others envision what caves are like. Have students illustrate their stories.

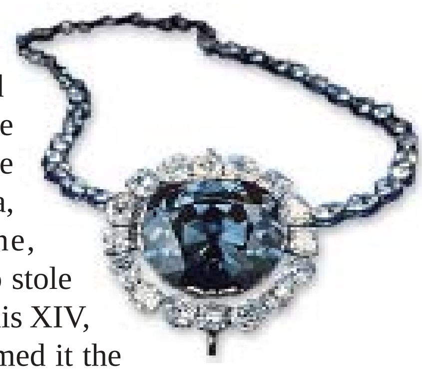
Reading. Either have students read or read aloud to them Gary Paulsen's *The Legend of Red Horse Cavern* (ISBN 0440410231). An adventure story about young people lost in a cavern could be a jumping off point to encourage students to do further research on caverns or to write their own stories.

Guest Speaker. Invite a gemologist to speak to the class, display some precious crystals and discuss how the crystals are cut to make them marketable. Try contacting a local jewelry store, geology club, or college or university department.



HISTORICAL VIGNETTE: THE LEGEND BEHIND THE HOPE DIAMOND

The famous blue Hope Diamond weighs 44.52 carats and is said to be unlucky for its owner. It is probably the most famous gemstone in history. Many of the people that owned the diamond were unlucky and it is believed that the stone was the cause of their misfortune.



The 112 carat Hope Diamond was mined in India and originally brought to France in 1668 by Jean Baptiste Tavernier. It was said to be cursed because a thief stole the diamond from the eye of a statue of the Hindu goddess Sita, wife of Rama. According to the curse, misfortune, unhappiness, and even death would come to anyone who stole the stone or took possession of it. Tavernier sold it to Louis XIV, who had it cut into a 67 carat heart-shaped stone and named it the "Blue Diamond of the Crown." Tavernier was reportedly killed by wild dogs on his next trip to India.

Louis XVI and Marie Antoinette inherited the "French Blue," as it was popularly known. In 1792 about the time of their executions, the French Blue and all of the other French crown jewels were stolen. Many of the jewels were recovered, but not the Blue Diamond of the Crown. There are reports that the French Blue was re-cut to its present size by Wilhelm Fals, a Dutch diamond cutter. It is believed that he died after his son Hendrick stole the diamond from him. Hendrick later committed suicide.

In 1830 a 44.5-carat deep blue oval-cut diamond appeared in London. It was believed to have been the French Blue that had been re-cut to conceal its identity. Henry Hope bought it and since then it has been called the Hope diamond.

Many Europeans owned the diamond, and many had similar tales of bad luck. It was sold to Evalyn Walsh McLean, a wealthy American, in 1911 and many members of her family also experienced bad luck. After she bought the Hope diamond, her son was killed in an automobile accident, her husband died in a mental hospital, and her daughter died in 1946 from an overdose of sleeping pills. After her death in 1947, Harry Winston, a well known jeweler, purchased all of her jewels including the Hope diamond. He gave the gem to the Smithsonian Institution in Washington, DC, in 1958, where it has remained on permanent display ever since.

Narrative writing.

Diamonds are a type of crystal. The Hope Diamond is a very famous example of a crystal.

Think about what happened to people who have owned the Hope Diamond. Pretend that you are now the owner of this diamond.

Write a short story about what has happened in your life since buying this diamond. Does the bad luck continue or are you the one to "break the curse?"

ARTIST VIGNETTE: GEORGES BRAQUE 1882-1963

Georges Braque was a French painter known for his influence on the cubist style of art. Braque was born in 1882 near Paris, France, and like his father and grandfather, apprenticed himself as a house painter. However, by 1902 he decided to pursue the study of painting as a fine art. He emulated the style of other painters who used brilliant colors and a loose structure of forms to express themselves. Braque also studied Paul Cézanne's work and his influence led him to paint in the manner that came to be called cubist. Braque frequently painted architectural structures in a geometric form resembling a cube or a rectangular prism. Crystals also inspired the cubist painters. They saw in them the shape of a village on a hillside, and in the skin and features of a face.

Picasso, with whom Braque began to work closely in 1909, had been developing a similar approach to painting. Both artists produced paintings of neutralized color and complex patterns of faceted form, now called analytic cubism. Both artists also began to experiment with collage, a technique of constructing an image from the materials of everyday life, for example, newspapers, labels or pieces of fabric. The work with Picasso continued until Braque enlisted in the French army in 1914. He was severely wounded in World War I and resumed his artistic career alone in 1917.

After the war Braque developed a more personal style with brilliant colors and textured surfaces. He continued to work throughout his life and produced many paintings, graphics and sculptures. Braque died in 1963 in Paris.

Activity:
Have students create a collage using different materials, selecting a theme and using the materials to create different shapes within the collage. Students may wish to use crystals, as some Cubists did, as the basis for their artwork using a medium other than collage.

Activity 14

Making Crystals

What is a crystal? Crystals are solids that form in special ways. There is a regular repeated pattern that occurs each and every time new crystals form. Because of this arrangement, crystals can take on strange and interesting shapes naturally.

When we grow crystals, the atoms and molecules are separated, and as the water evaporates, they fall naturally into their place in the repeated pattern. In this activity you will be learning how to make crystals.

Materials:

- ❑ Water (tap, distilled or filtered)
- ❑ Slides
- ❑ Baby food jars, clear film canisters, or other container
- ❑ Copper sulfate ($CuSO_4$), Epsom salts, table salt, sugar or borax
- ❑ Droppers or straws
- ❑ Teaspoon (a teaspoon holds 5 ml of liquid)
- ❑ Field Microscopes
- ❑ Science Notebooks

Procedure:

If you are making a copper sulfate solution, you will:

1. Place 10 ml (2 tsp) of warm water in a jar, or pill bottle.
2. Add 7g (1 tsp) of copper sulfate to the water.
3. Shake or stir until the copper sulfate is dissolved.
4. Take a dropper, or a straw, and put one or two drops of the liquid in the center of a slide.
5. Place the slide where it will not be disturbed.
6. You will examine the slide tomorrow.

Use the same steps to make crystals using Epsom salt, table salt, sugar, or borax.

What to do the next day?

Use your hand lens and field microscope to look at the crystals you made yesterday. Record your observations and answers to questions in your Science Notebook.

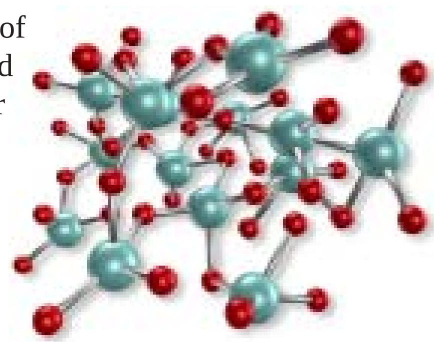
1. What is the difference between what your slide looked like yesterday and what your slide looks like today? Describe what you think happened.

2. Draw what you see while looking at each of the crystals you made with your field microscope. Be sure to label your drawings.

3. Look at another student's crystals. Do their crystals look like the crystals you made? How are they alike? How are they different?

ACTIVITY 15

What Variables Affect Crystal Growth?



Almost every solid that occurs in nature is made up of crystals. The minerals found on earth have differently shaped crystals. Salt looks like rough sand to the unaided eye, however when viewed through a magnifying glass or a microscope, it is actually made up of small cube-shaped crystals. Many crystals are transparent; others are colored. Some crystals, like salt are very small, while others are large enough to be seen without a hand lens or a microscope.

Some crystals are formed when molten rock cools and hardens. Others are formed when water containing dissolved minerals evaporates. In both cases, the atoms of the minerals form solids by coming together in regular repeating patterns. (See Activity 14) These repeating patterns make crystals both strong and hard. Crystals of the same mineral always follow the same growth pattern.

In this activity, students will design investigations about crystals. If they are trying to find out how different variables affect crystal growth, they need to first identify the variables they will be studying. There are two types of variables, manipulated and responding variables. If a variable is deliberately changed it is called a manipulated variable. The variable that may change as a result of changing the manipulated variable is called the responding variable. Students in this activity are going to investigate how variables affect crystal growth.

MATERIALS:

- ❑ Baby food jars, clear film canisters, or other containers
- ❑ Water (some warm, and some at room temperature)
- ❑ Measuring spoon (1 tsp = 5 ml)
- ❑ Copper Sulfate ($CuSO_4$), Epsom salt, table salt, sugar, borax or other crystal-forming substance
- ❑ Slides
- ❑ Droppers or straws
- ❑ Field microscope
- ❑ Science Notebooks
- ❑ Hand lens

WHAT WILL STUDENTS DO?

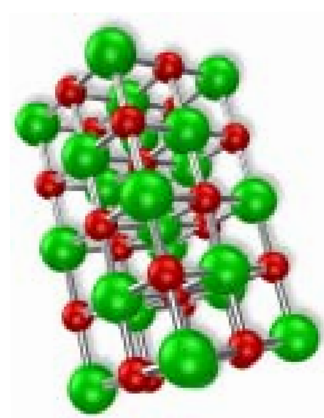
In this activity, students will be investigating variables that may influence the quality of crystals they will be making. In Activity 14, students were given instructions on how to make crystals and in this activity, students are going to determine what variables affect the size of the crystals. You may wish to refer to student answers to question #1 on the student page.

There are two options for implementing this activity. Activity 15A is open-ended where students decide what variables affect crystal growth and then decide on the manipulating variables they would like to study. Activity 15B is prescriptive and explains to students how to test three variables in making crystals. Following are teacher instructions for both Activity 15A and Activity 15B. Each activity has a student page.

Activity 15A

1. Once you have discussed the concept of variables, encourage students to first discuss and list in their Science Notebooks things to consider when making crystals. Some variables that students may suggest are: temperature of the mixture, temperature in the room, type of container used, amount of water, amount of solid, placement of slides, how the mixture is heated, or atmospheric conditions.
2. Students will need to choose what they would like to change, when making their crystals. This one thing is the manipulating variable.
3. Encourage students to design a way to find out how each variable affects the size, number, or formation of crystals.
4. Students will write down in their Science Notebooks all of the steps involved in testing each variable.
5. Students from another group should read the instructions to see if they are easy to understand.
6. Students predict the affect each variable has on the formation of the crystals they have chosen to make, then perform their experiment, and record all data in their Science Notebooks.
7. Have students examine their crystals using hand lenses and field microscopes and compare their results with the predictions they made prior to making the crystals.
8. Students will test each of their indentified variables.
9. Students will present their findings to the class.

Note: The crystals need to sit undisturbed for 24 hours.



Activity 15B

In this activity, students will investigate three variables that may influence the quality of the crystals:

Variable 1: Temperature

Variable 2: Method of mixing the solution

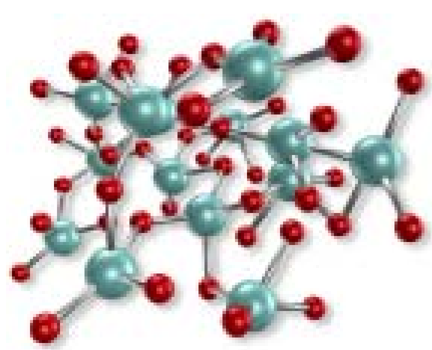
Variable 3: Amount of solid

By manipulating these variables, students will answer the following questions:

1. Does the temperature of the water in a solution affect crystal growth?
2. Does stirring or shaking a solution affect crystal growth?
3. Does the amount of solid added to water in a solution affect crystal growth?

Variable 1:
Students will manipulate the temperature of the liquid used to make their crystals.

1. Provide 2 containers (baby food jars, clear film canisters or other containers).
2. Students label their containers with their names and an H (heated) or a C (not heated). The same amount of water and copper sulfate or other chemical for each container will be used. The only difference is the temperature of the water (the variable) used to make each solution.
3. Provide room temperature water for one container and heated water (not boiling) for the other.
4. Students add 7 g (1 tsp.) of the chemical to 10 ml (2 tsp.) of water in each container. Stir gently until the chemical dissolves.
5. Students will place two drops of the warm solution on a slide, and two drops of the room temperature solution on another slide. These should be labeled and then placed where they will not be disturbed.
6. Students will examine the crystals the next day with hand lenses and with the field microscopes and record results in their science notebooks.



Variable 2:
Students will investigate the effect of stirring or shaking crystal-making solution on crystal growth.

1. Provide 2 different containers for students. Have them label their containers with their name and an S (stirred) or an NS (not stirred). Students will use the same amount of warm water and the same amount of copper sulfate ($CuSO_4$) or other chemical in each container. Everything but the variable should remain constant.

2. Have students add 10 ml (2 tsp.) of heated water and approximately 7 grams (1 tsp.) of the chemical to each container.

3. Stir the chemical and warm water in container S and do not stir the warm water and chemical in container NS.

4. After 5 minutes, take 2 drops of the liquid from container S and place it on a slide, and 2 drops of the liquid from container NS on another slide. Have students label these and place them where they will not be disturbed.

5. Students will examine the slides the next day with hand lenses and with the field microscopes and record results in their science notebooks.

6. Have students repeat the process, shaking the mixture.

Variable 3:
Students will investigate how crystal growth is affected by adding different amounts of chemical to water.

1. Provide 2 containers for students. Have students label containers with their names and one with a (3.5g) and the other container with a (7g).

2. Students will make solutions of two different concentrations. In the (3.5g) container they will add approximately 3.5 grams (½ tsp.) of copper sulfate ($CuSO_4$) or some other chemical to10 ml (2 tsp.) of warm water. In the container marked (7g) they will add approximately 7 grams (1 tsp.) of the chemical to 10 ml (2 tsp.) of warm water.

3. Students should either stir or shake both containers until the chemical is dissolved. They will base this decision on results from investigating variable 2.

4. Students take 2 drops of liquid from the (3.5g) container and place them on a slide. They should also take 2 drops of liquid from the (7g) container and place them on a different slide. Both slides should be labeled and set aside where they will not be disturbed.

5. Students will observe the slides the next day with hand lenses and field microscopes and record observations in their Science Notebooks.

EXTENSIONS:

Research and Art. There are six crystal systems: cubic, tetragonal, hexagonal, orthorhombic, monoclinic, and triclinic. Research the different crystal shapes and design a model of one of them to be shared with the class. Find the names of minerals that represents each system.

Research and Writing. Stalactites and stalagmites are structures often found in caves. Students pretend that they are tour guides explaining how these structures form to people on a tour. Write a script explaining this process. Encourage students to use models or visual aids that explain these and other stone features created by groundwater deposits.

HISTORICAL VIGNETTE:
DOROTHY CROWFOOT HODGKIN (1910-1994)

Dorothy Hodgkin, a Nobel Prize winning chemist made important contributions to biology, chemistry and physics during her lifetime. She was born in Cairo, Egypt but lived most of her life in England. At an early age, she developed an interest in chemistry and crystals, and on her sixteenth birthday received a book about using x-rays to study crystals from William Henry Bragg, a Nobel Prize winner in physics. This gift increased her interest in crystals, and started her on a career path toward using x-rays to study the shape and structure of crystals found in living things.

Although she was sick with rheumatoid arthritis from the time she was 24 years old, Hodgkin became one of the most skilled crystallographers of her time. She always chose projects to work on that others thought were impossible or too difficult. Hodgkin's hard work and knowledge of math, chemistry, physics and biology enabled her to determine the structure of penicillin, vitamin B-12, and insulin. The work she did using x-rays to discover the structure of these crystals helped other scientists learn how to determine the molecular structure of almost any crystalline material. Hodgkin was only the third woman to receive a Nobel Prize in Chemistry. This prize was awarded for her discovery of the structure of Vitamin B-12 and for other discoveries she made that changed the way scientists study chemistry.

ARTIST VIGNETTE: JUAN GRIS (1887-1927)

Juan Gris was a Spanish painter who was important in developing the style of painting known as Cubism. Two other important painters who used this style of painting were Picasso and Georges Braque. The Cubist style of painting usesflat, two-dimensional surfaces. Cubist painters used sharp lines and geometric shapes rather than painting objects using actual form and color.

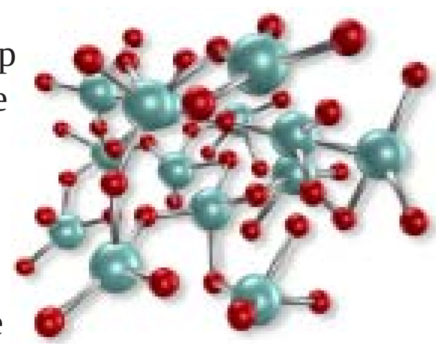
The use of stronger colors and larger and more decorative shapes distinguished the work of Juan Gris from that of Picasso or Braque. Gris portrayed the synthetic cubism form that used decorative shapes, stenciling, collage and brighter colors. Many of the Cubists also combined smooth and rough surfaces, and frequently used foreign materials such as newspapers that were pasted on the canvas in combination with the painted areas. This collage technique became another popular way of creating art. It was Gris who helped to popularized the Cubist style by systemizing the ideas of Picasso and Braque.

<u>Activity:</u>
The structure of ice crystals that produce a snowflake has been a source of fascination for young and old alike. It is said that no two snowflakes are the same, is that true? Encourage students to devise a way to find out using a variety of print and electronic media. Have students draw or make a model of a snowflake and present findings to the class.

Activity 15

What Variables Affect Crystal Growth?

Activity 15A



Almost every solid that occurs in nature is made up of crystals. The minerals found on earth have differently shaped crystals. Salt looks like rough sand to the unaided eye. However, when looked at using a hand lens or a microscope, it is actually made up of small cube-shaped crystals. Many crystals are transparent, others are colored. Some crystals, like salt, are very small, while others are large enough to be seen without a hand lens or a microscope. What causes crystals to be so different from one another?

In this activity you and your group are going to investigate variables that affect crystal growth. Before beginning this activity, think about how you made crystals in Activity 14. Using the materials below, you and your group members are going to design an experiment to test your ideas about crystal growth.

Materials:

- ❑ Baby food jars, clear film canisters, or other containers
- ❑ Water
- ❑ Measuring spoon (1 teaspoon = 5 ml)
- ❑ Copper Sulfate ($CuSO_4$), Epsom salt, table salt, sugar, borax or other substance
- ❑ Slides
- ❑ Droppers or straws
- ❑ Field microscope
- ❑ Hand Lens
- ❑ Science Notebooks

1. Think about how you made crystals in Activity 14. With your group, write down a list the things necessary for crystals to form in your Science Notebook. Then, choose one or more things to change (your variables) when you make a new batch of crystals.

2. Design a way to test how each variable affects crystal growth and how you are going to record your data. Record your plan in your Science Notebook.

3. Exchange Science Notebooks with another group. Can they understand which variable you are testing? Do they know what materials are needed? Are your instructions clear enough so that they could copy your experiment?

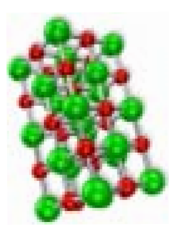
4. List each variable that you wish to test and predeict what you think will happen. When you are done with your experiment, you can look back and see how accurate your predictions were. Now conduct your experiment, let the crystals sit undisturbed for at least 24 hours and record the results.

5. Draw the crystals in your science notebook.

6. Share your results with the class.

7. Answer the following questions in your Science Notebook:

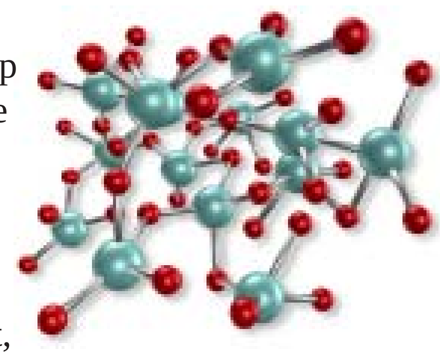
- ❑ Did other groups choose the same variable? Were their results the same?
- ❑ What other questions do you have about crystal making?



ACTIVITY 15

What Variables Affect Crystal Growth?

Activity 15B



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In this activity you and your group are going to investigate variables that affect crystal growth. Before beginning this activity, think about how you made crystals in Activity 14.

You will be making crystals three different ways. Each time you will be changing one thing (this is called a variable) when you make your crystals. The three different variables you will be testing are: temperature, method of mixing the solution, and amount of solid. In doing this, you will try to anwer the following questions:

1. Does the temperature of the water in a solution affect crystal growth?

2. Does stirring or shaking a solution affect crystal growth?

3. Does the amount of chemical added to the water affect crystal growth?

VARIABLE 1: TEMPERATURE

MATERIALS:

- ❑ 2 containers (for example, baby food jars, or clear film canisters. One container will be labeled with an (H), and one of the containers will be labeled with a (C). Make sure that your name is on both containers.
- ❑ Cup containing warm water and a cup containing cool water
- ❑ Measuring spoon (1 tsp. = 5 ml)
- ❑ 2 teaspoons of copper sulfate ($CuSO_4$) or some other chemical
- ❑ 2 slides
- ❑ A dropper or straw to put liquid on the slide
- ❑ Field microscope
- ❑ Hand lens
- ❑ Science Notebooks

Day 1:

1. Put 10 ml (2 tsp.) of warm water in the container marked (H).
2. Put 10 ml (2 tsp.) of cool water in the container marked (C).
3. Add about 7 grams (1 tsp.) of copper sulfate or the chemical you are using to each container.
4. Shake or stir each container until all of the chemical is dissolved.
5. Label two microscope slides (H) and (C).
6. Using a dropper or straw put 2 drops of liquid from container (H) on to slide (H). Put 2 drops of liquid from container (C) on to slide (C).
7. Put the two slides where they will not be disturbed. You will observe them tomorrow.
8. Answer the following questions in your Science Notebook:
   - ❑ Based on the crystals your grew in Activity 14, what do you think your new crystals will look like?
   - ❑ What do you think the results of your experiment will be? How do you think the temperature will affect the crystals?

Day 2

1. First use your hand lens to observe both slides and record what you see in your Science Notebook. Then use your microscope and do the same thing. Record observations by writing and drawing what you see.
2. In your Science Notebook write about the difference between the crystals grown using warm water, and the crystals grown using cool water.
3. Can you answer the question, Does the temperature of water in a solution affect crystal growth? Be prepared to share your results with the rest of the class.

VARIABLE 2: METHOD OF MIXING THE SOLUTION

MATERIALS:

- ❑ 2 containers (for example, baby food jars, or clear film canisters. One container will be labeled with an (H), and one of the containers will be labeled with a (C). Make sure that your name is on both containers.
- ❑ Warm water
- ❑ Measuring spoon (1 tsp. = 5 ml)
- ❑ 2 teaspoons of copper sulfate ($CuSO_4$) or some other chemical
- ❑ 2 slides
- ❑ A dropper or straw to put liquid on the slide
- ❑ Field microscope
- ❑ Hand lens
- ❑ Science Notebooks

Day 1

1. Put 10 ml (2 tsp.) of warm water in the container marked (S).
2. Put 10 ml (2 tsp. of warm water in the container marked (NS).
3. Add about 7 grams (1 tsp.) of copper sulfate or some other chemical to each container.
4. Shake or stir container (S) until all of the chemical is dissolved. Do not shake or stir the copper sulfate in the container marked (NS) Allow this to sit for about 5 minutes.
5. Label 2 microscope slides (S) and (NS).
6. Using a dropper or straw put 2 drops of liquid from container (S) onto slide (S). Put 2 drops of liquid from container (NS) onto slide (NS.)
7. Put the two slides where they will not be disturbed. You will observe them tomorrow.
8. Answer the following questions in your Science Notebook:
   - ❑ Based on the crystals your grew in Activity 14, what do you think your new crystals will look like?
   - ❑ What do you think the results of your experiment will be? How do you think the method of mixing the solution will affect the crystals?

Day 2

1. First use your hand lens to observe both slides and record what you see in your Science Notebook. Then use your microscope and do the same thing. Record observations by writing and drawing what you see.
2. In your Science Notebook write about the difference between crystals grown using a solution that was stirred or shaken and thcrystals grown using a solution that was not stirred or shaken.
3. Can you answer the question, Does the method of mixing the solution affect crystal growth? Be prepared to share your results with the rest of the class.

VARIABLE 3: AMOUNT OF CHEMICAL

MATERIALS:

- ❑ 2 containers (for example, baby food jars, or clear film canisters. One container will be labeled with an (1/2), and one of the containers will be labeled with a (1). Make sure that your name is on both containers.
- ❑ Warm water
- ❑ Measuring spoon (1 tsp. = 5 ml)
- ❑ 1 1/2 teaspoons of copper sulfate ($CuSO_4$) or some other chemical
- ❑ 2 slides
- ❑ A dropper or straw to put liquid on the slide
- ❑ Field microscope
- ❑ Hand lens
- ❑ Science Notebooks

Day 1

1. Put 10 ml (2 tsp.) of warm water in the container marked (1/2).
2. Put 10 ml (2 tsp.) of warm water in the container marked (1).
3. Add about 3.5 g (1/2 tsp.) of chemical to the container marked (1/2).
4. Add approximately 7 g (1 tsp.) of chemical to the container marked (1).
5. Shake or stir both containers until the chemical is dissolved.
6. Label two microscope slides. One slide should be marked (1/2) and one slide should be marked (1).
7. Using a dropper or straw put 2 drops of liquid from container (1/2) on to slide (1/2).
8. Put two drops of liquid from container (1) on to slide (1).
9. Put the two slides where they will not be disturbed. You will observe them tomorrow.
10. Answer the following questions in your Science Notebook:

    - ❑ Based on the crystals your grew in Activity 14, what do you think your new crystals will look like?
    - ❑ What do you think the results of your experiment will be? How do you think the amount of chemical will affect the crystals?

Day 2

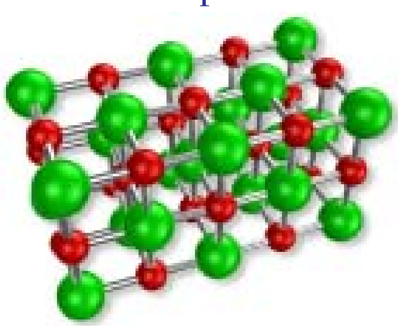
1. First use your hand lens to observe both slides and record what you see in your Science Notebook. Then use your microscope and do the same thing. Record observations by writing and drawing what you see.
2. In your Science Notebook write about the difference between crystals grown using different amounts of chemical.
3. Can you answer the question, Does the amount of chemical affect crystal growth? Be prepared to share your results with the rest of the class.

ACTIVITY

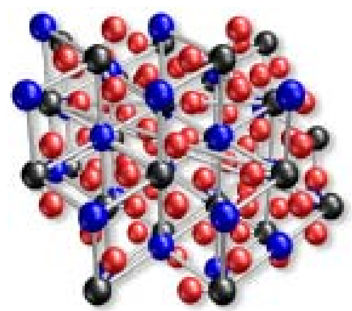
Using Microscopes to Investigate Birefringence in Crystals

One way to explore light and color using a microscope is to view crystals. The use of crystals with your students will capture their imaginations and it is an activity that can be done safely, quickly, and easily. Substances that have crystalline structures have atoms and molecules that are arranged in an orderly pattern that is repeated over and over again. The simplest crystal structure is cubic, which means that the atoms are uniformly spaced along three mutually perpendicular axes. Crystal structure is said to be **isotropic** if the spacing of the atoms is the same along each axis. If the spacing or arrangement of atoms along one axis is different from that of another axis, then the crystal is said to be **anisotropic**. If the atoms or molecules of a solid are not arranged in a regular periodic structure, then the solid is said to be **amorphous**.

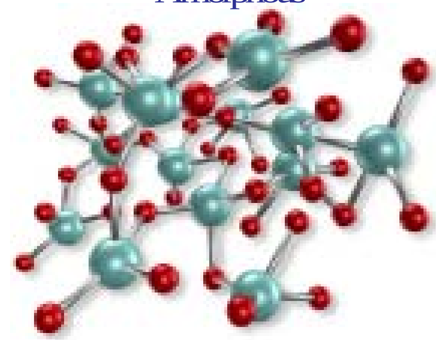
Isotropic



Anisotropic



Amorphous



Glass and plastic are examples of amorphous solids; table salt is an example of an isotropic crystal; and snowflakes or calcite are examples of anisotropic crystals. This pattern is predictable and can be manipulated by scientists using, for example, high magnetic fields. Crystals are easy to make and observe with the naked eye, a hand lens, or a microscope. Each of these tools reveals a different level of complexity in the crystal. This activity introduces students to crystal structures and a new way of looking at things. If your students are proficient at using microscopes, then they can now investigate some special properties of crystals.

A birefringent material refracts light twice, so when you look at a birefringent material (like the crystals) using the field microscope, you can do special things to manipulate the image. (Calcite or calcium carbonate is the most common birefringent mineral found in nature.) The property of birefringence allows us to use polarizers (the kind of lenses that are used in most sunglasses) to manipulate the colors that appear when we observe crystals through the lens of a microscope.

Photomicrography is a technique that involves using polarized lenses and cameras to observe birefringence in crystals. This technique is used at the National High Magnetic Field Laboratory (NHMFL) by Mike Davidson whose images are used on ties, scarves, exercise wear, book covers, folders, and many other items. The beautiful images that have been created using this technique can be accessed at the following web site: http://micro.magnet.fsu.edu/.

There is a scientific application as well as an artistic application. The process has been used for a long while by biologists and in the medical sciences. Interest in semiconductors, which directly relates to the work at the NHMFL, has required new tools to explore the surface features of new materials. In general, photomicroscopy is used as a tool to examine the surface of crystallized samples.

In this Activity, you and your students will be making crystals and examining them using the naked eye and the compound light microscope. You will also be looking at the crystals using polarized light film that will allow you to view the many colors in birefringent crystals, like Epsom salt crystals or copper sulfate crystals.

Materials:

- ☐ Field microscopes or other compound light microscopes
- ☐ Glass slides
- ☐ Epsom salt, copper sulfate, or vitamin C powder
- ☐ Warm water
- ☐ Polarizers
- ☐ Science Notebook

What will the students do?

1. Students will make crystals (see Activity 14, this Module) using Epsom salts, copper sulfate, or vitamin C powder.

   *Encourage students to try using different types of solvents other than water. Rubbing alcohol and acetone (fingernail polish remover) may be used and students might get better quality crystals.

2. Students will be observing crystals with their eyes and using their field microscopes. Each observation is structured and each sample is represented with a drawing in students' Science Notebooks (see student page).

3. Students will be investigating the various crystals using the polarizers and the field microscopes.

How To Use the Polarizers:

1. Place one polarizer beneath the slide
2. Place the slide containing the crystal sample and the polarizer on the stage of the microscope.
3. Place the other polarizer on top of the eyepiece of the field microscope.
4. While looking at the different crystals, rotate the lens on top of the eyepiece. Notice and record which crystals are birefringent.
5. Crystals that are birefringent will produce beautiful colors as the eyepiece polarizer is rotated.

Remember, not all of the crystals that the students made will be birefringent. Those that are not birefringent will appear to be clear when viewed through the polarizers rather than exhibiting many colors.

DEMONSTRATION:

Take a clear plastic cup and place it on an overhead projector. Put about an inch of Karo syrup in the bottom of the cup. Turn the projector on and students will see colors projected on the screen. This is because plastic is birefringent. Karo syrup is the medium used to display this property. Encourage students to try other media and record their observations.

EXTENSIONS:

<u>Narrative Writing.</u>

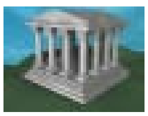
> *Each of us has seen the beauty of crystals after they are polished and cut and made into jewelry.*
>
> *Before you begin writing, think about a time that you saw a lovely piece of jewelry that was special to someone.*
>
> *Now write a story about that special piece of jewelry and why it was special.*

<u>Reading.</u> Read aloud poems from *Once Upon Ice and Other Frozen Poems* by Jane Yolen (ISBN 1-56397-408-8) and have students compare the crystals they made with ice crystals. Then have students write poems about the crystal shapes they observed.

<u>Research.</u> Students can research birthstones and other gemstones. Encourage students to research myths and legends that have been written and/or passed down from generation to generation regarding gemstones. Have them identify their birthstones and share with the class.

Biography. Wilson Bentley (b. 1865) was a photographer who concentrated on capturing the unique beauty of snow crystals. *Snowflake Bentley* by Jacqueline Briggs Martin (ISBN 0-395-86162-4) is an introduction to the biography genre for younger students and can be a starting point for older students to research Bentley's life and work. Bentley's work was as a developer of the process of microphotography, which began in his Vermont childhood. Bentley's career choice was based on childhood curiosity about snowflakes. He took his first pictures of snowflakes when he was only 19.

Art. Students can create a coloring book of patterns they observed when examining the crystals they made. Students can do a color-by-number page for younger students to color. You may wish to have them research photomicrographs of crystals whose special properties have been used to create color images.



HISTORICAL VIGNETTE: ANTONY VAN LEEUWENHOEK

Antony van Leeuwenhoek was a Dutch zoologist born in 1632 (d. 1723). He is best remembered for his depiction of red blood corpuscles. Van Leeuwenhoek was able to draw these tiny structures only after he experimented with different simple microscope designs. The simple microscope van Leeuwenhoek used was metal with a single lens. It had such a short focal length that the instrument had to be held very close to his eye so that the object he was looking at would be in focus. Some of his designs magnified objects up to 250 times.

Leeuwenhoek is often given credit for inventing the microscope. However, compound microscopes (microscopes using more than one lens) had been built and used as early as 1595, well before Leeuwenhoek was born. What he did was to make improvements to the lenses that were used in microscopes, using his talents as a lens grinder to develop lenses that magnified over 200 times. He also recognized that one needed to take great pains to properly adjust the lighting that was used with microscopes to maintain clarity. His detailed drawings and descriptions distinguished Leeuwenhoek from his contemporaries. Interestingly, and of some interest to young students, Leeuwenhoek was not very good at illustrating his own descriptions, so he hired an artist to complete the artwork.

Until his death in 1723, Leeuwenhoek met with artists, scientists, and other interested people (for example, Tsar Peter the Great from Russia) who were fascinated by the odd things he was able to see. This included the "animacules, a-swimming" in his mouth and all manner of animal and plant tissue.

Activity. Working in pairs, one student will observe an object using the microscope and describe it in words to his or her partner. The partner will attempt to draw the object based on that description. Encourage students to communicate with one another as the drawings progress. Then, check the drawing against the image seen through the microscope.

Writing and History. Van Leeuwenhoek stated the following:

> *. . . my work, which I've done for a long time, was not pursued in order gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than most other men. And therewithal, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed thereof. (Letter written in June 12, 1716)*

Have students discuss why it is important to record their observations, discoveries, questions, and possible answers. Many scientists are famous for their diaries and journals (for example, Leonardo da Vinci and Galileo Galilei). Students pretend they are writing (or describing) to a friend who knows nothing about microscopes how the instrument works and what they saw using the microscope.

ARTIST VIGNETTE: PABLO PICASSO

Pablo Picasso (1881-1973) was a prolific artist whose work expressed many different artistic movements. Picasso, the son of an art teacher, was born in Barcelona, Spain. One of the many and varied techniques that Picasso experimented with was Cubism. This technique incorporates flattened images that appear fragmented. It is a blending of shapes used to express the artist's emotion. Although Picasso was schooled in the great masters of the past, he is known as a modern painter.

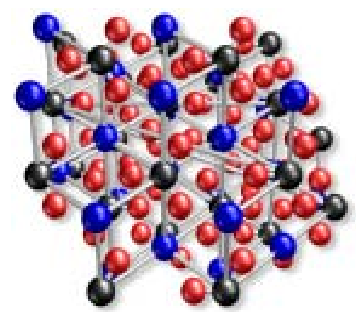
Most Americans knew little of the Cubist movement until 1913 and the famous Armory Show in New York. This was the first time that new radical European art was featured in a major art show. Even though most of the show (two-thirds) was devoted to realist mainstream American art and featured American contemporary artists, it is best remembered for introducing modern art to Americans.

Activity. Encourage students to use the crystal shapes they observed to create art. Whether they use the shapes to create recognizable figures or as the basis for abstract art, students should be able to explain their work to others. It may represent an emotion, a scene, a person, people, animals, or an event. Making art could take other forms such as sculpture or collages.

Activity 16

Using Microscopes to Investigate Birefringence in Crystals

In this activity you will be making crystals, observing some special properties of crystals, and using microscopes with polarizers to observe birefringence in certain crystals. Birefringence is another word for double refraction. When light passes through a crystal that is birefringent, the light rays are bent or refracted twice.



In some materials a double image is produced. Double refraction can be seen by comparing two materials, glass and calcite. If a pencil mark is drawn on a piece of paper and then covered with a piece of glass only one pencil mark will be seen. However, if this same pencil mark is covered with a piece of calcite crystal, and the crystal is turned a certain way, then two pencil marks will be seen rather than one.

Scientists use many tools to look at things like crystals. One of those tools is a microscope. Although crystals are large compared to other things that scientists look at using a microscope, there are many things we can learn by observing crystals in different ways. You will look at the crystals that you make using your eyes, your field microscope, and polarizers. Each time you observe the crystals draw what you see.

Materials:

- ❑ Field microscopes or other compound light microscopes
- ❑ Glass slides
- ❑ Epsom salt, copper sulfate, or vitamin C powder
- ❑ Warm water
- ❑ 2 Polarizers
- ❑ 1 Piece of calcite crystal
- ❑ Science Notebook

1. Make crystals (Epsom salt, vitamin C, and copper sulfate) or use the crystals you made in Activity 14. In your Science Notebook, write down the procedure you used in making the three types of crystals. Be sure to include solvents other than water that you used. Also include any questions that you have about crystals or crystal making.

2. Look at the crystals made by other students. Are they all the same shape and size? Describe similarities and differences in your Science Notebook.

3. If you made these same crystals again, what would you do to make sure that your crystals were the largest they could be?

4. In your Science Notebook, draw and label each crystal sample.

5. Discuss with other students in your class the similarities and differences among the drawings. Also discuss your answers to the questions you wrote in your Science Notebook.

6. Now, look at your crystal samples using 2 polarizers and the field microscope.

   How to use the polarizers:

   - Place one polarizer under the slide containing the crystal sample.
   - Place the slide and the polarizer on the stage of the microscope.
   - Place the other polarizer on top of the eyepiece of the field microscope.
   - While looking at the different crystals, rotate the lens on top of the eye piece. Notice and record which crystals are birefringent. (Crystals that are birefringent will produce beautiful colors as the top polarizer is turned.)

7. In your Science Notebook, create a chart or some other way of recording data. Write down the name of the crystal, draw what the crystal looks like, and tell whether or not the crystal is birefringent.

Using calcite to observe birefringence:

Calcite is a natural birefringent material. Place a glass slide over some text and observe the writing. Now place a calcite crystal over the same writing and observe what you see. How is this different from what you saw when you looked at the writing through the plain glass slide?

Student SELF-CHECK

Module 6: Microscopes and Crystals

Now that you have completed Module 6, follow the directions below as a self-check to see if you need more practice.

1. Describe or draw how the letter "e" looks when you look at it through the water droplet magnifier.

2. How is the field microscope different from other magnifiers?

3. What advice would you give to a classmate who was going to make crystals?

4. Some crystals have special properties that you can see using polarizers. Draw or describe in words what you saw when you looked at copper sulfate with the field microscope.

MODULE m7

How Can I Learn More About ...?

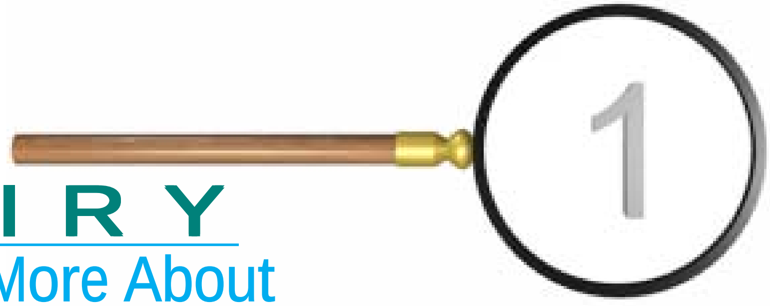
INTRODUCTION

Module 7 provides you with research ideas that may be used to encourage students to find out more about real-world applications of the concepts covered in Modules 1-6. Activities are included to encourage students to think creatively about how these concepts can be used to solve problems.

These inquiries can be used at any time during the *Science, Optics and You* unit of study. They are enhancements to the Modules; for example, Inquiry 4 could be used with Module 5, Shadows.

Inquiry 1: How Can I Learn More About Eyeglasses?
Inquiry 2: How Can I Learn More About Animal Vision?
Inquiry 3: How Can I Learn More About Telescopes?
Inquiry 4: How Can I Learn More About Eclipses?
Inquiry 5: How Can I Learn More About People in Optics?

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Eclipse of the Moon and Solar Eclipse, Intel Play QX# Computer Microscope Simulator, and Human Vision, http://micro.magnet.fsu.edu/optics/tutorials/index.html



INQUIRY
How Can I Learn More About Eyeglasses?

Research. Using a variety of media, have groups of students research the following types of eyeglasses: traditional eyeglasses for nearsightedness and farsightedness, bifocal lenses, monocle or eye ring, lorgnette glasses, contact lenses, bifocal contact lenses, sunglasses, or pince-nez glasses. Students may come up with other types of eyeglasses to research. Encourage groups to present their findings to classmates. Models of special types of glasses like lorgnettes or jealousy glasses can be displayed.

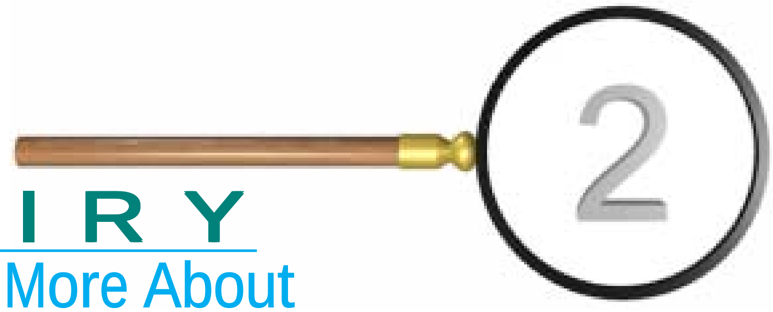
Writing, Research, Practical Applications. Have students pretend that they are visiting an eye doctor because they may need eyeglasses. While in the doctor's office they see a pamphlet that describes how the eye of a person that is near-sighted is different from the normal eye. Have students create a pamphlet that explains this information, and describes what type of lenses would be needed in glasses to correct near-sightedness (myopia).

Careers. Encourage students to conduct an interview with an optometrist or opthamologist or both. Interview questions would differ considerably based on the fact that an opthamologist has a medical degree and an optometrist is a technician.

Reading. Either read aloud, or have students read *The Eyes of Kid Midas* by Neal Shusterman (ISBN 0-812-53460-3). A young boy finds a pair of magic sunglasses that grant him every wish. He struggles with using the glasses for personal gain and must decide whether to keep the glasses or get rid of them. This is suitable for grades 4-6 and would be a good source of discussion about eyeglasses.

Inventions, History, Social Studies. Believe it or not, sunglasses are not a 20th century invention. The Inuit people used materials from their environment to fashion protective eyewear to cut down on the sun's glare. The blinding glare called "snow blindness" is caused when light reflects off snow. Items used to make these sunglasses were driftwood, deer's hooves, and baleen (whalebone).

Have students research the development of protective eyewear and invent or design a type of protective eyewear out of unusual materials found in nature.



INQUIRY

How Can I Learn More About Animal Vision?

Several of the activities that follow encourage students to research different animals and how they see, where their eyes are located, and why these animals have these special adaptations. The book, *Extraordinary Eyes: How Animals See the World*, by Sandra Sinclair (ISBN 0-8037-0806-8), is an excellent resource that students can use to provide context for their animal vision projects.

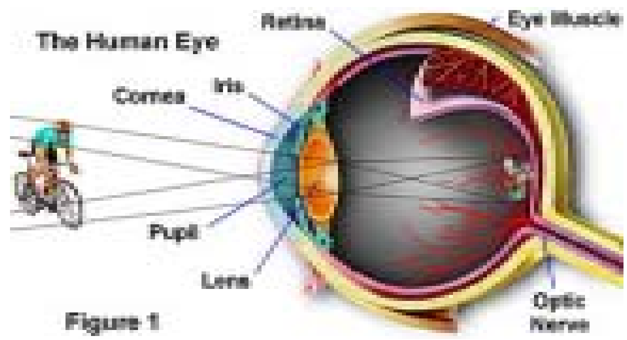


Figure 1

<u>Model of the Human Eye.</u> Research and make a model of the eye and all of its parts. Include a written description of how the eye parts work together to produce an image. Encourage students to use what they learned about lenses to design "working" models. Have them investigate materials that have the same properties as lenses, for example, clear gelatin.

<u>Vision in Animals.</u> Some animals have eyes in different places. The position of an animal's eyes determines what it can see. Have students choose an animal that has eyes in an unusual place (for example a hammerhead shark, a starfish, a snail, or a scallop), and find out where their eyes are located and what they can see. Students report on their findings.

<u>Art and Writing.</u> If you could have eyes anywhere on your head, where would you put them and why? What would these new eyes help you see? Draw a picture of yourself with eyes in different places and write a short story about how these new eyes would help you see.

<u>Binocular Vision.</u> Humans and other animals have binocular vision. (Binocular means two eyes.) Binocular vision is also called 3-D vision. Research what would happen if you did not have two eyes. What things would change in your day to day activities? Have students write a story explaining the consequences of being able to see out of only one eye.

Mythology. The mythological creature, Cyclops, had one eye. Read to students the story of Cyclops and have them imagine what Cyclops would see as compared to what they can see with two eyes. How would having one eye affect Cyclops' vision?

Animals with Compound Eyes. Have students complete the following activity: Some animals have compound eyes. These are eyes that are made of many lenses rather than just one. Insects, spiders, and crustaceans (crabs, lobsters, shrimp, and crayfish) are examples of animals that have compound eyes. Students find out what these animals can see, and design an animal that has compound eyes. The drawing of the animal should be neat and any features that are unusual should be labeled. Encourage students to make up a name for your animal, and write a short description of where the animal lives, what it eats, and how the eyes work to help it survive in its environment.

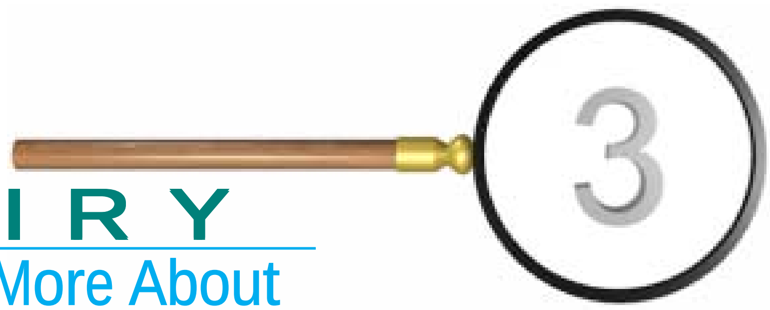
Research Color Vision. Humans and some other animals are able to see color. Students research why we can see colors. What does it mean for someone to be color-blind? What causes color-blindness? Invite a guest speaker to address the class and/or have students interview someone who is color blind and share their results with the rest of the class. Approve questions before students schedule their interviews.

Birds. Have students find pictures of birds in magazines and create "bird collages." This will provide a frame of reference with which to complete the rest of this activity. The eyes of birds are more advanced than many animals. Some can see very far distances. Students can choose a type of bird to study and draw the head and eyes of the bird. Have students compare drawings. "How are the eyes of birds that hunt for food different from the eyes of birds that eat seeds?" is one question that may be answered. List students' questions about animal eyes on chart paper, checking them off as answers are given through student presentations.

Reading. Read aloud *Silverwing* by Kenneth Oppel (ISBN 0-689-82558-7). Although this is a fictional account of a family of bats, there is a lot of information on how bats navigate, why they fly at night and not during the day and how echolocation is used. Comparisons are made between bats and other animals. This is an entertaining story that contains a great deal of information about vision.

Bats and Vision. Have students answer the following questions: Are bats really blind? How do bats gather food? Are there different kinds of bats? What kinds of bats are found in Florida? How are bats like other nocturnal animals? How are the eyes of bats like those of other nocturnal animals? Local nurseries often provide workshops on making bat houses and producing environments that will encourage bats to live there. Attending a workshop such as this and then presenting this information to the class is a way to tie classwork to real-world applications.

Careers. There are several careers that involve the study and care of eyes. Students can research or interview an ophthalmologist, an optometrist, or an optician. As a class, design a questionnaire to find out how much education is required, what they like best about their job, what they like least about their job, what the potential salary is, and other things that students might want to find out. Groups of students present their findings to the class.



INQUIRY
How Can I Learn More About Telescopes?

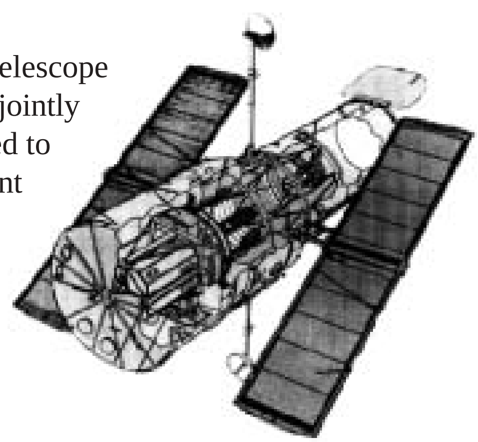
Who really invented the telescope? There is still some confusion about the first person to use a telescope. Have students work in groups, each group researching one of the following people: Galileo Galilei, Johannes Kepler, Hans Lippershey, or James Metius. Each group will share results by presenting their "case" to the class. Then have the class decide who (if anyone) they think should be given credit for inventing the telescope and why.

Students could design an instrument that summarizes their findings and asks others (parents, friends, other teachers and students) who they think the first person to use a telescope was. In addition, students discuss if it is important to give credit at all. Is it important to know *who* the first person was to use a telescope or is the invention itself the issue?

As an extension to this activity, once students have decided who they believe should get the credit, have them look in a variety of encyclopedias, textbooks, and other media and record which inventor was given credit most often.

THE HUBBLE TELESCOPE.

Current issues. At a cost of two billion dollars the Hubble telescope is the most expensive scientific instrument ever built. Built jointly by NASA and the European Space Agency, it was designed to allow astronomers to look at the universe in new and different ways. There have been problems with the telescope. Have students research the problems scientists have had with this telescope and how scientists and astronauts fixed these problems?



Writing. Set the scene with the following statement:

The Hubble Space Telescope just had a tune-up. Just like your car, the giant telescope that orbits Earth needs a checkup every year or two. The Hubble telescope uses instruments called gyroscopes to point it at stars and galaxies and to keep it in place while a picture is taken. It has six gyroscopes, and needs at least three working perfectly in order to point itself correctly. Recently four of the six gyroscopes broke, and had to be repaired.

Students research how the astronauts fixed this problem and prepare a "repair journal" that includes what they would do daily during a space mission to prepare and repair the telescope. (John Grunsfeld, an astronaut on the Space Shuttle mission to Hubble kept a repair journal. Students can read his journal on the Internet.)

Working in Space. One of the difficult things about working in space is doing work with gloved hands and spacesuits. During the recent Hubble Telescope repair mission, astronauts had difficulty with the seemingly simple task of using a screwdriver to remove or tighten a screw. Have students design a task for a partner to do while they are wearing gloves. For example, students could use gardener's gloves or work gloves to simulate the gloves astronauts use to put a nut on a bolt, use a screwdriver to put a screw into a block of wood, or some other job that they may have to do. In their Science Notebooks, students write a paragraph describing what you experienced while doing this activity.

Make a Telescope. The following is a story of how Hans Lippershey (1570-1619) may have invented the first telescope. It may be true or it may be a story that has been told many times, but this is how the story is usually told. Use the story to introduce the activity.

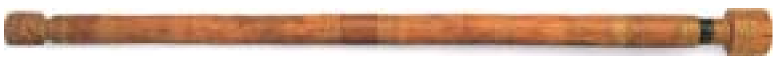
Lippershey was handling some lenses in his shop when he happened to look through two lenses that were shaped differently. He was holding them up toward the light of the open doorway, when he was startled to see a distant church tower seem to jump to the door of his shop. He was amazed to see even the weathervane on the church spire clearly. His first idea was to use this curious effect he discovered to attract customers. He set up a display with the two lenses, so people who came to his shop could look through them and see how the church appeared to be so close. Lippershey eventually enclosed the two lenses in a tube to make what he called a looking glass.

MATERIALS:

- ❑ Tape
- ❑ Scissors
- ❑ Cardboard tubes of varying diameters
- ❑ Science Notebook
- ❑ Flat pieces of cardboard that may be cut to be the “lens holders” for telescopes

1. Encourage students to experiment with the lenses in the package and two cardboard tubes of different diameters put together so that one of the tubes can move back and forth inside of the other one. (This reinforces the concepts of focal length encountered in Module 2).

2. Have students devise a way to attach the lenses at opposite ends of the tube. Encourage them to record in their Science Notebooks the type of lenses they used (the names of the lenses are on the envelopes), make diagrams of how they put together their telescope, and include instructions on how to make a home-made telescope.

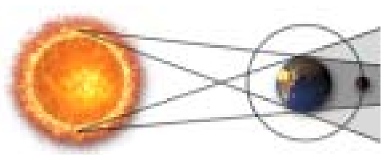


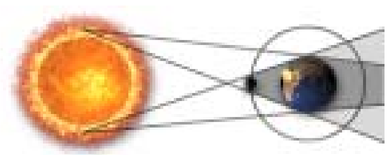
Galileo’s Telescope

INQUIRY 4

How Can I Learn More About Eclipses?

What is an eclipse? The moon revolves around the earth and the earth and moon revolve around the sun. As this occurs, some of the sun's light is blocked by the moon's shadow or by the earth's shadow. When the earth's shadow falls upon the moon, a lunar eclipse occurs; conversely, when the moon's shadow falls upon the earth, a solar eclipse occurs.





These are difficult concepts to model for students particularly because we usually try to do this with light bulbs and models of Earth and the moon. Light bulbs, however, are small sources of light and the light spreads as it nears the models. A better way to demonstrate a solar eclipse, for example, would be to use a wall clock or other large circular object and a coin or other small circular object. If the clock is the sun and the coin is the moon, students can position themselves and the objects so that the coin eclipses the clock.

<u>Activity.</u> Encourage students to design a way to demonstrate both solar and lunar eclipses to someone who does not understand them. Having completed Modules 4 and 5, students should be able to discuss shadows, light, and clarity of images that are produced when there is a bright light source (like the sun). Challenge students to use sunlight to provide the distinct shadows they need. Have students present and explain their models to the class.

<u>Cultural interpretations.</u> People from many cultures have developed myths and legends about eclipses. Some believe that an eclipse is a sign of impending natural disaster such as a flood or an earthquake. Others believed that it meant the death or downfall of a ruler. The Chinese believed that an eclipse of the sun occurred because a dragon was eating the sun. As a result, the Chinese would produce great noise such as drumming and banging on pans to frighten the dragon away and to bring back the sunlight.

Have students research any myths or legends about eclipses from other cultures. For example, myths from India, China, Japan and the native cultures of North and South America. There are many Native American myths and legends that are based on solar and lunar eclipses. These are attempts to explain to others natural occurrences. Native Americans see themselves as part of the Earth and part of nature as a whole so their stories are used to teach young and old alike about natural events and about relationships among people and people and nature. “How Coyote Was the Moon,” for example, is a Kalispel story about the moon in general and it could be used to get students talking about the moon and what it looks like. *Keepers of the Earth* by Michael J. Caduto and Joseph Bruchac (ISBN 1-55591-027-0), is an excellent source for Native American myths and legends that enhance classroom science. Science activities accompany each of the stories.

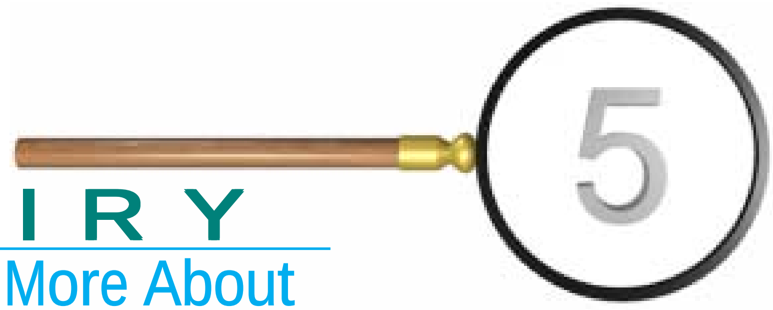
<u>Role Play</u>. Students design a skit or play that illustrates various cultural beliefs about eclipses. These skits could be performed for the rest of the class as they study how different cultures interpret the meaning of eclipses.

<u>Medical research.</u> Whenever a solar eclipse occurs, we are warned by the media and the medical community not to look directly at the sun. While looking directly at the sun is never a good idea, it is particularly harmful during a solar eclipse. Challenge students to find out why by asking the question, “Why is it harmful to look directly at the sun during an eclipse?” Encourage students to list reasons why the sun’s rays are particularly concentrated, describe cases of actual damage to the eye caused by looking at the sun, and to list sources for their information. Then, have students design a way to present this information to a larger audience: the school, other classes, or the general public.

<u>History.</u> It is believed that Christopher Columbus used his knowledge of solar eclipses to impress West Indian natives. Because he knew when the eclipse was to occur, he was able to use this natural event to solidify his power over the native population. Discuss with students the quote “knowledge is power” and have students brainstorm and research other instances where knowledge of the natural world translates into power for those who “own” the knowledge.

<u>Reading.</u> Read to the students *A Connecticut Yankee in King Arthur’s Court* by Mark Twain (ISBN 0553211439). This is the story of a man who travels back to the time of King Arthur. It includes an episode where he uses the knowledge of when a solar eclipse occurred to save his own life.

<u>Writing.</u> Obtain an almanac and provide students with a list of dates when solar eclipses occurred. Have them choose a date and then write a story in which the solar eclipse plays an important part. Use *A Connecticut Yankee in King Arthur’s Court* as a guide.



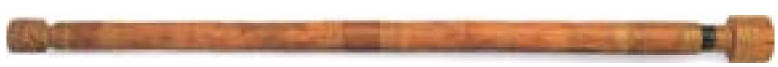
Inquiry

How Can I Learn More About People in Optics?

This is a series of suggestions for research about people who have influenced the study of optics, people who have invented instruments that have extended the study of optics, or people that have influenced the process of scientific discovery. Provided here are different ways of looking at science, discovery, and invention that could be used as the basis for research projects in your classroom. Reports, public presentations, poster sessions, computer programs, debates, skits, role-plays, and models, are appropriate ways to present student work.

Scientific discoveries usually happen as a consequence of a problem identified or a question that has been asked. However, scientists do not work in isolation and do not conduct their work outside of the realm of political and historical events. Some early scientists and inventors had direct connections to kings and courts that supported their work by providing an income, a place to live, and a way to disseminate their findings.

Galileo, for example, supported himself, his family and his extended family through an official appointment to the University of Padua and the sponsorship of the de Medici family in Florence, Italy. The political and religious climate of the times prevented Galileo from widely disseminating his writings that contradicted the popular belief of the time that the Earth was the center of the solar system. There are many stories of scientists and inventors that were either helped or hindered by the political and religious milieu in which they lived and worked.



Some discoveries are the result of serendipity – an unexpected result of an experiment or an accidental discovery or breakthrough. This is not to say that scientists wait around for something to happen. Usually, the serendipitous discoveries occur as the result of curiosity and a desire to understand how the world works. Sometimes being the right person in the right place is enough to propel a curious person into the spotlight as a discoverer, developer or inventor.

Charles Darwin, for example, is one such example. He did not organize the expedition to the Galapagos Islands; rather he was invited to join the crew on its second voyage to test a new clock that had just been invented to work on ships. As a result of his observations, curiosity, and ability to write about his adventure, he has become one of the most influential scientists of recent history.

While observing charts from a Cambridge telescope, Jocelyn Bell and Anthony Hewish discovered pulsars in 1967. They were not trying to discover pulsars since no one knew that they existed! Instead they were measuring radio emissions from stars, working with astronomers both in Great Britain and the United States, accessing different kinds of optical instruments.

Have students use a variety of media to research people that have made discoveries, invented instruments, or used instruments in new and exciting ways related to the study of light and optics. Encourage creativity and inventiveness in presentations of what students discover.

The *Science, Optics & You* Timeline in Optics, http://www.micro.magnet.fsu.edu/optics/timeline/index.html, traces important events in the science of optics and the physics of light and color from the beginning of recorded history to the present. Many of the scientists and discoveries that students will be interested in can be found on this timeline and are a good starting point for their research.

MODULE m8

How Does It Work?

INTRODUCTION

Module 8 contains five inquiries that facilitate exploration and explanation of how some of the practical applications of optics influence the day to day lives of students:

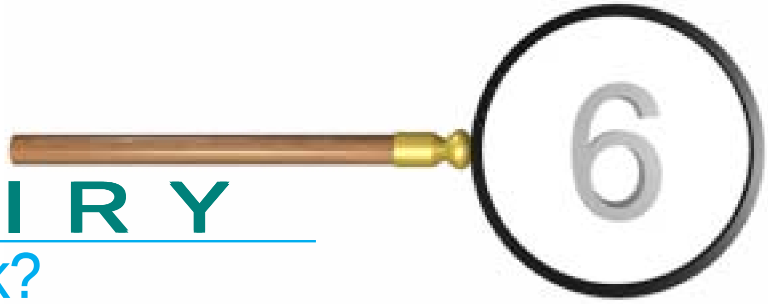
Inquiry 6: Cameras and Photography
Students investigate making and using pinhole cameras. Suggestions for ways to investigate the history of cameras and photography in are also provided.

Inquiry 7: Lighthouses
There is a brief history of how lenses are used in lighthouses. There are also several suggestions on how to link the study of lighthouses with science, art, math and language arts.

Inquiry 8: Binoculars, Periscopes, and Kaleidoscopes
There is information on how various optical instruments work. Included are discussions of binoculars, periscopes and kaleidoscopes. Information on how to make some of these optical instruments is included.

Inquiry 9: 3D Images and Holograms
The principles behind 3D images and holograms are explained. Students are also encouraged to investigate some of the current applications of holograms.

Inquiry 10: Project Ideas for Light and Optics
Extensions to the activities are provided as well as enrichment opportunities for students who wish to learn more. Also included, are instructions for making periscopes and kaleidoscopes.



INQUIRY
How Does It Work?
Cameras and Photography

Pinhole images have been seen since the time of Aristotle. What he saw were images and shapes flickering through the tiny holes made between several leaves overlapping. Pinhole photography is the capturing of those images and shapes onto film using no lens. A tiny hole replaces the lens. Light passes through the hole and an image is formed on the back wall of the camera. The image is upside down because light travels in straight lines and therefore crosses at the hole. If looking at an outdoor scene, the sky is at the bottom and the ground at the top. Pinhole cameras can be small or large. They can be made of seashells, oatmeal boxes, film canisters, soda cans or any size box. Even cars and rooms in large buildings have been used as pinhole cameras. In the Renaissance and later centuries the pinhole was mainly used for scientific purposes in astronomy. However, as time went by the pinhole image (often called a *camera obscura*) was used more and more as a drawing aid for artists and painters.

<u>Make a Pinhole Camera.</u> A simple device called a pinhole camera is an easy and safe way to view the Sun. It involves projecting an image of the sun through a tiny hole onto a white sheet of paper. Students should be closely monitored while making pinhole cameras so they do not look directly a the sun.

Students will need a sunny day, a partner and two pieces of white paper. Have students follow theses directions:

1. Punch a hole in the center of one piece of paper. Go outside, hold the paper up, and aim the <u>hole</u> at the sun. DO NOT LOOK AT THE SUN!
2. Move the other piece of white paper back and forth until the image of the sun is on the paper and is in focus (the clearest image of the sun you can see). What you are seeing is not just a dot of light, but an actual image of the sun.
3. Experiment by making the pinhole larger or smaller. Record in your Science Notebook what happens to the image of the sun.
4. What happens if you punch 2 holes in the piece of paper? Or, try bending your paper so that the images from the 2 holes are placed one on top of another. Record your observations and compare them with other students. Write a paragraph about your experience. Include possible uses for a pinhole camera.

Research. Students can be encouraged to find out more about cameras and photography by researching some of the following topics.

- **Magic Lanterns** were once considered the most famous and entertaining inventions in history. The early form of the magic lantern is considered the forerunner of our current day slide projector or overhead projector.

- **Daguerreotypes** were pictures on metal. These were the first quality photographs but they could not be reproduced.

- **Calotypes** were the first type of photographs that produced a negative picture on paper; the lights of the image were recorded as darks, and the darks as lights.

- In 1888, Thomas Edison created an apparatus that he called a **kinetoscope** which means "Moving View." The invention consisted of photographing continuously a series of pictures occurring at intervals greater than eight per second. The images were recorded in a continuous spiral on a cylinder plate in the same manner as sound was recorded on the phonograph. In groups, students could study the life of Thomas Edison and report on some of the inventions he patented during his lifetime and note the creative way he attempted to answer his own questions about the world around him.

- In 1900 the **Brownie Camera,** which was made for children to use, sold for $1.00. The intention was to make cameras available to as many people as possible. The Box Brownie contained a roll of film with 100 exposures. Once the film was used, the camera and the film were sent back to Kodak where the film was developed and new film was put into the camera.

- In 1947 the **Polaroid Land Camera** produced instant pictures within 60 seconds, and became one of the most popular cameras of all times. Have students research and find out how these instant cameras operate. Polaroid film and cameras are still being manufactured and have undergone many changes since the original instant camera. Here is the story of how Edward Land got the idea for the instant camera:

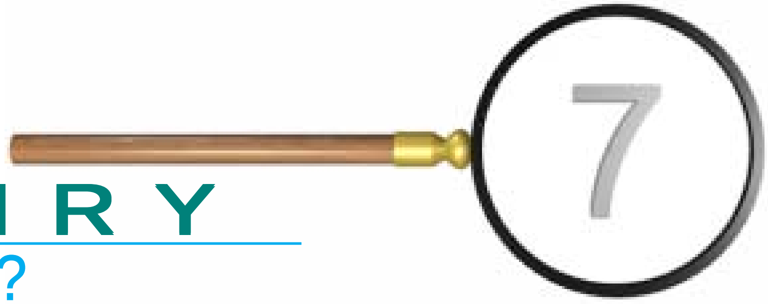
  Edward Land was taking pictures of his family on vacation in the southwest. His young daughter asked, "Why do we have to wait to see the pictures?" and Land thought to himself, "good question!" He later sketched out some of his ideas and experimented with them after he returned to his lab in Boston. The Polaroid camera and the science of instant photography emerged soon thereafter.

- **Motion Picture Cameras**: Thomas Edison and George Eastman from Kodak worked together to produce the first motion pictures. Students could conduct research about this partnership to answer the question: "Was it the partnership of the two men that facilitated the invention?"

- Students can research the history of movies and movie technology. Encourage them to include how films are being restored because the film itself deteriorates and how movies have changed over time.

- A **photocopier** is an invention that has made our lives more convenient. The term "xerography" comes from two Greek words meaning dry writing. Chester F. Carlson in 1938 first invented this technique which gave rise in 1959 to the first office copier produced by Xerox. Photocopiers today use lenses, mirrors, color filters, lamps, and toners of magenta, cyan, yellow and black to reproduce images.

- Some students are already familiar with the **video camera** and **digital camera** technology. Students could use newspapers to research the cost and features of various types of video cameras and digital cameras. They could then design an ad that would encourage consumers to purchase a particular type of camera.



INQUIRY

How Does It Work?
Lighthouses

The first great lighthouse was built on an island in the harbor of Alexandria, Egypt. The Pharos tower, built around 280 BC, was 450 feet high, and the light produced by a fire kept blazing on its roof, could be seen from as far away as 29 miles out in the Mediterranean. Sailors needed the Pharos light because the city of Alexandria was on the flat Nile Delta. There were no mountains or other natural features to help them find the city. Ancient peoples built fires on hills and mountainsides to bring sailors home from the sea. The Pharos tower attracted sailors from far distances and, as a result, Alexandria became one of the busiest ports in the world.

How did sailors navigate over long distances in earlier times? By day, it was best to remain in sight of the land. That way the sailors could identify features of the land. Most of the travel was local because sailors knew their own waters well and could spot where the water swirled around hidden rocks. At night, however, the open ocean was a better place to be in order to avoid underwater reefs and rugged coastlines. The light from the stars and the moon helped them to navigate.

An open fire produced the light that emanated from early lighthouses. Wind direction would cause the light to be bright or less bright on the side facing the sea. Heavy rains created problems that were solved by using covered lanterns or enclosing lanterns with glazing. As a result the light was greatly reduced, especially if the keeper did not keep the glazing clean. Fuel for the fire was wood and forests were often destroyed to keep the light burning. After AD 1500 coal was used in lighthouses. This method was effective at producing light except when blown by the wind, because the fire became hot enough to melt the grate holding the coal. However, coal-burning lighthouses continued to be used well into the 19th century. Some lighthouses used oil lamps, which consisted of small containers filled with oil and a floating wick. Later a cresset, a stone bowl containing oil and a fixed wick, was used. The type of oil preferred was sperm whale oil. Petroleum oil or kerosene was used around the 1870's in regular lamps. In the early 1900's the incandescent oil vapor lamp came into use. This lamp produced a bright light that was used with the Fresnel lens. Electric generators were used until 1875 to provide electricity for the lighthouses until power lines could be run.

Many different materials were used to construct lighthouses, for example, stone, iron, wood and iron, bricks, limestone, and concrete. By 1820, the United States had 55 coastal and harbor lighthouses. The lighting system used at the time was the Argand lamp that consisted of a lens and a parabolic reflector. By 1850, however, the government authorized use of the multiprismed lens invented in France by Augustin Fresnel in 1822 (see Historical Vignette, Module 2, Activity 5). Fresnel lenses are shaped like a beehive, with concentric rings of prisms around a lens that acts as a magnifier. All of these features focus scattered light from a lamp or bulb into a tight beam. In the 19th century, each lens cost $12,000 plus shipping costs from France. The lenses were ranked in six "orders." The order of the lens was determined by the distance of the flame from the lens, known as the focal distance. The weakest, ranked sixth, was used to light lakes and harbors. The largest, first-order lens, made up of over 1000 prisms, stood 10-12 feet tall, measured 6 feet in circumference and weighed up to 3 tons. When these lenses were mounted at 100 feet above sea level the light could be seen for up to 18 miles at sea.

The study of lighthouses in the classroom is an excellent way to integrate social studies, science, art, math and language arts into the curriculum. Below are some suggestions for studying lighthouses:

K-W-L Chart: Students, in cooperative groups, create a K-W-L chart on lighthouses. After they have created their charts, have them plan how they will answer their questions. Encourage students to answer the questions and share with the rest of the group.

Art. Have students work in cooperative groups to design and draw what they think a lighthouse looks like. Encourage them to put as much detail into their drawing as possible and discuss features that they think are necessary to create a working facility. This will entail some research on the student's part on different types of lighthouses.

Parabolic Reflector Model. Parabolic reflectors were used to increase the amount of light produced by a light source in lighthouses. They were made out of curved metal, usually copper, and coated with a silvery compound. Provide students with cardboard, candles or a flashlight, aluminum foil, aluminum pie plates, lenses and other items needed for them to design a parabolic reflector that could concentrate and increase the amount of light coming from a candle or a flashlight. Have them design a model, draw their model and then create a working model.

Diorama. Have students design a diorama showing what a lighthouse and surrounding area would look light along the Florida coast or along the California or Oregon coast. (Generally speaking, lighthouses found on the Pacific coastline were not very tall because of the rocky terrain, whereas the ones found along southeast coastline were usually quite tall.)

Poetry. Lighthouses have been the inspiration for many poems. Three poems about lighthouses follow. After you read them, have students write a poem with a lighthouse as the theme or have students find other poems about lighthouses.

The Lighthouse

by Henry Wadsworth Longfellow

The rocky ledge runs far into the sea,
and on its outer point, some miles away,
the lighthouse lifts its massive masonry,
A pillar of fire by night, of cloud by day.

Even at this distance I can see the tides,
Upheaving, break unheard along its base,
A speechless wrath, that rises and subsides
in the white tip and tremor of the face.

And as the evening darkens, lo! how bright,
through the deep purple of the twilight air,
Beams forth the sudden radiance of its light,
with strange, unearthly splendor in the glare!

No one alone: from each projecting cape
And perilous reef along the ocean's verge,
Starts into life a dim, gigantic shape,
Holding its lantern o'er the restless surge.

Like the great giant Christopher it stands
Upon the brink of the tempestuous wave,
Wading far out among the rocks and sands,
The night o'er taken mariner to save.

And the great ships sail outward and return
Bending and bowing o'er the billowy swells,
And ever joyful, as they see it burn
They wave their silent welcome and farewells.

They come forth from the darkness, and their sails
Gleam for a moment only in the blaze,
And eager faces, as the light unveils
Gaze at the tower, and vanish while they gaze.

The mariner remembers when a child,
on his first voyage, he saw it fade and sink
And when returning from adventures wild,
He saw it rise again o'er ocean's brink.

Steadfast, serene, immovable, the same,
Year after year, through all the silent night
Burns on forevermore that quenchless flame,
Shines on that inextinguishable light!

It sees the ocean to its bosum clasp
The rocks and sea-sand with the kiss of peace:
It sees the wild winds lift it in their grasp,
And hold it up, and shake it like a fleece.

The startled waves leap over it; the storm
Smites it with all the scourges of the rain,
And steadily against its solid form
press the great shoulders of the hurricane.

The sea-bird wheeling round it, with the din
of wings and winds and solitary cries,
Blinded and maddened by the light within,
Dashes himself against the glare, and dies.

A new Prometheus, chained upon the rock,
Still grasping in his hand the fire of love,
it does not hear the cry, nor heed the shock,
but hails the mariner with words of love.

"Sail on!" it says: "sail on, ye stately ships!
And with your floating bridge the ocean span;
Be mine to guard this light from all eclipse.
Be yours to bring man neared unto man.

THE DIAMOND BY THE SEA

Like a ruby in an antique brooch with sentiment untold,
The gem in the tower glistens with beauty to behold!
Its glow reflects where sea meets sand in sapphire rivulets
That trickle down with the ebbing tide to the ocean's treasure chest.

The jewel on the horizon worn with dignity and grace
has romance and security wrapped up in its embrace
Beneath the sky of topaz shining brilliantly
the lighthouse is the brightest gem - The Diamond by the Sea.

-unknown–

THE LIGHTHOUSE LULLABYE

Lay down your head and close your eyes
and rest your weary soul,
For the lighthouse shines through fog, and rain,
and night as black as coal!

Though winds are lashing and waves are crashing
on coral reefs below,
The beacons calls and beckons all
with its majestic beam aglow.

When stars are out and seas are calm
and eventide draws nigh -
The seafarer rocks in a cradle of waves
to The Lighthouse Lullabye.

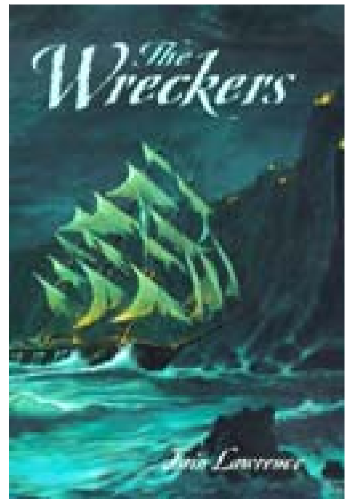
- unknown -

Design a Game. The light keepers on many of the earlier lighthouses often remained isolated for long periods of time. Students in cooperative groups could make a list of things that a light keeper might do to for entertainment. Have students share their ideas and design a game or an activity for a child their age that was a child of a lightkeeper. Students could then play the games and imagine what it would be like to live in a lighthouse. Students design a list of all of the items they would need to bring with them for an extended stay at a lighthouse. Rooms were small so they would only be able to take one suitcase.

Writing. Have students write a story about life in a lighthouse. What would they miss most? What would meals be like? How would they get to school?

Life Science. Many light keepers or their wives became involved in gardening to beautify the lighthouse. Have students design and draw a plan that would beautify the lighthouse grounds. Encourage students to consider conditions plants would have to tolerate in order to fluorish. Students may wish to include vegetable gardens, however they would have to find varieties of vegetables that suit the environment.

Art and History. Lighthouses along coastlines were often used as “daymarks.” A daymark is a landmark used during the day by sailors. Lighthouses along some coastlines were identical in design. Therefore, they had to be painted in different ways so that they could be used as daymarks. Have students draw several lighthouses of the same design and color them in ways that would be visible from far away. Once these are completed display them in class. Students will be surprised at the variations.



Reading. Read the book *The Wreckers* (ISBN: 0-440-41545-4) by Iain Lawrence as an extension of their studies of lighthouses. This is the story of a boy and his father who become shipwrecked in a village populated by wreckers. Located on the English coast, the village is populated by villagers who feed and clothe themselves with what they could salvage from shipwrecks.

Geography. Have students research the geography and history of the lighthouses along the Florida Coast. Students could take a map of Florida and locate the lighthouses that still exist on the map. Many of these lighthouses are open for tours and belong to the National Parks Service. Have students plan a trip to one of the open lighthouses close to them and calculate how much money the trip would cost.

Because the Florida Keys were one of the most dangerous sea lanes and many ships wrecked in the narrow strait between the Gulf Stream and the Florida Reef, the area became a prosperous resource for "wreckers" and pirates. Wreckers were individuals who recovered the cargo from wrecked ships and sold it at auction. This was a legitimate business at the time, but there were also "mooncussers" who illegally tried to have ships wreck for salvage and profit.

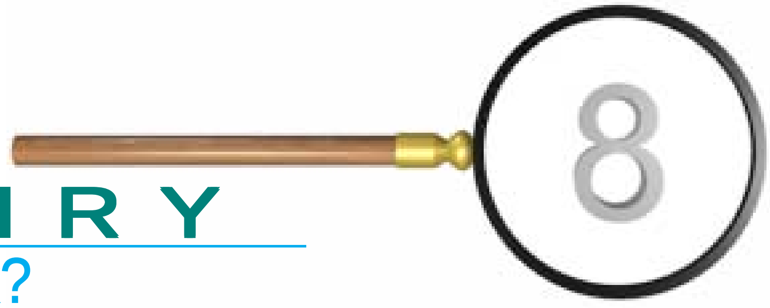
Journal Writing. Light keepers usually kept a journal or log documenting the events of the day. Have students pretend they are keeping a log and record some of the things they might encounter during a two-week stay at a lighthouse. What ships did they see? What did they do? Have students discuss in small groups the kinds of things they could write about before they begin.

Research. There are Fresnel lenses found in other things beside lighthouses, have students find out some of them and be able to explain how they help us. For example, Fresnel lenses are now created out of plastic and are used for solar energy collection.

Models. Using print and electronic media, students design a model or draw a picture of a lighthouse that exists somewhere in the United States. The name of the lighthouse, its location and the date it was constructed should be on this project. Encourage students to research the type of light or lens used and to include historical information such as whether it has been moved due to coastal erosion, if the lighthouse is part of the National Parks system, or if the lighthouse was also a residence.

Current Issues. Even though many lighthouses are not currently operational, there are conservationists who believe these should be preserved. In some locations, erosion has caused the land on which the structures rest to become unstable. Divide students into groups to debate whether or not lighthouses should be preserved, restored, or moved to another location. Students should justify their ideas and opinions with facts.

Reading/Social Studies. Read *A Light in the Storm* by Karen Hesse (ISBN 0-590-56733-0). This is a Civil War diary of a young woman who is part of a family responsible for the lighthouse on Fenwick Island, Delaware. This story not only provides a literature connection to light and optics and can enhance study of the life during the Civil War.



INQUIRY

How Does It Work?
Binoculars, Periscopes, and Kaleidoscopes

Binoculars, periscopes, and kaleidoscopes use mirrors, lenses, and/or prisms. Learning about these optical instruments can enhance your students' study of light and optics. This activity introduces each of these instruments and provides instructions for constructing models.

How do binoculars work?

Binoculars are used to make distant objects look larger. Binoculars are really just two refracting telescopes joined together with a hinge. Soon after telescopes were invented, people started to fasten two of the long tubes together to make binoculars. These long binoculars were heavy and difficult to handle. Since it was difficult to keep these tubes parallel to one another, the image seen was often doubled.

Around 1900 a German physicist named Ernst Abbe made a pair of binoculars using prisms that reflected the incoming light twice. This meant that it was possible to make a shorter instrument.. By using two prisms the image appeared rightside up.

Binoculars are found in three designs: 6x30, 7x50, and 8x30. The first number tells the magnification of the binoculars and the second number gives the diameter of the objective lens in millimeters. When using binoculars, you look at an object and light reflects off the object and enters the front of the binoculars through the objective lens. This forms an image that is upside down and reversed. Prisms correct the image before we see it through the magnifying eyepiece lenses.

Life Science. Encourage students to use binoculars to observe birds. They can record some of the following features used for the identification of birds. The shape and color of the eyes, feet, color of the plumage, shape of the head, shape of the tail feathers, and beak shape and color. They should record in their Science Notebooks some of these features, sketch what they observe, or both. Using guidebooks for the identification of birds and bird observation may turn in to a life-long hobby.

What is a Periscope?

Periscopes are instruments that allow the viewing of objects that are not in the direct line of vision. Periscopes found in submarines have tubes that may be up to 30 feet long. Tanks also contain periscopes that allow people inside of a tank to view the surrounding area while remaining protected. With the development of fiber optics, periscopes have been developed that allow doctors to view inside the human body without having to use major surgery. These types of periscopes are called endoscopes or cystoscopes and are very useful in medicine.

The construction of periscopes by your students will allow them to experiment with mirrors and the correct placement of them in the container, whether they use a tube or a milk carton. Students will have fun looking around corners.

MATERIALS:

- ❑ One or two empty quart-sized cardboard milk or juice containers (one for a short periscope and two for a long one)
- ❑ Two small rectangular mirrors, mirror paper or mylar*
- ❑ Tape
- ❑ Scissors or a craft knife.

* Transparency film on black construction paper works like a mirror and the materials are accessible and inexpensive.

Following are two sets of instructions; the first is more discovery-oriented and the second set of instructions are more prescriptive:

Procedure I

1. Place students in cooperative groups of 2-3 students.
2. Discussing, experimenting with the mirrors, and perhaps drawing their periscope design should be encouraged before actually constructing the periscope.
3. Help students discover the angles at which the two mirrors must be placed in order for them to use their periscope. This periscope reflects light two times before it reaches their eyes.

Procedure II

1. Cut the tops off of two milk cartons.
2. Cut a hole about 5 cm in diameter in one side of each carton near the bottom.
3. Tape a mirror, tilted at a 45-degree angle, in the bottom of each carton, with the shiny side facing the hole.
4. Tape the two cartons together so that the holes are on opposite sides of the periscope. In other words, where you look into the periscope is on the opposite side of the tube from the hole where light is coming in.

Students answer the following questions in their Science Notebooks:

1. What do you see when you look into the periscope?
2. How could you use your periscope?
3. Have you ever seen a periscope used? Or, have you seen another instrument that works like a periscope? Describe where you have seen a similar instrument.
4. How can you improve upon the design of your periscope?

What is a Kaleidoscope? It is really all done with mirrors.

The kaleidoscope was invented by Sir David Brewster about 1816 and patented in 1817. It was sold mainly as a toy, but has practical uses as well.

A kaleidoscope uses the image-forming properties of combined inclined mirrors. Depending on the number of mirrors and the angle between them, the kaleidoscope will produce multiple symmetrical patterns.

A simple kaleidoscope is made of two thin, wedge-shaped mirror strips touching along a common edge or a single sheet of bright aluminum bent to an angle of 45 or 60 degrees. The mirrors are enclosed in a tube with a viewing eyehole at one end. At the other end is a thin, flat box that can be rotated. This flat box is made from two glass disks, the outer one ground to act as a diffusing screen. In this box are pieces of colored glass or beads. When the box is turned or tapped, the objects inside tumble into different groups and when the diffusing screen is illuminated by natural or artificial light, six or eight different symmetrical images appear. The number of combinations and patterns is without limit.

There are five different types of kaleidoscopes. The ***Chamber Kaleidoscope*** has an enclosed object case with free-tumbling jewels, glass, beads or other objects. The ***Liquid Chamberscope*** has an object case filled with liquid (usually glycerin) in which the jewels, glass beads or other objects float. The ***Wheel Scope*** has one or more wheels at its objective end that may contain glass, translucent rocks like agates, pressed flowers, beads, jewels other objects. The ***Refillable Scope*** features a removable object chamber. The contents of this chamber can be changed and users can experiment with their own assortment of colors and objects. The ***Teleidoscope*** uses mirrors and lenses alone. Anything that is viewed is multiplied.

Following are directions for making kaleidoscopes using a Pringles can or a paper towel roll.

Pringles Can Kaleidoscope

MATERIALS:

- ☐ Pringles can
- ☐ Nail and hammer
- ☐ Scissors
- ☐ Compass
- ☐ Transparency film
- ☐ Black construction paper
- ☐ File folder
- ☐ Glue
- ☐ Pen and ruler

Pringles Can Kaleidoscope

1. Make a hole in the center of the metal bottom of the Pringles can with the hammer and nail. With the point of the scissors or other object, expand the hole to a 1.5 cm diameter. This will be the eyehole of the kaleidoscope so it is important that there are no sharp edges.

2. Cut out a 4 cm square of transparency film. Glue the transparency square over the eyehole of the kaleidoscope.

3. Cut from the file folder three 7.5 cm x 19.5 cm strips. Do the same with the black construction paper and the transparency film.

4. Glue the strips together in the following order: file folder, black construction paper, then transparency film. You should now have 3 sets of layered strips. The transparency on top of the black paper should provide a mirror-like surface.

5. Place each set of strips into the open end of the can, edge to edge, with the mirror surfaces facing the center of the can. Looking into the can, the top edges of the strips should form an equilateral triangle.

6. Cut 2 strips from the file folder (23 cm x 1.5 cm). Fold one strip in half the long way. Glue the folded strip along the long edge of the unfolded strip.

7. Glue the combined strips around and along the inside edge of the open end of the can above the mirrors. The folded strip should be closest to the mirrors. Let the glue dry.

8. Cut a circle of transparency film with a diameter of 7.5 cm (the same diameter as the opening of the can).

9. Place the transparency circle inside the open end of the can with its edge against ledge created by the folded strip. Glue circle in place with rubber cement.

10. Place various objects (beads, shells, gemstones, etc.) on top of the transparency circle. Place lid of can back on.

11. Your kaleidoscope is done! Look through the eyehole while turning the can and see the kaleidoscopic show.

Paper Towel Roll Kaleidoscope

MATERIALS:

- ☐ Paper towel roll
- ☐ Scissors
- ☐ Masking tape
- ☐ Compass
- ☐ Pen
- ☐ Ruler
- ☐ Glue
- ☐ Black construction paper
- ☐ Transparency film
- ☐ File Folder

1. Trace the top of the paper towel roll on the folder. Using a compass, draw a circle 1.5 cm larger around the circle you traced. Cut out the larger circle.

2. Make a hole about 1.5 cm in diameter in the center of the circle. This will be the eyehole for the kaleidoscope.

3. Make small cuts around the outer edge of circle from the edge to the traced line. The cuts should be made about every 1.5 cm around the circle. The cuts will form little tabs around the edge of the circle.

4. Cut out a piece of transparency film large enough to cover the eyehole. Glue it over the eyehole.

5. Place the circle on the one end of the roll with the transparency piece facing inside the roll. Fold down the tabs all around the outside of the roll. Secure it to the roll with masking tape.

6. Cut from the file folder three 6.5 cm x 27 cm strips. Do the same with the black construction paper and the transparency film.

7. Glue the strips together in the following order: file folder, black construction paper, then transparency. You should now have 3 sets of layered strips. The transparency film on top of the black paper will provide a mirror-like surface.

8. Place the strips side by side, mirrored surface down, on top of your work surface. Put masking tape across the strips at the top and bottom.

9. Fold the connected strips to form a three sided column 27 cm long with the mirrored surface facing inside. Tape around the column to hold it together. Looking into the column, the top edges of the strips should form an equilateral triangle. Place the column into the open end of the tube.

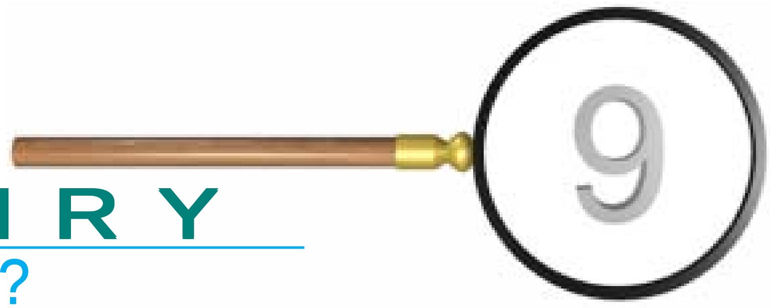
10. Cut out two circles from the transparency film using the directions in steps 1 and 4. You should now have two circles of transparency film with 1.5 cm tabs around it.

11. Fold back the tabs of one of the transparency circles then place it into the open end of the tube so the circle is touching the mirrored column and the tabs are facing out. Secure the circle to the tube with tape.

12. Place your choice of colorful objects (beads, gems, rocks, etc.) into the open end of the tube.

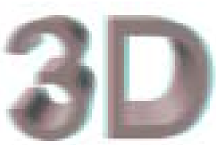
13. Now place the other transparency circle over the open end of the tube. Fold down the tabs all around the outside of the roll. Secure it to the roll with masking tape.

14. Your kaleidoscope is done! Look through the eyehole while turning the tube and see the kaleidoscopic show.



INQUIRY
How Does It Work?
3D Images and Holograms

Three-dimensional Images



Stereoscopic or 3D photography works because it is able to recreate the illusion of depth. Our eyes are about two and a half inches apart, so each eye sees something different. If you view two photographs that are taken the same distance apart with a stereoscope, then you will be able to see depth.

To show how your eyes see things different, hold your finger about a foot from your nose and close one eye, then reopen it and close the other. Your finger will appear to jump from side to side.

The principles of three dimensional or 3D images were known even before photography was invented. Charles Wheatstone experimented with stereoscopic drawings of simple objects in 1832. After the discovery of photography a few years later, the two principles were combined and stereoscope viewers were made. They became a very popular form of home entertainment. In 1844 a technique for taking stereoscopic photographs was demonstrated in Germany, and David Brewster developed a much smaller and simpler viewer that used prismatic lenses in Scotland. Stereoscope viewers were used to look at cards called stereographs. A stereograph is a twin photograph with two images mounted side by side. Each picture is taken from a slightly different viewpoint that is equal to the spacing of the eyes. When looked at through the stereoscope viewer, the picture appears as a three-dimensional image.

Anaglyph images are the type of 3D images with which students are most familiar. Louis Ducas Du Hauron, a French scientist, patented this method of stereoscopic photography in 1891. A pair of images taken from slightly different points is color corrected and superimposed so that one image is offset slightly from the other. Typically the image for the left eye is printed in red ink and the right eye image is printed in green ink. When observed with the naked eye, the image looks overlapping, doubled and blurry. However, when viewed through a pair of glasses with different colored lenses, the image appears to be 3-dimensional. The glasses used to view these objects are usually red and blue with the red lens covering the left eye and the blue or sometimes green lens covering the right eye.

The stereoscope is considered a form of mass media. This instrument allowed many people to "travel" to far off lands without leaving home. Some things that particularly interested people were the pyramids and tombs of ancient Egypt, the sights of New York, Chicago and San Francisco, and the abbeys and countryside of Europe. The great events of the day also found their way into stereo slides. Among these were the building of the Panama Canal, War World I, the Johnstown Flood, and the San Francisco earthquake. The Chicago World's Fair of 1892 and the St. Louis World's Fair of 1904 could be enjoyed even by those who could not be there. Have students design a series of stereoscope programs that show a current or historical event. Discuss why the depiction of events was more important around the turn of the century.

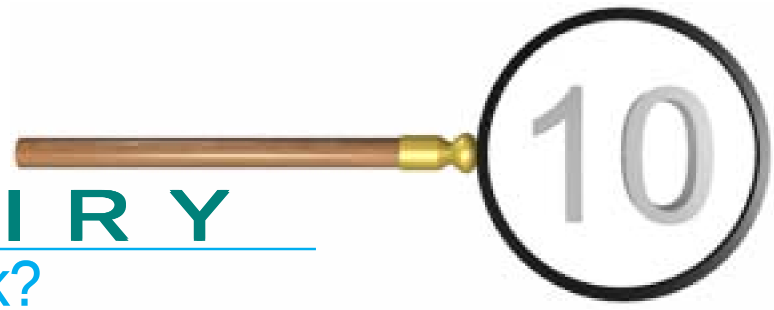
Holograms

The method of making three-dimensional photographic images *without* a lens is called holography and the images are called holograms. A British physicist, Dennis Gabor, developed theories involved with holography in 1947. However, the first production of holograms did not take place until the 1960's when laser technology became available.

Holography has very little in common with regular photography. Holograms contain information about the size, shape, brightness and contrast of the object being recorded. Lasers are used to produce holograms because their light is one color and highly directional. Holograms record images of light waves emitted from a laser as they are reflected off an object. This hologram when lighted and viewed under ordinary light, presents a three-dimensional re-creation of the original object.

Today holograms are used in security applications, commercial and consumer applications, and promotional pieces. Holograms are used to protect financial documents, credit cards, tamper-evident stickers, and on paper money. The reason for using holograms is that they are difficult to copy. Some commercial/consumer applications would include greeting cards, collectibles, trading cards, packaging and displays. Promotional pieces would include T-shirts, tags on merchandise, stickers and key chains.

Activity. In cooperative groups have students create a list of all of the places they have seen holograms. Compile a class list after each group has completed their group list. Ask students to comment on the reasons why these are used. It is said that, in the very near future, holograms will be broadcast over television. Have students discuss and write about this would change television? How would their favorite TV program change if this happened?



INQUIRY
How Does It Work?
Project Ideas

The following ideas can be used during the study of optics as extensions to the activities or as the main focus for your unit.

<u>Research.</u> Assign to pairs of students one of the following vision problems or diseases:

- Nearsightedness
- Farsightedness
- Astigmatism
- Color blindness
- Macular degeneration
- Retinitis pigmentosa
- Cataracts

Each student pair finds and presents answers to the following questions:

1. What causes this vision problem or disease?
2. How different parts of the eye are affected?
3. How can this vision problem or disease be helped by technology, devices or surgical procedures?
4. How does each device or procedure work to change the affected parts of the eye to enhance better vision?

Once students have completed their research, have them prepare a poster, pamphlet, or other form of presentation that explains to others the causes and treatment of the problem or disease they investigated.

<u>Research/Interview.</u> Students research how eyeglasses or contact lenses are made and how they are designed to correct various vision problems. Encourage students to report on changes in the design of contact lenses and materials used to make them since the first ones were made available to the public (for example, the evolution of hard contact lenses, soft contact lenses, disposable lenses, or bifocal contact lenses). Students could conduct an interview with an optician or opthamologist to find out more about the fitting of contact lenses and the problems they encounter.

Model Design. Students design models that illustrate the similarities and differences between the human eye and devices that use lenses, such as cameras, microscopes and telescopes.

Timeline. To integrate history and the study of optics, students research and prepare a timeline large enough to be displayed in the classroom on the history of lenses, the history of optical instruments, or the history of basic theories involving light and its properties. Refer to the *Science, Optics & You* Timeline at http://micro.magnet.fsu.edu/optics/timeline/index.html

Scientist Trading Cards. Students design a *Famous Scientist Trading Card* (adapted from Biology Biography activities by Nora C. Doerder). The Scientists Cards are colorful, collectible cards in the following format:

Front of the Card:
- Photograph or portrait
- Name of Scientist
- Time Period
- Most significant contribution
- Awards and Honors
- Areas of Study

Back of the Card:
- Stats: Basic biographical information
- A quote
- A picture related to this person's work.

Scientist Scrapbook. Students work in groups to prepare a Famous Scientist Scrapbook (adapted from Biology Biography activities by Nora C. Doerder). The scrapbook can have a colorful cover to serve as an introduction to the scientist and the contributions he/she made to the study of optics, color and light, physics, or photomicroscopy. The cover can be illustrated with a picture or portrait of the scientist and pictures relating to the scientist's work. The following are some suggested scrapbook entries:

1. A personal timeline for the scientist. Display the high points of your scientist's personal and professional life and include at least five events.

2. A birth announcement and birth certificate. Create a certificate and appropriate information.

3. A letter written by the person as a young man/woman revealing information to a friend about his/her interests.

4. A letter of recommendation for this person to a college from a high school teacher.

5. A speech or essay written by this person on the topic "Advice to Young People Who Want to Succeed in Science."

6. A letter of introduction from the scientist to the class. A letter written by a student appearing to be from the scientist as if he/she were alive today.

7. A newspaper article reporting and explaining important events in which this person was involved.

8. A script for a radio commercial featuring this person and their work.

9. A color advertisement about this person and their work.

Research: Scientists Related to the Study of Optics.

General Optics: Ali Alhazen, Roger Bacon, Johannes Kepler, Hans Lippershey, Galileo Galilei, Francesco Grimaldi, Willebrod Snell, Rene Descartes, Pierre Fermat, Robert Hooke, Isaac Newton, Christaan Huygens, Thomas Young, Joseph Von Fraunhoffer, Augustin Fresnell, Christian Doppler, Michael Faraday, Jean Foucault, Albert Einstein.

Microscopy: Hans Jansen, Robert Hooke, Karl Friederich Gauss, Antonie Van Leeuwenhoek, Christaan Hyygens, Joseph Jackson Lister, Zacharias Jansen, Carl Zeiss**.**

Refer to the *Science, Optics & You* Timeline at http://micro.magnet.fsu.edu/optics/timeline/index.html