



6-8: Seeing the Light

Curriculum Connections

Life Sciences

- Understand the structure and function of cells, tissues, organs (cow's eye), and organ
- Systems and how they interact with each other in complex organisms

Scientific Connections

- Understand and describe examples of the importance of scientists, science, and technology and the impact that they have on our lives
- Understand the relationship between form and function, order and organization

Physical Sciences

- Explain and give examples of how energy is transferred or transformed from one form to another

** Based on the New York State Elementary Science Core Curriculum and the New York City New Standards™*

National Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes in properties in matter
- Motions and forces
- Transfer of energy

Content Standard C: Life Science

- Structure and function on living systems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology

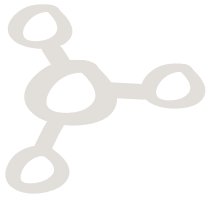
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources and environments
- Risks and benefits
- Science and technology in society

6-8 Exhibits List

After Image
Aurora
Benham's Disk
Bird in the Cage
Blind Spot
Blood Vessels of the Eye
Bridge Light
Cardboard Tube Syllabus
Cheshire Cat
Changing Illusions
Circular Deformations
Color Contrast
Color Reversal

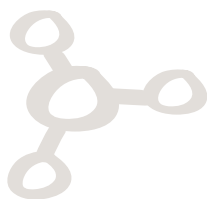




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Columns
Convection Current
Corpuscles of the Eye
Cow's Eye Dissection Demonstration
Depth Spinner
Diffraction Grating
Disappearing Glass Rod
Far Out Corners
Horse and Cowboy
Horse's Tail
Hot Light
Laser and Optics Demonstration
Lens Table
Light Island
Long Path Diffraction
Lux Rota
Mirrorly a Window
Motion Detector
Old Woman or Young Lady
Peripheral Vision
Persistence of Vision
Professor Pulfrich's Universe
Rainbow Edges
Recollections
Resonator
Resonant Pendulum
Resonant Rings
Reverse Distance
Reverse Masks
Shimmer
Sliding Gray Step
Spectra
Spinning Rings
Squirming Palm
Stereo Pictures
Stereo Rule
Trapezoidal Window
Two Eyes



Guide Theme

The theme of these guides are based on popular crime and detective show investigations on TV; a mystery unfolds, questions are asked, evidence is gathered, conclusions are drawn. This process is similar to what scientists go through with the inquiry method. For more details see About the Guides.



Begin the Investigation At School

A mystery unfolds, questions are asked...

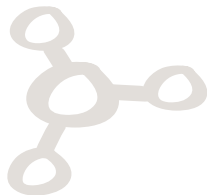
There are several ways you can introduce the topic and start the investigation. Here are some ideas that will help students start thinking about the topic and generate questions:



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- Create a mystery about the fact that only ten percent of the electrical energy of a light bulb emits light. What does the other ninety percent do? (Mystery solved at Hot Light exhibit)
- Create a mystery about light traveling in waves. Waves? Is it possible to see light waves? (Mystery solved at Bridge Light, Soap Films exhibits)
- Create a mystery about being able to see the blood vessels and corpuscles within your own eye without having to use a microscope. (Mystery solved at Blood Vessels of the Eye and Corpuscles of the Eye)
- Create a mystery about seeing moving walls, disappearing rods, masks that follow your movement. (Mystery solved at Depth Spinner, Disappearing Glass Rod, Reverse Masks exhibits)
- Create a mystery about how gases make light. (Mystery solved at Spectra exhibit)
- Create a mystery about a hidden art collection that students will find in the science exhibition. (Mystery solved at Aurora, Circular Deformations, Lux Rota, Professor Pulfrich's Universe, Recollections, Shimmer, Spinning Rings, Stereo Pictures and Triple-Aye Lightstick exhibits)
- Demonstrate one of the Laboratory Activities with no explanation-let the questions begin
- Do one of the Laboratory Activities and facilitate a probing discussion



Prepare for Investigation at the New York Hall of Science

Once students have generated questions around the topic tell them they are going to continue the investigation at the New York Hall of Science.

At this point you may want to begin one of the Continuum Activities. These activities have the following features:

- Vary in length and depth
- Provide continuity and purpose for the visit
- Provide a way of assessing student understanding

Orientation and Planning: If you do nothing else, do this!

Here are five reasons to conduct student orientation and planning before going on a field trip:

1. Students focus on exploring and investigation versus the novelty of the location
2. Students don't have to worry about logistics like restrooms, schedule, eating etc.
3. Students who understand the plan and purpose of the visit are more likely to stay focused
4. Students who have clear goals for their visit are less likely to race from one exhibit to another with little understanding
5. Students who get involved in the planning of the visit, take ownership and are less likely to misbehave

Read more about the Orientation and Planning Process

Investigation at the New York Hall of Science

Evidence is gathered...

Okay. The class has arrived at the next phase of the investigation. The students have questions and seek answers. Everyone knows what exhibits they should visit and why. Everyone knows the schedule for the day. Students have materials to record findings or work on a Continuum Activity if required.

If all of the above is true, congratulations on a successful Orientation and Planning.



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If you are curious about what teachers can do on site, we've put together a little piece called Teacher Role.



Finish the Investigation Back at School

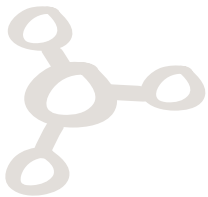
Conclusions are drawn...

There are several ways you can complete the investigation. Some require less time than others. Here are some ideas:

- Student or group oral or written reports on investigation questions and answers
- Student or group illustrations of visit with answers to questions or mystery
- Do one of the Laboratory Activities
- Complete the Continuum Activity

Continuum Activities

Continuum Activities are designed to carry through the entire investigation. Some activities require less time than others.



Investigation Map

Description: Detectives will often map out related events, evidence and suspects during an investigation. This helps them get an overall picture. Students can map out their investigations with a concept map. The concept map will help you assess what students learn.

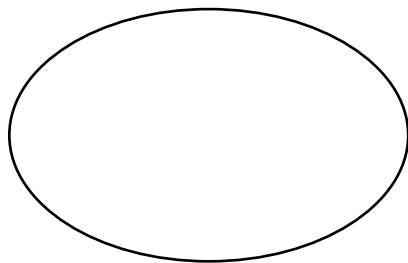
Time: (3)15-30 min. Sessions

Materials Needed:

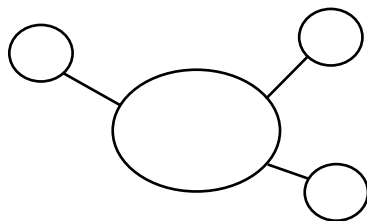
- Blank paper
- Pencils, colored markers

Procedure:

1. Begin with a center circle and write in the name of the main topic. (Students who do not write can have an adult assist or draw a representation of the main topic)



2. As students generate questions about the topic, they can add offshoot circles. They can also add circles for facts they know about prior to the visit to the New York Hall of Science.



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- When students return from their investigation at the New York Hall of Science they add additional circles of information. Their final map should reflect everything they know about the topic. Teachers can easily assess what is learned based on how the map develops.



Investigation Journals

Description: Investigation journals provide a way for students to record their questions and findings throughout the investigation.

Time: (3) 15-30 min. Sessions

Materials Needed:

- Blank or lined paper
- Pencils, pens or colored markers
- On-Site Investigation Handout (print out from this web site and make copies)
- Zip-lock bags (for on-site handout only)
- Soft yarn or thick soft string (for on-site handout only)

Procedure:

- Ask students if they have ever seen a detective take notes when trying to solve a mystery. Tell students that as “science detectives” they too will make a record of the mystery.
- Have students begin their journal or report with questions that are generated when they Start the Investigation at School.
- Students who do not have writing skills can make a large question mark and draw representations of their questions. If an experiment or demonstration is done, non-writing students can sketch what they observe.
- Older students with writing skills can list their own and other students questions in their journal.
- We strongly advise students not bring journals to the New York Hall of Science where they can get lost. We have provided an On-Site Investigation Handout that can be copied if students want to record observations or make sketches.
- When students return from their investigation at the New York Hall of Science have them write answers to questions or draw what they observed.



Science TV- Investigative Reporters

Description:

In this activity, students plan and produce a TV show featuring investigative reports on the topic. This is a cooperative learning activity that integrates language arts, science and technology. There is a significant amount of writing involved, however students who are not prolific writers can also contribute as camera people, script supervisors, directors and on-camera reporters. Students will video tape at school and at the New York Hall of Science so pre-planning is essential for this activity.

Time: (3) 45 minute sessions (writing)

- video shoot at school
- video shoot at the New York Hall of Science
- 45 minute session (writing)
- video shoot back at school
- 30 minute session for viewing final TV show

Materials Needed:





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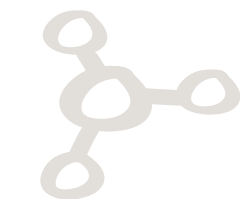


- Video camera
- (1) video tape per student group
- External wired microphone for camera (optional but suggested for good audio)
- TV
- Cables to run camera to TV for viewing
- Student internet access (optional for research)
- Lined paper and pencils
- Large plain paper and markers (cue cards)

Procedure:

First Session-Planning

1. Tell students they are going to plan and produce a TV show with investigative science news stories that are 4-5 minutes in length.
2. Divide the class into groups of four or five students.
3. Have students or the teacher chose a writer/script supervisor, camera person, director and on-camera reporter for each group.
4. Tell students about the various roles in the production team:
 - Writer-writes groups ideas for script, makes revisions
 - Cameraperson-operates camera
 - Director-supervises camera person and on-camera reporter, calls for action and cuts
 - Script Supervisor-makes cue cards for on-camera reporter, makes sure script is followed
 - On-Camera Reporter-person who reports and appears in video
5. Tell students that everyone the group will work together to create the script.
6. Remind students of the topic of study and the trip to the New York Hall of Science.
7. Instruct students to begin to create questions around the topic for the news show. They may want to create questions for interviews with New York Hall of Science “Explainers” too.
8. Tell students to watch the local news on TV so they can observe how news reporters do their job.



Second Session-Location Scout and Scriptwriting

1. Tell students they are going to do a location scout of the location they will be shooting at the New York Hall of Science.

Scouting the location will help them think of more questions and give them ideas for what to shoot on location.

2. Make prints outs of the exhibits the class will visit at the New York Hall of Science OR have students access the exhibits online themselves.
3. Once students have become familiar with the exhibits, allow time for more scriptwriting. Make sure scripts have the following components:
 - Introduction to the report (name of reporter, where they are, news headline)
 - Questions the investigative report will answer
 - Conclusion (to be done after video shoot at New York Hall of Science, comment, opinion about answers, reporter sign-off)



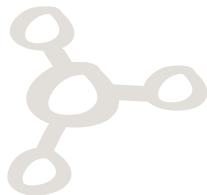


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Third Session- Rehearsals and Final Script



1. Remind students about the various roles in the production team:
 - Writer-writes groups ideas for script, makes revisions
 - Cameraperson-operates camera, responsible for video tape
 - Director-supervises camera person and on-camera reporter, calls for action and cuts
 - Script Supervisor-makes cue cards for on-camera reporter to read, makes sure script is followed
 - On-Camera Reporter-person who reports and appears in video
2. Have groups rehearse their roles using the scripts. (Camera people can use their hands to frame shots)
3. Advise groups to make script revisions if they notice problems during rehearsal.
4. Rehearsals can be done in front of whole class or in individual groups depending on your classroom space and noise level.
5. After rehearsal have groups meet and finalize the pre-New York Hall of Science script.



Homework

Have groups give script supervisor the pre-New York Hall of Science script so they can make cue cards. (Script supervisor can ask others to help make cue cards too)

Video Shoot at School

During this session each group will shoot the introduction to their news story. Each group will have their own video tape. Make sure each group tape is labeled. If possible you may want to have groups shoot in a quiet separate location from the others or schedule group shoots during breaks in the day. If the entire class is present during shoots, make sure the others are quiet and don't distract the shooting. After shooting make sure camera people return the group tape to the teacher for safe keeping.



Video Shoot at the New York Hall of Science

1. Make the shooting schedule for the day.
2. Allow 15-20 minutes for groups to shoot in their location.
3. Choose a central location for production groups to meet the adult who will have the video camera and group tapes.
4. Make sure production groups stay together at the New York Hall of Science and Chaperones know the schedule for the day.
5. If students plan to interview a staff "Explainer", locate the Explainer in the area before shooting and ask for their assistance and cooperation for the shoot.
6. After shooting make sure camera people return the group tape to the adult for safe keeping.



Conclusion Script Back at School

1. Production groups will need to write the conclusion to their video script after their New York Hall of Science video shoot.
2. The conclusion should include a summary or opinion of the overall story as well as the reporter sign off.

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3. Allow production groups to review their video footage (if necessary) so they can form opinions or summaries.
4. Have script supervisors and others in the group make up the final cue cards and conduct short rehearsals.

Video Shoot at School

During this session each group will shoot the conclusion to their news story. If possible you may want to have groups shoot in a quiet separate location from the others or schedule group shoots during breaks in the day. If the entire class is present during shoots, make sure the others are quiet and don't distract the shooting. After shooting make sure camera people return the group tape to the teacher for safe keeping.

View the Show

Hook up the camera to the TV and run the group tapes from the beginning. Enjoy the show.

Become an Explainer

Description: Students practice observation skills and investigate one exhibit with the goal of being able to explain it when they return to the classroom. Students can choose a variety of methods to explain and make presentations.

Time: (3) 45 min. Sessions

Materials Needed:
(per student pair)

- Interesting objects for student observation that will fit in a lunch bag
- Lunch bag
- Print outs of On-Site Investigation Handout

(optional suggestions)

- Variety of craft materials (pipe cleaners, popsicle sticks, straws, string, paints)
- Variety of clean, household recyclables (meat trays, cardboard tubes, aluminum foil, plastic wrap)
- Any other odds and ends students can construct with
- Poster board or paper
- Markers, crayons, colored pencils

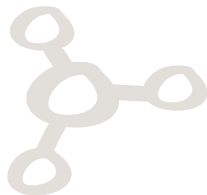
Preparation:

Place interesting objects for observation in lunch bags to keep hidden from student view.

Procedure:

First Session

1. Tell students as they will be investigating exhibits at the New York Hall of Science and will choose one exhibit to explain to the class when they return. (students can work in groups or individually)
2. Tell students they are going to do an activity to practice their observation and describing skills.
3. Distribute materials to student pairs.
4. Tell students that the person who is holding lunch bag will now describe the object inside to the other person without naming the object or describing what it is used for. Only descriptions of what the object looks like are allowed. The other student must guess what the object is.
5. Allow student pairs to complete activity and then switch lunch bags with another student pair. Each student pair should have a new object.
6. Repeat activity.



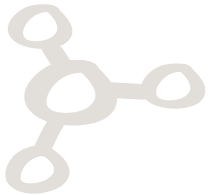


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7. Conclude activity by telling students they will need these same skills of careful observation and detailed describing to explain exhibits they investigate.
8. Conclude the session by leading a discussion about what students can do at the New York Hall of Science to help explain and record what they see. Ideas include:
 - sketching
 - writing
 - using exhibit pictures on this web site
 - photography
9. Distribute The On-Site Investigation Handout for use at the New York Hall of Science.
10. Go to the New York Hall of Science.

Second Session



1. Upon return to class from the trip, tell students they will spend time preparing to explain one of the exhibits they saw.
2. Here are some suggestions for student presentations:
 - Verbal explanation (with or without picture-good for ESL students)
 - Labeled diagram
 - Group or individual poster showing how an exhibit worked
 - Group or individual model using materials to represent exhibit (materials can be used to substitute and represent real materials from exhibit— ex. Clear plastic wrap simulates glass, cardboard tube becomes a rocket etc.)

Third Session (optional)

Use this time for students to make their class presentations if they made posters, drawings or models.



Note: Your class may want to make their presentations to another class or younger students as well.

Science Court-The Great Light Debate: Particles or Waves?

Description:

In this activity students will research and debate the age old scientific question:
Is light made up of particles or waves?

Time: (4) 45 minute sessions

(1) trip to the New York Hall of Science (Visit Seeing the Light)

Materials Needed:

- Print outs of Print Resources
- Student internet connection
- Index cards





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Procedure:

First Session

1. Tell students they will be participating in a mock court session debating the question:
Is light made up of particles or waves?
2. Tell students they will be divided into two groups to present both sides of the debate:
 - Particles
 - Waves
3. Tell students the case will be decided by the judge (teacher) or a jury (another class).
4. Divide the class into the Yes Group and No Group.
5. Hand out the print resource, Light is Made of Particles to the students in the Particles Group.
6. Hand out the print resource, Light is Made of Waves to the students in the Waves Group.
7. Use the remaining time to let students read through the articles and discuss them in their groups.

Second Session

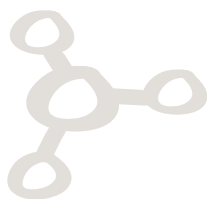
1. Divide class into the two groups; Particles and Waves.
2. Have students review the print resources and highlight major points they want to use in their argument.
3. Conduct a preliminary hearing by having each group reveal one or two facts for their argument.
4. Tell students that they now have some idea about their opposition and are more likely to win their case if they have more facts than the other side.
5. Help students to see where they may need more research by asking the following questions:
 - Does your group have more facts or opinions? (opinions don't hold much weight in a debate)
 - Does your group have enough information to oppose the other side?
 - What arguments from the opposition do you need to do more research on?
6. Discuss research sources where students can further prepare for their case. (Library, internet)
7. Assign research for homework.
8. Tell students they will prepare their case in the next session.

Third Session

1. Have students divide into their groups and discuss their research findings.
2. Have student groups choose a 2-3 representatives to present their case in court.
3. Have student groups choose 2-3 writers who will make index cards for the representatives.
4. Tell students they will have 15 minutes to present their group's case.
5. Student groups spend the remainder of the time preparing their case for the court session.

Fourth Session

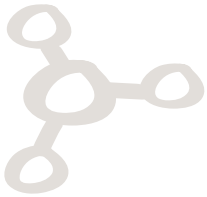
1. Court is in session.





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2. Set up the room so that representatives from each student group can present their case.
3. Allow each group 15 minutes to present their case.
4. Allow 10 minutes for the other class jury to deliberate on who presented their case the best.
5. If another class jury is not available spend 10 minutes discussing who presented their case the best with the entire class. The teacher acts as judge and makes a final ruling.





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Print Resources



Light is Made of Particles

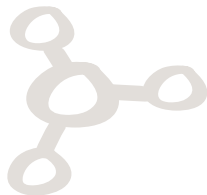
Light behaves like particles because it travels in straight lines and bounces off things like a mirror. Waves do not travel in straight lines.

Photons make light so light is made up of particles.

X-rays, a form of light we cannot see are able to penetrate matter, therefore the light must be made of particles.

The photoelectric effect proved that light is made up of particles. When a sheet of metal was bombarded with light, electrons on the metal were ejected. The electrons were ejected by photons hitting them. The greater the intensity of light the more electrons were ejected.

Go to this web site to read the history of the light wave/particle debate
<http://micro.magnet.fsu.edu/primer/lightandcolor/particleorwavehome.html>



Light is Made of Waves

In 1807 Thomas Young proved that light was made of waves when he pointed a light through a narrow slit and the light spread out after passing through the slit. If light were made of particles it would not have radiated out like a wave.

Young's experiment can be duplicated by shining a flashlight through two narrow slits of cardboard onto a surface. The result shows waves overlapping.

If light were made of particles crossing beams of light would not be possible because the particles would bump into each other.

The electromagnetic spectrum appears as wavelengths and can be measured with a spectrometer.

Go to this web site to read the history of the light wave/particle debate
<http://micro.magnet.fsu.edu/primer/lightandcolor/particleorwavehome.html>



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Laboratory Activities

Laboratory Activities are designed for the classroom and generally require simple materials. These activities can be done before or after a visit to the New York Hall of Science. To help students use higher-level thinking and generate questions, facilitate discussion with these types of questions:

- What do you notice here?
- Tell me about this.
- What do you see?
- Why do you suppose this happens?
- What can you conclude from the evidence?



Build a Thaumatrope

Description: Students build a popular 19th Century optical illusion known as the thaumatrope to better understand persistence of vision.

Time: (1) 30 minute session

Materials Needed:

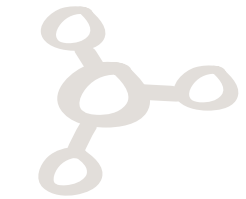
(Per student)

- (2) Unlined 3x5 index cards
- Plastic straw
- Clear Scotch tape
- Colored markers or felt tip pens

Procedure:

1. Tell students they are going to construct an optical illusion where the brain sees two images as one.
2. Distribute two index cards, one straw and scotch tape to each student.
3. Instruct the students to draw a picture on each card that when the two pictures are combined, you create a full picture. Some popular images for thaumatropes are bird in a cage, clouds and a rainbow and a lightning bolt and the sky.
4. When students have completed their drawings, tell them to center and tape the straw securely in between the two cards and tape it together with the complimentary pictures facing outward.
5. Instruct the students to place the straw between the palms of their hands and rub them back and forth. (Students will see two images become one)
6. Tell students the following story:

In 1826, Dr. John Ayrton Paris conducted an experiment about persistence of vision, and thus invented a popular 19th Century optical toy known as the thaumatrope. On one side of a disk he drew a picture of a bird, and on the other side a picture of a cage. He drilled a small hole on each lateral side of the disk, knotting a string through each hole. When he would spin the disk rapidly, it would appear as if the bird was in the cage. When you spin a thaumatrope, your brain sees these two separate images as one. The faster you spin it, the more apparent this illusion. This phenomenon is called persistence of vision. Motion picture and animation developed partly from the fascination of persistence of vision. Movies are composed of individual frames being projected at 24 frames per second. The images are discontinuous; they are separated by darkness. Movies seem continuous because one image is blending into the next. This is known as persistence of vision. For this same reason, when we blink we do not see darkness, but a continuous image. In addition to thaumatropes, flipbooks and zoetropes also follow this phenomenon.



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7. Once students understand the illusion they may come up with other ideas for pictures.



Reversing Flag

Description:

Students create a green, yellow and black American flag and see the proper colors in an after image. An explanation of this phenomena is provided.

Time: (1) 20 minute session

Materials Needed:

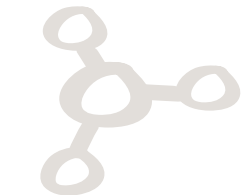
- internet access and a color printer OR blank paper and green ,yellow, black markers
- a white wall, blank white paper or large white surface

Procedure:

1. Point to the blank white wall or surface and tell students that they will see an American flag appear on the surface during this experiment.
2. Explain to students that, first you need a picture of an American flag. Not just any picture of a flag, but a very special one. We want a picture that has all of the wrong colors. Instead of red, white and blue, we want a flag that is green, black and yellow!
3. There are two ways to get this strange flag image. The easiest is to go to (<http://www.krampf.com/EOW/flag.html>). This is a website page which has the image ready for student use.
4. Another way is to have students draw their own flags, with colored markers. The blue part of the flag should be yellow, the red part of the flag should be green and the white parts of the flag should be black.
5. Once students have this image, they are ready for the experiment.
6. Tell students to stare at the center of the flag and try to keep their eyes from wandering.
7. Keep staring at the flag for at least 20 seconds. (The longer they stare, the better this will work.)
8. After staring for a while, have students look at a blank piece of paper or a blank, white surface.
9. Students should see a glowing image of the American flag, in its proper colors.
10. Explain to students that:

When you look at something that is blue, the blue light hitting the back of your eye releases a chemical that tells the nerves that you are seeing something blue. As you stare at the blue for a long time, these chemicals build up. Your eye gets “tired” of seeing blue and starts to ignore it. Once your eye starts to ignore some of the blue light, then you stare at a white sheet of paper. White light reflects from the paper and enters your eye. Your eye ignores the blue part, and sees a yellow afterimage instead. For each color that you stare at, you will see a different, reverse afterimage color.

Adapted from Experiment of the Week #239, Robert Krampf's Science Education Company www.krampf.com



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A Hole in your Hand

Description:

Students experience the illusion of a hole in their hands. This experiment shows how the brain and eyes work together to create 3-dimensional perception.

Time: (1) 10 minute session

Materials Needed:

- (per student)
- a sheet of paper

Procedure:

1. Tell students they are going to see a mysterious illusion where a hole appears in their hand.
2. Distribute paper.
3. Tell students to roll the paper into a tube. It should be at least large enough to stick 2 fingers into.
4. Tell students to hold the tube up to their right eye, so that they are looking through it.
5. Have students hold their left hand about 6 inches in front of their face, with the hand open, the palm facing towards them, and the base of their little finger against the side of the paper tube.
6. With both eyes open, they should see a strange sight. They will see their hand in front of their face, with a hole through it. If they don't, have them try moving their hand a little farther away until it comes into focus.
7. Explain to students that:

Normally, both of your eyes see the same thing, just from slightly different angles. Your brain combines these two slightly different views to let you see in three dimensions and judge distances.

You have changed that. You are giving your brain two different images. One eye is seeing the palm of your left hand. The other eye is seeing the other side of the room, viewed through the tube. In combining the two images, your brain has to decide what is more important to see.

Most of the view from your right eye is blocked by the dark sides of the tube, so you mostly see the view from your left eye. The one exception is the bright circle of image that your right eye sees through the tube. Since this is the one bright spot from your right eye, your brain pays extra attention to it. As your brain combines the two images, you wind up seeing your hand with a hole through it.

Adapted from Experiment of the Week #323, Robert Krampf's Science Education Company www.krampf.com

Making Waves- Demonstration

Description:

Two student volunteers make waves with a long rope to simulate light waves. Photon energy as it relates to color, frequency and wavelengths are explained. A mathematical formula for calculating the wavelength of photons is also introduced.

Time:

Materials Needed:

- Long rope (the longer the better, but not less than six feet)
- Image of visible light electromagnetic spectrum or rainbow (red, orange, yellow, green, blue, indigo, violet)



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- Blackboard or other drawing surface (students)
- Colored markers or pencils (red, orange, yellow, green, blue, indigo, violet)
- Science journal, notebook or unlined paper

Procedure:

1. Display image of the electromagnetic spectrum or rainbow.
2. Ask for two student volunteers.
3. Give each student volunteer an end of the rope and have them spread apart so the rope is extended, but still loose. Tell them to wait for your instructions.
4. Tell students they are going to see what a long rope has to do with the colors in the rainbow or spectrum.

5. Explain to students that:

- Scientists believe light is created by photons
- Photons have different energy levels and produce different colors

6. Instruct one of the student volunteers to move one end of the rope up and down slowly while the other students holds onto the other end of the rope tightly.
7. Explain to students that:
Here we see low energy photons and the wave of light they produce.
8. Tell students to observe how big the waves are and how many are created.
9. Point to the color red on the rainbow or spectrum and tell students that this wave action represents the lowest energy on the spectrum, the color red.
10. Now instruct the student volunteer to move the rope up and down slightly faster.

11. Explain to students that:

As the photon energy increases another color is produced. This time orange.

12. Tell students to notice how big the waves are and how many are created.

13. Now that students get the idea of wave action as it relates to color, have the student volunteer gradually increase the speed of the wave action as you verbally call out the rest of the colors and point to the rainbow or spectrum:

Yellow

Green

Blue

Indigo

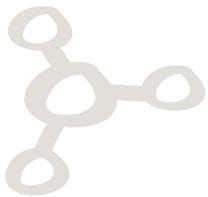
Violet (the rope waves should be at maximum speed now)

Okay, let's give these light wave makers a rest.

14. Draw a wave motion on the blackboard.

15. Explain to students that:

- Light waves have specific properties. Waves have crests (high points) and troughs (low points). A wavelength, measured from crest to crest, determines the color of the light.



6-8: Seeing the Light



- Frequency, or the amount of waves going through a fixed point per second, establishes the type of electromagnetic wave, such as visible light or radio waves.
- It is not actually possible to directly measure the frequency of a single photon of light. This is because a single photon is going to behave more like a particle than a wave, and the concept of frequency (cycles or alternations per second) only applies to waves. A spectrometer is a device that disperses the path of impinging photons through an angle that is dependent on their wavelength. In this way it is possible to closely estimate the wavelength of the photons.
- The wavelength measurement is then used in a simple equation relating speed of a wave, its wavelength and frequency: frequency = speed / wavelength.

16. Show the following example on the board:

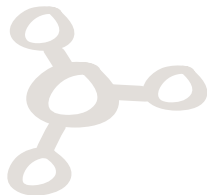
The speed of light is defined exactly as 299,792,458 m/s

$$F=299,792,458$$

A photon of red-orange light from a HeNe laser has a wavelength of 632.8 nm

$$F=299,792,458/632.8\text{nm}$$

Using the equation gives a frequency of 4.738×10^{14} Hz or about 474 trillion cycle per second.



17. Tell students they are now going to diagram and illustrate light waves.

18. Tell students you are going to repeat the light wave action with the rope and that they should carefully observe how the wavelength and frequency changes as the colors change.

19. Instruct the student volunteers to start making slow waves and increase speed as you call out the colors.

Red

Orange

Yellow

Green

Blue

Indigo

Violet



20. Now instruct students to use their colored markers or pencils to make light waves that represent the different colors. (wavelength should decrease and frequency increase as students move through the spectrum)





6-8: Seeing the Light

Book List

Light

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- Bender, Lionel. *Lasers in Action*. The Bookwright Press, 1986.
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Gardner, Robert. *Experimenting with Illusions*. Franklin Watts, 1990.
White, Laurence B. Jr. and Ray Broekel. *Optical Illusions*. Franklin Watts, 1986.

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- Palin, Michael & Lee, Alan & Seymour Richard. *The Mirrorstone: A Ghost Story with Holograms*. Alfres A. Knopf, Inc., 1986.
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- Gardner, Robert & David Webster. *Shadow Science*. Doubleday & Company, Inc., 1976.

