# How do we see things?

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Subject: Light and Color
Level: 9th grade Conceptual Physics
Standards: NYS MST Standards #1, #4, #7
**Schedule: Three 40-minute periods**

## Objectives:

The objectives of this lesson are to engage students in a self-guided investigation of light; to lead students to justify their conclusions based on their data; and to make them understand the basic principles of light.

## Students will:

- See explanations of two or three competing theories of light
- Carry out a number of mini-experiments involving light, color, and diffraction
- Draw a conclusion as to which theory of light fits their data best
- Present their results and justify their conclusion to the class

## Vocabulary:

Reflection
Diffraction
Color
Light
Color

## Materials:

**For Each Pair:**
There will be four set up around the room. Each station will have a different kind of mini-lab. See attached for descriptions.

Brief summary of stations:
1.) Black Box
2.) Prisms and Diffraction
3.) Mixing Colors with Fans
4.) Color and Filters

## Safety:

1.) Prisms are made of glass and breakable.
2.) The fan has moving parts that might hurt.

## Science Content for the Teacher:

The teacher must be ready to provide explanations and answer questions assuming *several different theories* of light. The teacher also must be aware of logical weak points in he students' arguments (including "Appeals to Authority"; see the *Explain* section below).

This lesson will be more successful if the students understand the properties of waves and phenomena such as reflection and diffraction.

## Preparation:

Each of the four stations must be prepared before class. The preparation necessary is described at the end of the lesson.

If the teacher wishes, students can be provided with a handout describing the different theories of light discussed in class for note taking and reference. This must be prepared by the teacher.

This activity supposes that students do not know the nature of light already! It would be worthwhile for the teacher to know ahead of time what the students think about light. A pre-evaluation should be given so that the teacher can make informed decisions about group designation.

## Classroom Procedure:

***Engage (Time: 10 minutes)***

At the beginning of class, the teacher will present three different theories (or "explanations" or "understandings) of how we see light and the nature of light. Each theory should be given equal weight by the teacher and should be explained using appropriate "scientific language," so that no particular theory is given favor over the others. The three explanations are paraphrased below. In each case, the title is given for the teachers' benefit and should not be provided to the students.

*The Greek Theory (Theory #1)*

Particles of light are generated by the optic nerve in the eye. These particles interact with objects being heated by the sun or other sources, and send a signal back to the eye which interprets them as light.

*The Modern Theory (Theory #2)*

Objects reflect light particles that are generated by a light source. The reflected light enters the eye and creates a signal in the optic nerve for the brain.

*The Emission Theory (Theory #3)*

Particles of energy from the sun heat objects. When objects are heated, they emit a signal that is characteristic of the material. This signal is interpreted by the optic nerve as light.

The teacher should ask students to volunteer to draw a picture of each theory on the board. If possible, this picture (and the descriptions above) should stay posted in the class for the duration of the lesson.

***Explore (Time: 70 minutes)***

The students are presented with their task. Around the room they will find four interactive stations as described above. In their groups of four, they will visit each station, follow the directions they find there, and record their predictions and observations (Activity Sheet 1).

Once they finish they must use their data to determine which theory is most accurate in explaining the behavior of light. They must tabulate their data for and against each theory and choose which theory they think is correct. They then must develop an experiment that will test their theory of light (Activity Sheet 2). If possible, they can carry out their experiment or they can explain it in their presentation described below.

***Explain (Time: 30 minutes)***

Now that they have come to their conclusion the students must present it to the class. Each group will be given three minutes to convince the class of their theory using the data they found in class and any other data in their experience that they find relevant. Once every group has presented their data the class must vote on the most accurate theory.

Students should be encouraged in their presentations and voting to work in favor of "what makes sense" rather than "what's right." Inevitably one or two students will actually research the modern theory of light and find Theory #2 to come closest. You should prevent them from presenting or voting for an "Appeal to Authority" argument (e.g. "We think this is right because Newton/Einstein/Wikipedia says so."). The class theory must coincide with their data – that is the final test of truth for this activity.

***Expand (Time: 10 minutes)***

Once a class theory is agreed upon, the teacher will moderate a discussion about predictions we can make if this theory is true. The teacher should guide students with questions like:

- "What does this theory mean?"
- "How is each part of the theory important?"
- "According to this theory, if we shot a laser at (a screen, the moon, the sun, the ocean floor, my eye, etc.), what would happen?"
- "How does this theory explain a light bulb? A neon light? A rainbow?"

These and other probing questions should expand whatever critical thinking the students were using during the presentations and voting.

When the lesson is complete, the students' should be asked to write journal entries either for homework or in class (time permitting). They should answer one or several of the following prompts:

- "What did you learn in this activity?"
- "What did you like/dislike about this activity?"
- "Are you happy with the class theory of light?"
- "How do you think our development of the class theory was similar to the work of a scientist? How was it different?"

## Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

| | Engage | Explore | Explain | Expand/Synthesis |
|---|---|---|---|---|
| 1 | Notes taken on four different theories; Questions written or asked in class | All investigations completed in a timely manner; Data Sheet and Evidence Sheet filled out completely in full sentences; experiment is well-designed and relevant; creativity and thoroughness is evidenced throughout process | Group presents its theory using all available evidence effectively; stays within time limit; is able to respond to class questions; asks questions of other groups | Students participates in oral discussion; answers 2 or more journal entries sufficiently; displays exceptional creativity in extending class theory |
| 2 | Complete notes of four theories | All investigations completed; Data Sheet and Evidence sheet mostly completed; some blanks in sheets; experiment is relevant | Group presents its theory using some of its evidence; stays close to time limit; is able to respond to class questions | Student answers 2 or more journal entries sufficiently; displays effective attempt in extending class theory |
| 3 | Incomplete notes of four theories | Some investigations completed; Data Sheet and Evidence Sheet incomplete or filled out incorrectly or in sentence fragments; experiment needs improvement | Group uses some evidence that is flawed (Appeal to Authority); goes well over time limit or well under; has difficulty with class questions | Student answers 1 journal entry sufficiently |
| 4 | No notes taken | Few or no investigations completed; Data Sheet and Evidence Sheet blank; No evidence of effort present | Group refuses to present | Student does not participate in discussion or complete journal entries |

## Extension Activities and Supplemental Information:

Students can choose to research the sources of the different theories of light presented at the beginning of the class. For instance, a student could write a summary of the various Greek theories of light and how they contrast with the modern theory of light, or the development of the modern theory of light by Huygens and Newton.

As an extension activity, the teacher can reproduce the pinhole phenomena for the class and ask them to explain it based on their theory. Before doing the experiment, the teacher should ask the students to make predictions of the outcome and to justify their prediction based on their theory. A good online resource for the materials and execution of this experiment is: http://www.exploratorium.edu/IFI/activities/pinholeinquiry/. The link "Pinhole Images – What's Happening Here?" is a good model for class discussion, but the students should come to these conclusions without your assistance.

There is a possibility that at the end of this lesson the students will have developed an inaccurate or incomplete theory of light. It is at the discretion of the teacher how to go about correcting this (or whether to correct it all depending on your dedication to the students' process of inquiry). Some teachers might elect to have the students develop further experiments to test the predictions based on the class' theory. Others might decide to present a lesson describing the development of the theory of light, emphasizing the logic behind each theory and for an advanced class the modern paradox of the wave/particle duality of light.

I would recommend against direct instruction to "correct" the students' "errors," as this might set a precedent of reliance on the teacher as the only source of knowledge. If the students get into this mindset there is a chance that activities like this will lose their impact. Students' will be unmotivated to develop their own ideas and theories if they think the teacher will step in at the end to tell them the current, accepted theory.

## Safety: Students should be careful in their use of prisms and fans.

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- CCMR Staff and Facility managers
- Wikipedia

## Station Setup

| Task | Materials | Before class, the teacher should… | Student Instructions (at the Station) |
|---|---|---|---|
| #1: The Black Box | 2 shoe boxes, scissors, black and yellow paint, paint brushes | 1. Cut a hole in the end of each box<br>2. Paint the interior of one box black and the interior of the other box yellow<br>3. Paint the surface of both boxes black | "What do you see when you look through the hole? When you open the box? Why? |
| #2: Prisms and Diffraction | Overhead projector, prism, deep tray, water, mirror, stiff white paper, (light source) | 1. Fill the tray with water.<br>2. Rest the mirror against the inside.<br>3. Face the mirror so that sunlight (or light from a source) falls onto the mirror. | "1. Turn the projector on and put the prism on the glass. What do you observe? Why?<br>2. Hold the paper in front of the water and move it until you see a spectrum. Why does it appear?" |
| #3: Color Spinners | 2 small fans, construction paper (red, blue, and green), tape, scissors | No prep needed. | "1. Cut out pieces of each color of paper so that you can tape them on to the blades of the fan. What happens when you turn it on?<br>2. Try out combinations. How does it change? Why does it change?" |
| #4: Fun with Filters | Red filter paper, green filter paper, red apple, green apple | No prep needed. | "1. Place the apples together on the table.<br>2. View both through the red filter. What do you notice?<br>3. Repeat with the green filter. What do you notice?" |