Lesson Title: The Science of Light and Photography

Subject	Grade Level	Timeline
Physical Science	5 - 12	60 - 90 minutes

Objectives
This lesson explores some of the ways in which light can be manipulated to create images. Students will manipulate light by building pinhole cameras, and by investigating the effects that lenses and prisms have on light.

Standards

Next Generation Science Standards
Middle School Physical Sciences Storyline
https://www.nextgenscience.org/sites/default/files/MS%20PS%20DCI%20Combined%206.13.13.pdf

Students who demonstrate understanding can:

MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)

Materials

For introduction activity:
- Cyanotype pretreated sheets - commonly sold as “sunprint paper” or “sun sensitive paper”
- Acrylic or overhead transparency sheets
- Stencil (can be made with foil or card stock, or can be thin opaque objects like plant leaves)
- Shallow container to hold water - big enough to rinse the cyanotype pretreated sheets

For pinhole camera:
- Empty cereal box or cardboard ½ gallon drink container
- Wax paper
- Tape
- Pins or thumbtacks
- A dimly lit room with a bright light source (windows, flashlights, or computer screens can work)

For prism exploration:
- Glass or plastic prisms (1 per group)
- Sunlight
- Incandescent lamp or flashlight, fluorescent lamp, LED light (optional)
- Light ray box (This is a light source inside a box, with a slit opening the light can pass through. This can be simulated with a flashlight or lamp blocked by cardboard, with a slit for light to pass through.)

Vocabulary

Cyanotype - a photo printing process that produces monochrome cyan-blue images

Prism - a transparent object with at least two flat surfaces that are at less than right angles to one another

Lesson Plan

Introductory activity:
Use cyanotype paper (sun print paper) to make photographic images. Cyanotype paper can be made in the classroom (see “Resources” below) or it can be purchased where science classroom supplies are sold. In either case, the treated paper should be kept away from light until ready for use. For this activity you will need a flat, opaque object to use as a stencil. In the STEM in 30 video, Marty uses a NASA mission patch, but you could use a shape cut out from card stock, or small items like keys or leaves.

1. Fill a shallow container with water. Be sure the container is big enough to fit a piece of the cyanotype paper in it, because that is exactly what you will need to do in a later step. It is a good idea to bring the container of water outside when you have to take the cyanotype to the sunlight.
2. Somewhere away from sunlight, arrange your stencil or items on top of the cyanotype paper. Direct sunlight will quickly cause the blue paper to develop. Even indirect sunlight will cause it to develop, though more slowly, so be mindful.

3. Place the piece of clear acrylic on top of the stencil or item to hold it in place and to press it against the cyanotype paper. Items that are not held tight against the cyanotype will form images that do not have clear edges.
4. Take the cyanotype paper outside and expose it to direct sunlight for about 2-4 minutes, or indirect sunlight for about 4-8 minutes. The UV in the sunlight will break down the blue dye on the cyanotype, and you will be able to see the color become lighter.
5. Submerge the cyanotype paper in water to halt the dye's interaction with sunlight. Leave the paper in the water for at least a full minute. The water will react with the area the sun has "bleached," while it simultaneously rinses the unexposed cyanotype dye away from the areas that were protected.
6. Leave the paper out on paper towels or another absorbent surface. Once it dries, it will be done reacting and it can be displayed safely.

Ask students if light can change physical objects besides cyanotype paper. If students say yes, ask for examples. Students may have experience with materials that experienced color fading due to exposure to light, especially sunlight. You may even be able to find examples in the classroom. For example, removing items from a corkboard sometimes shows that the covered cork is darker than cork that has been exposed to light.

Explain: Ultraviolet light (UV) has enough energy to damage the bonds in some molecules, including most pigments and dyes. Over time, exposure to UV can "bleach" the color and weaken the molecules in other ways. Paints, photographs, clothing, and many other items will have their color fade over time due to light, especially sunlight.

Student Activities:

1) <u>Pinhole Camera</u>
   - Each student pair will need a box.
   - Use wax paper to completely cover the open end of the box. Use tape to hold it in place.
   - Use a pin or tack to make a single small, clean hole in the box at the opposite end from where the wax paper was taped. For best results, aim for right in the middle - not near an edge - of the side opposite the wax paper.
   - Turn off the lights in the room and point the pinhole side of the box at the light source.
   - Look at the wax paper end of the box. Students should see an image of the light source projected onto the wax paper.

Questions:

- Is the pinhole camera image sharp and clear? Does moving toward or away from the light source change that?
- Do you think making the pinhole a little bigger would make the image better or worse? Give it a try!
- What else do you notice about the image?

2) <u>Prisms</u>

- Each student group will need a prism.
- If you have any of the following light sources available, take turns holding the prism a few inches in front of your eyes and look through it at the light source:
    - Incandescent bulb
    - Fluorescent bulb
    - LED bulb
- Describe the array of colors you see through the prism.
- What color is the light from the bulb if you do not look through the prism?
- <u>Without looking directly at the sun</u>, look through the prism to see how it arrays sunlight into colors. Record how the color order compares to the lamp you looked at.
- Set up the light ray box on a table so the light passes through the slit and forms a “beam” or “ray” of light across the surface of the table. Dim the lights in the room and stand the prism up on its end directly in the path of the light beam. If you turn the prism so the light hits at different angles, you should be able to see a full spectrum of colors.

Explain: A prism separates light into different wavelengths, which our eyes see as different colors. When light enters a material like glass, plastic, water, or even air, each wavelength will have a slightly different amount they turn. They come into the prism as a single beam, but because of the shape of the prism, the light beam spreads out by the time it leaves the prism. This is even true for wavelengths we cannot see - beyond the violet light is a beam of ultraviolet our eye cannot detect. And just past the red is a beam of infrared.

Our eyes can only detect three different colors: red, blue, and green. All other colors that we see are our brain’s interpretation of seeing red, blue, and green in differing amounts. These are the primary colors of optics, which are different from the primary colors of pigments. In the spectrum, notice that yellow is between red and green. If you combine equal amounts of red light and green light, you will see yellow light. Green combines with blue to make cyan, and blue combines with red to make magenta. Again, all other colors are your brain’s interpretation of your eye seeing unequal amounts of red, blue, and green.

If you see an object that normally looks red, it means that the object is reflecting red light to you and absorbing any other colors. This is why red items (like clothing) look different in colored lighting. If there is no red light shining on your red shirt, the shirt has no red light to reflect out to our eyes. This is how different colors of light will make items appear to be different colors, when the item itself isn’t changing at all.

White light from bulbs and the sun are a combination of colors that our eye detects. Sunlight is a full array of colors, as are incandescent bulbs. A fluorescent bulb, however, makes multiple colors that transition less smoothly across the spectrum. As long as the lights are producing red, blue, and green, we normally see it as white light. But items in this light don’t have a full spectrum of colors to reflect, and may look less colorful than if the item was in sunlight.

Extensions

Pinhole camera cyanotype image: Try building a pinhole camera with cyanotype paper instead of wax paper, and pointing it at a scene that has a combination of light and dark areas in sunlight, like a tree against a light colored building or white clouds in a blue sky (without aiming at the sun). If the camera is steady, you can actually make a cyanotype photograph in this way.

Exposure time will vary, depending on the brightness and contrast of the scene, and the size of the pinhole. The best way to get good at this is to try it several times. If you like, you can share your pinhole camera cyanotype images with the STEM-in-30 team via Twitter (https://twitter.com/STEMin30) or Facebook (https://www.facebook.com/STEMin30/) so we can see your results!

Resources

Alternativephotography.com - This lesson shows how to make the chemical solution found in the Sunprint Kit: http://www.alternativephotography.com/cyanotype-classic-process/ Instead of buying sun print paper, your class can make the solution and paper in class with just two chemicals - potassium ferricynanide and green ferric ammonium citrate.

Look up the cyanotype photographs of **Anna Atkins**, the British botanist who published the first ever book that included photographic images.