Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This activity requires two 50-minute blocks. During the first session, pairs of students respond to a series of challenges involving the path of a beam of light from a laser light source to a target. In the second session, students use a pegboard light lab to meet challenges that require them to use the straight path of light, reflect light (and trace its reflected path), change the path of light, absorb light, and draw conclusions about properties of light. In the context of their light lab experiences, students recognize and eventually name properties of light.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- the straight path of light
- light can bounce off of things (be reflected)
- light can change its path going through things, (be refracted)
- light can be absorbed

Students demonstrate this knowledge and understanding by using these properties of light to meet challenges in a pegboard light lab. They also name each property in context.

Correlations to NC Science Standards

4.P.3.2 *Recognize that light travels in a straight line until it strikes an object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.*

Correlations to the Common Core State Standards for Mathematics

Mathematical Practices for Grade 4: reason abstractly and quantitatively, construct viable arguments and critique the reasoning of others, model with mathematics, use appropriate tools strategically, attend to precision, look for and make use of structure.

4. MD Geometric measurement: understand concepts of angle and measure angles.

5. Recognize angles as geometric shapes that are formed wherever two rays share a common endpoint, and understand concepts of angle measurement.

4. G Geometry

3. Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry.

Brief Science Background

When light travels through something transparent such as air or water, it travels in a straight line. However, the path of light can change when it passes from one material to another, such as from air to glass. This change of path is called refraction. When light strikes an opaque object, some light bounces off, or reflects, and some soaks in, or is absorbed. Much of the light striking a dark object is absorbed, and only a little reflects. That is why the object looks dark. Most of the light striking a white object is reflected, and only a little is absorbed. That is why the object looks bright. See the appendix for a more detailed explanation of light's path, refraction, absorption, and reflection.

Part 1 — Light Lab –50 minutes

Materials

Materials for the whole class

- pegboard diagram sheets
- copies of student directions with safety tips for student use of laser lights
- several 1-oz cups of cornstarch
- to project for the class: BLMs 1-7

Materials for groups of 2 students

- pegboard base
- pegboard diagram sheets
- laser light and stand setup
- on dowels: 2 white plastic targets, one piece of clear green plastic (give out a second piece later), 3 mirrors
- on a stick: drinking straw
- a capped 1-oz. cup of water
- a toothpick
- a science notebook

Preparation

1. Pour water into 1-oz. cups for each setup and cap the cups.
2. Fill three 1-oz cups about 3/4 full of cornstarch and place these in a location where you can supervise their use.
3. Have paper towels, sponges, or rags available in case of spills
4. Laser pointers in this kit are Class 3R 5mw diode lasers, wavelength 630 - 680 nm. They are not likely to damage the eye but may cause a few minutes of spots in the field of vision similar to looking into a flash when a picture is taken. Momentary exposure such as from the beam sweeping across someone's eyes poses no danger. However, longer exposures can cause longer lasting symptoms. Always supervise children using laser pointers. Prominently post these rules when students use laser pointers (**BLM 7**):

    - Never look directly into a laser beam.
    - Never point a laser beam at a person.
    - Do not aim the laser at reflective surfaces outside the light lab setup
    - Never view a laser pointer through binoculars or a microscope.

Part 1 (cont.)

The first four steps below are for students to engage with materials and ideas, ask questions, and share what they notice. Avoid teaching content here, even during discussions.

Procedure

1. Briefly demonstrate a laser light source and stand.

2. Give or allow students to get materials listed above under "Materials for groups of 2 students." Let them have just one of the two pieces of green plastic and hold the other one back. Ask students to put the target in the pegboard, set up their laser light source, and hit the target with the beam.

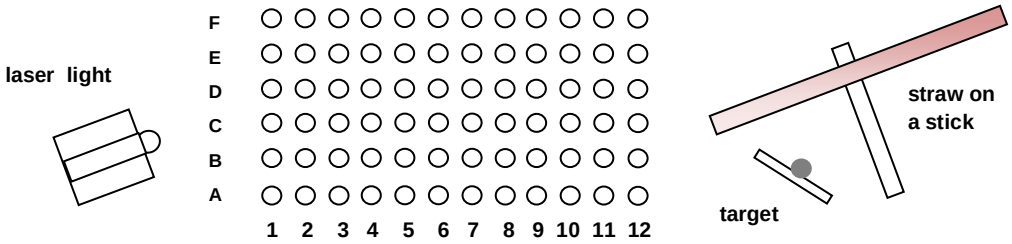
3. Ask students to take 5 minutes to explore things they can do with the light, objects and pegboard. Stress the rule that when turned on, the laser light source must remain in its holder on the desk top.

   Notebook Prompt 1: List things you were able to do with the light, and how you did these things.

4. Lead a brief discussion in which students share the things they were able to do with the light. Students should have a sense that light can do some pretty interesting things! Let them know that the rest of the class is dedicated to exploring some properties of light.

   Get students ideas here, and delay teaching vocabulary and concepts about light until later in this lesson.

5. Challenge all teams to figure out a way to arrange the laser light source, straw, and target shown in BLM 1 so that the light goes through the straw without hitting the straw, and then hits the target. Students must provide evidence that the light is going through the straw in their set up. Students can move the straw, target and laser light source/holder, but must keep the laser light source and holder on the desk top.



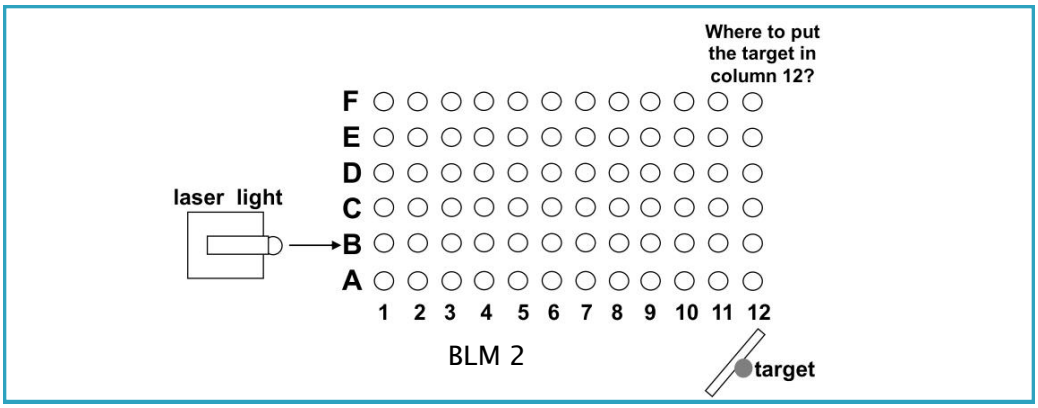
BLM 1

6. Lead a discussion to get students to describe the path of light. How did they know the light went through the straw? Ask what this experiment shows about the path of light. What was the path of the light? How do they

Part 1 (cont.)

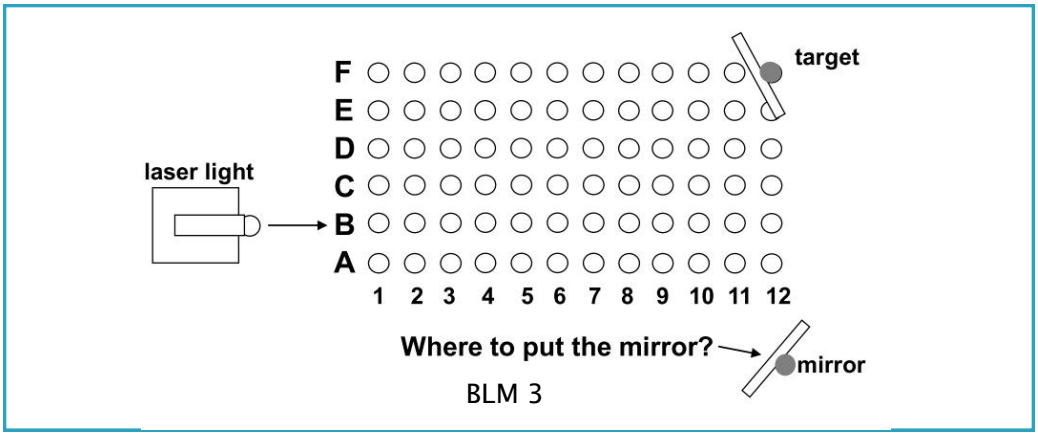
know? At this point, begin to build a written list of properties of light on chart paper, whiteboard, or smartboard. Ask students to also keep this list for themselves in their notebooks. The first property is "light travels in a straight line." **Introduce the term "beam." We call the straight path of light a beam.**

7. Ask students to turn the laser light source off and point it straight across row B as shown in BLM 2. Ask students to leave the light source in position and place the target somewhere in column 12. Challenge them to use what they learned about the path of light to put the target where they think the beam will hit it when they turn on the laser light source. As students say they are ready, let them turn on the laser light sources.



BLM 2

8. Ask students to keep the beam pointed across row B (as-is) and place a target in hole 12F as shown in BLM 3. They can leave the beam on. Challenge them to position a mirror so that the beam hits the target in 12F without moving the laser light source and holder.



BLM 3

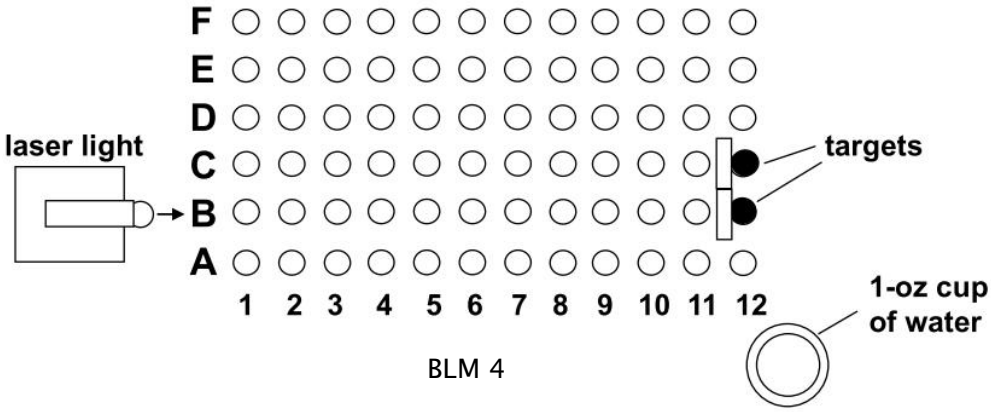
Notebook Prompt 2: Diagram the path of light. Include the laser light source, the mirror, and the target. Describe what you notice about the path of light.

9. Ask students how they are able to see that the beam hit the target. Introduce the term "reflection" to the list of properties of light. **Reflection is light bouncing off of things. A reflected image in a mirror is just one kind of reflection. Most things reflect light in some way, and are visible because they reflect light. Most of the light we see is reflected. The only light that is not reflected comes from sources such as a bulb or the sun.**

Part 1 (cont.)

10. Ask students to position all 3 mirrors so that the beam hits all three, then hits the target in 12F as shown in BLM 3.

11. Ask students to put one target each at 12B and 12C, and point the laser light source to hit the target in 12B, as shown in BLM 4. Challenge them to, without moving the laser light source, place the cup of water so that the beam goes through the cup and hits the target in 12C. After they hit the target at 12C, ask them to record what they did to get the light to hit this target instead of the target at 12B.



BLM 4

12. Have several open 1-oz cups of cornstarch where you can supervise their use. Ask one member from each team to bring a toothpick, dip it a half inch into the cornstarch, and carefully return the cornstarch-tipped toothpick to their station. At their station, the partner will remove the cap from the 1-oz cup of water and the student with the toothpick can stir it in the water. With the cap off, have teams shine the beam through the slightly cloudy water to hit the target in 12C. Ask them to look down into the cup from directly above to see the beam change direction through the water.

Notebook Prompt 3: Draw a diagram showing the path of light through the cup to the target. Include the laser light source, cup, and both targets in your drawing.

Hold a brief discussion in which students describe what they notice about the path of light through the cup to the target.

After discussion, add "refraction" to the list of properties of light. Students should write the definition in their notebooks. Refraction is a change in the path of light when light goes through two or more different transparent materials, such as water and air. The path of light changes where the materials meet. For example, light enters a person's eye through a lens, changes direction once as it crosses from air into the lens, and again when it crosses from the lens into the fluid in the eye. The lens shape causes most of the light to hit sensors at the back of the eye, where an image forms. Glasses, telescopes, microscopes, and cameras all refract light using lenses.

13. Ask students to position the beam to shine through a piece of green plastic in the board and hit a target in the board. Ask them to move the green plastic in and out of the beam, look at the light on the target, and talk about what they notice.

Part 1 (cont.)

Notebook Prompt 4: Describe what you notice about differences in the light on the target when the beam is going through the plastic and when the beam is not going through the plastic. Explain what you think is happening. Predict what you think will happen when two pieces of green plastic are between the laser light source and the target.

14. Lead a brief discussion of students' observations and questions. Ask students to again set up the laser light source and green plastic as in the previous step. Give out a second piece of green plastic and ask them to move it in and out of the beam anywhere between the laser light source and the target. Ask them what they think is happening to the light.

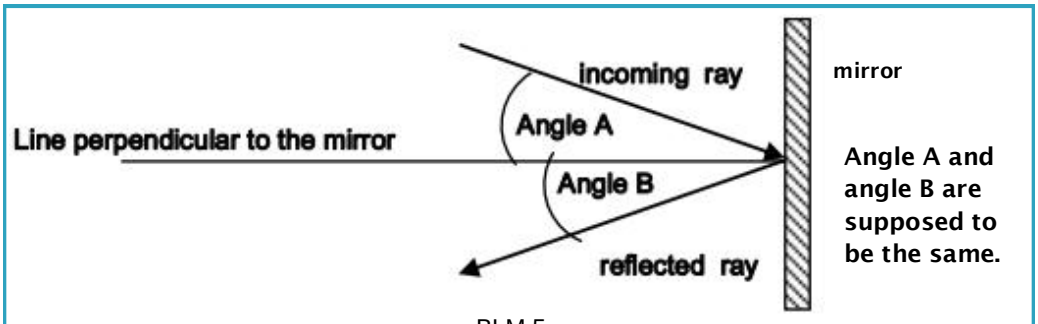
Define "absorption," add it to the list of properties of light, and ask students to record it in their notebooks. When light strikes an object, some light is reflected or passes through the object. However, some light seems to disappear, or be soaked up. This light does not go away, but changes to other forms of energy that are not visible, such as heat. For example, on a sunny day, a brick wall reflects some of the light from the sun and also absorbs some of it. The absorbed light turns to heat and warms the wall.

Some students might expect the laser beam to turn green after passing through the plastic. The beam would turn green if it were white. White light includes all colors. The plastic absorbs most (but not all) light that is not green, letting green pass through. However, the laser's pure red light contains no other colors, including green, so that any laser light that passes through the green plastic is still red. After the beam passes through the green plastic, much of the red is absorbed, and the beam hitting the target is dimmer than it was.

Part 2 — Light Lab (50 minutes)

MATH INTEGRATION

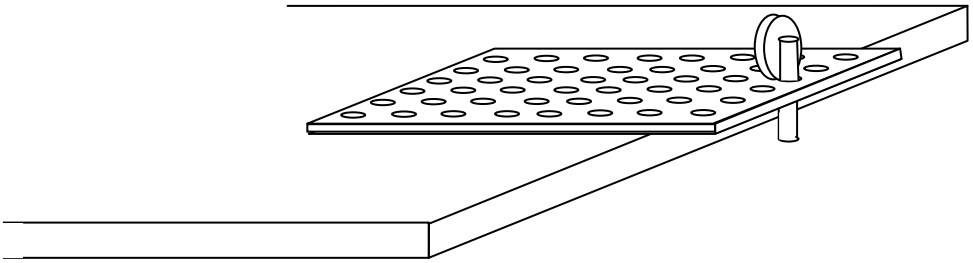
Explain to students that a flat shiny surface like a mirror reflects light according a basic law. The law says that if you make a line perpendicular to the surface where a ray hits, the incoming and reflected rays will always make the same angle with that line, as in BLM 5.



BLM 5

Part 2 (cont.)

Does this law describe what really happens? Challenge students to use materials from the activity (e.g. laser , pegboard, mirror, etc.) to test whether this is true . **There are many ways to do this by shining a beam to just skim a piece of paper. To reflect a beam that skims the paper, the mirror must touch the paper. To do this, hang the last row of pegboard holes over the table edge and push the mirror post all the way through, as shown. To draw a perpendicular to an edge of the paper, use any square corner. Place the paper under the mirror with the perpendicular centered on the mirror and the mirror aligned exactly with the paper edge. To track the incoming and reflected rays, lay paper on the pegboard and adjust its height (with something underneath) so that, with the laser flat on the tabletop, the beam skims the paper and strikes the mirror. Use a pencil to mark dots along the beam and connect the dots with a straight edge. To show the angles are equal, fold the paper along the perpendicular and look through the page in bright light to see whether the A and B lines align. If they do, the angles are equal.**

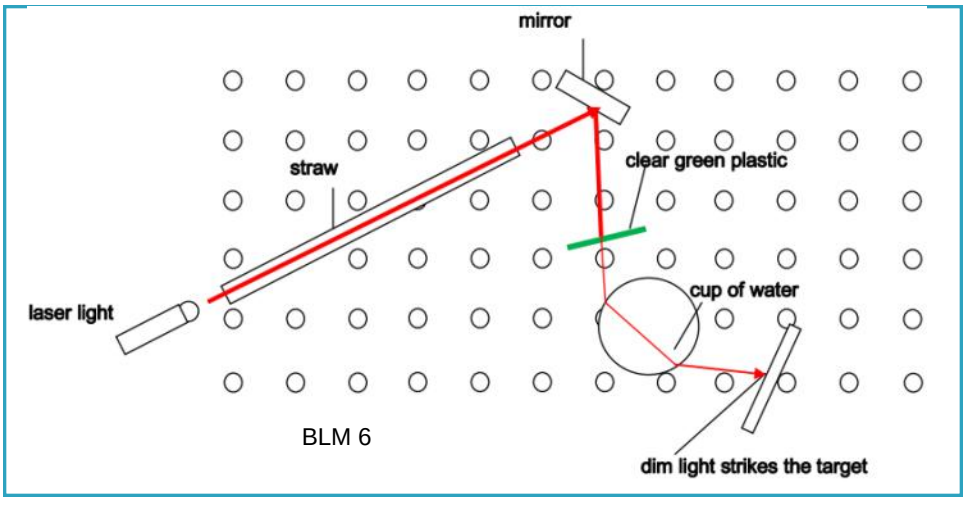


Guided Practice – 20 minutes

Guided Practices are similar to tests, but require students to reveal their thinking. They are ungraded, and intended to expose misconceptions *before* assessment to promote discussion, and guide re-teaching. Pose the following "test items" to the class and ask them to respond in their notebooks.

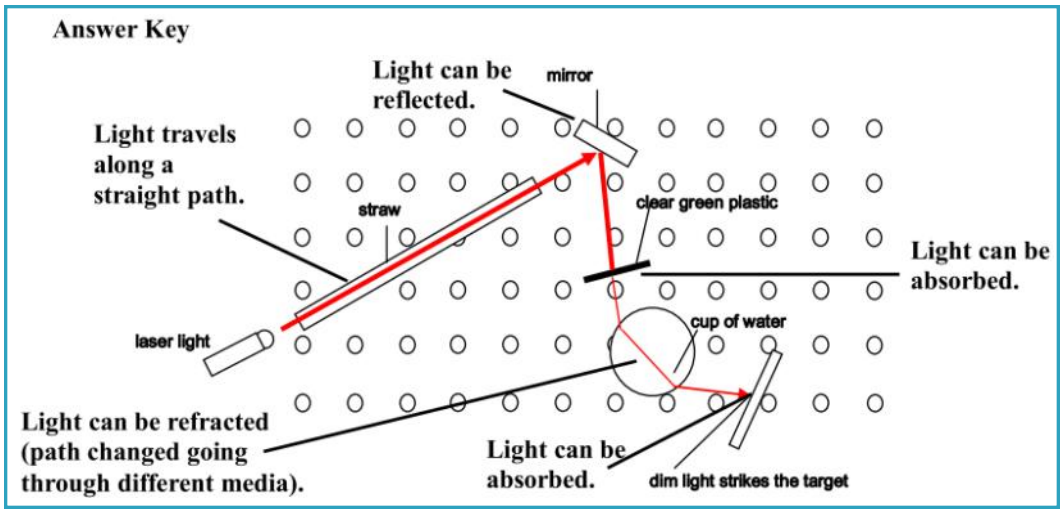
1. Label the diagram (see Blackline Masters diagram 6) at one or more places where you see one of the following properties of light demonstrated:

   - Light travels along a straight path.
   - Light can be reflected.
   - Light can be refracted (its path changed).
   - Light can be absorbed.



BLM 6

Part 2 (cont.)



2. Name the properties of light that apply to the following situations:

a. A car's headlights shine straight ahead.
b. Grass is green.
c. When you wear sunglasses, everything looks darker.
d. Some people need to wear eyeglasses in order to see well.
e. We can see ourselves when we look in a mirror.
f. Glitter looks shiny.
g. If you shine a flashlight in a dark room, the only things you can see clearly are those the flashlight points at.

Answer key

a. light travels in a straight line
b. b. reflection and absorption
c. absorption
d. refraction
e. reflection
f. reflection
g. light travels in a straight line

3. Read the scenarios below and respond in writing with your own opinions about the ideas expressed in each.

a. Some friends were going skiing over the weekend, and they met to plan their trip. One of the students, Annie, said, "Don't forget to bring sunscreen for your face." But Elliot said, "That's silly. You only need sunscreen in the summer."

Part 2 (cont.)

"Annie is right," Jamal said. The snow will reflect the sun's light, and we'll be outside all day." Then Tori responded, "It might reflect a little bit of light, but snow is white so it will absorb most of it. That means we don't really need sunscreen."

b. After doing the same light activities that you did, some students asked their teacher to borrow a hand lens. When the teacher asked why, they answered that they thought they could change the light's path with it because the light would be refracted when it passed through the lens.

Answer key

a. Annie and Jamal are correct. Their faces will be exposed to sunlight both from above and from below, where light is reflected up from snow on the ground. Tori is not correct, because white surfaces reflect light well. The dark colored surfaces absorb more light.

b. The students' idea is a good one. Lenses are used to refract light for useful purposes, so with some experimenting they will be able to change the path of the laser's beam.

Wrap-Up – 10 minutes

Challenge students to use any materials from the activity to set up a system that shows examples of four things they learned about properties of light:

- Light travels in a straight line
- Reflection
- Refraction
- Absorption

Notebook Prompt 5: Diagram your setup, including the path of light through it. Label where each property of light is demonstrated. For each label, explain how you know what the light is doing at that point.

After students write, review the four properties of light.

Answer Key

- Path of light – as long as light travels in the same medium (such as air at the same temperature) it travels in a straight line.
- Refraction – when a light beam travels through different substances, such as air and water, its path changes direction as it goes from one substance to the other. This change of path is called refraction.
- Reflection – We see things either because they give off light (such as a light bulb or a flame) or because light from some other source (such as the sun or a light bulb) is bouncing (reflecting) off of them. For example, when we look at a person across the room, we see the light they reflect.
- Absorption – When light strikes things, or in the case of transparent things, goes through them, some of the light is usually absorbed. When the laser light goes through clear green plastic, some of the light passes through but some of it is absorbed.

Part 2 (cont.)

Lead a brief discussion and question session about the ways we experience the properties of light in our everyday lives, such as:

a. We wear sunglasses to protect our eyes when it is very bright outside, because the dark plastic lenses absorb a lot of the intense light before it hits our eyes.

b. The combination of absorption and reflection allows us to see different colors. An orange ball is orange because the material its surface is made of reflects only orange light and absorbs all other colors.

c. If objects reflect light, why don't we see ourselves when we look at them, like we do with a mirror? Most things absorb some of the light they reflect, so we do not see our own images reflected in their surfaces like we do with a mirror. If you hold a basketball in front of your face, you see the surface of the ball instead of your own reflection. Shiny, smooth surfaces, like most metals, reflect more light than dull, textured surfaces, like a basketball or a carpet.

d. Which property of light causes a hand lens (magnifying glass) to make objects look bigger? Refraction causes the light passing though the lens to change direction. The curved shape of the lens makes the light bend in a way that makes objects look bigger.

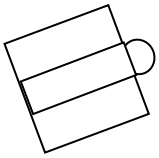
e. Dark colors absorb more light and light colors reflect more light. That's why it's easier to see white objects at night than dark ones. It's also why dark clothing feels hotter on a warm, sunny day than light-colored clothing. Dark clothing absorbs more sunlight than light-colored clothing, and a lot of the light's energy turns into heat in the dark clothing.

f. Why is it especially important to wear sunscreen at the beach, or on a boat in a lake? Sunlight can reflect off the surface of the water and hit our skin, along with the sunlight that's already hitting our skin from above. At the beach, sunlight can also reflect off the sand.

g. Shadows are evidence that light travels in a straight line and that light is absorbed or reflected by solid objects. Light can't flow around a solid object. The dark shadows we see are the absence of light on the opposite side of an object from the light source.

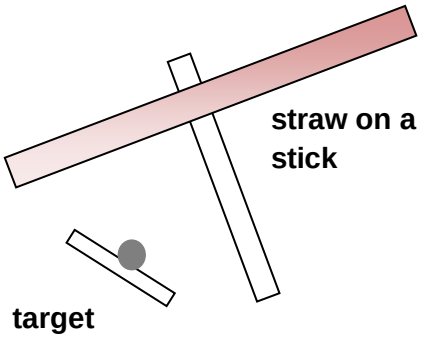
BLM 1

laser light

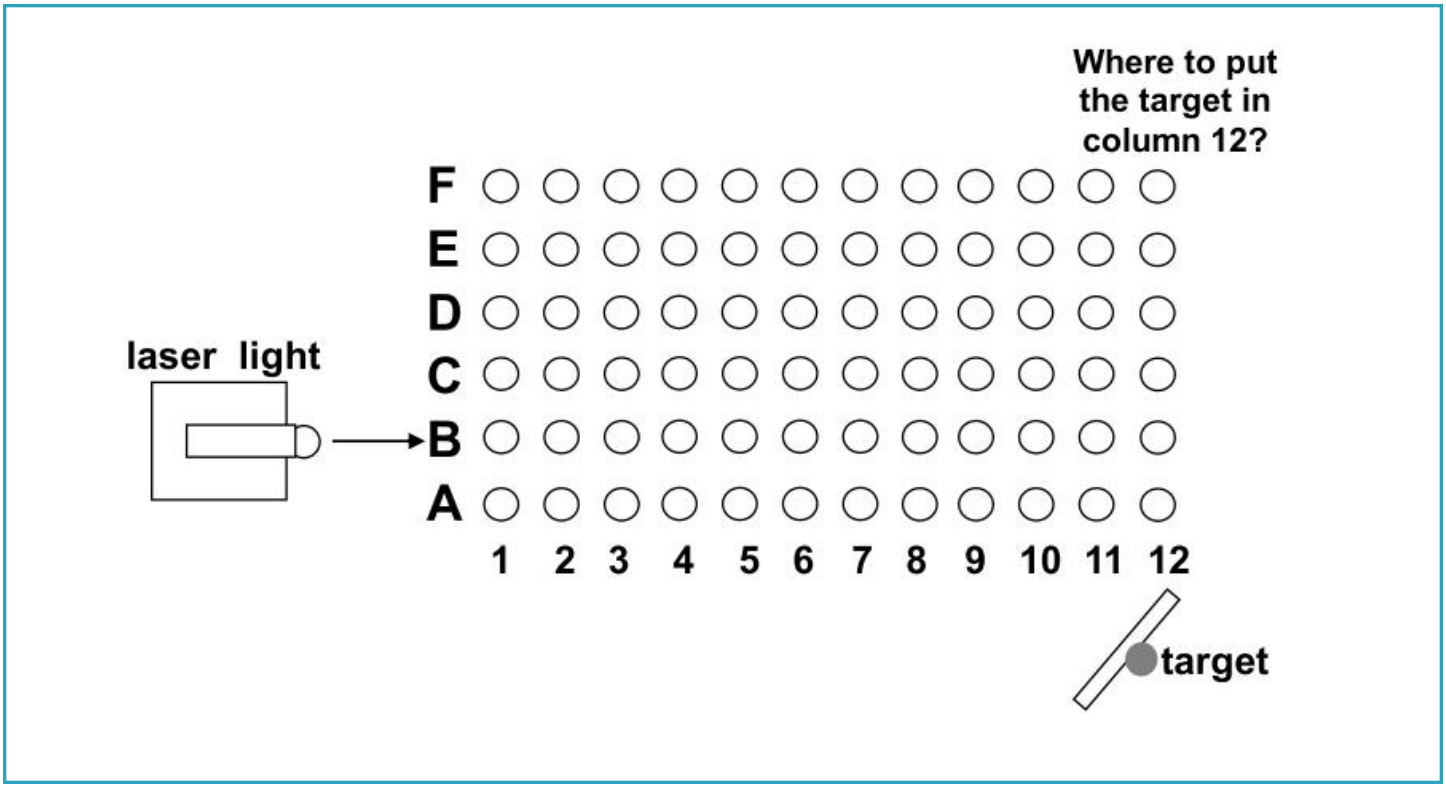


F
E
D
C
B
A

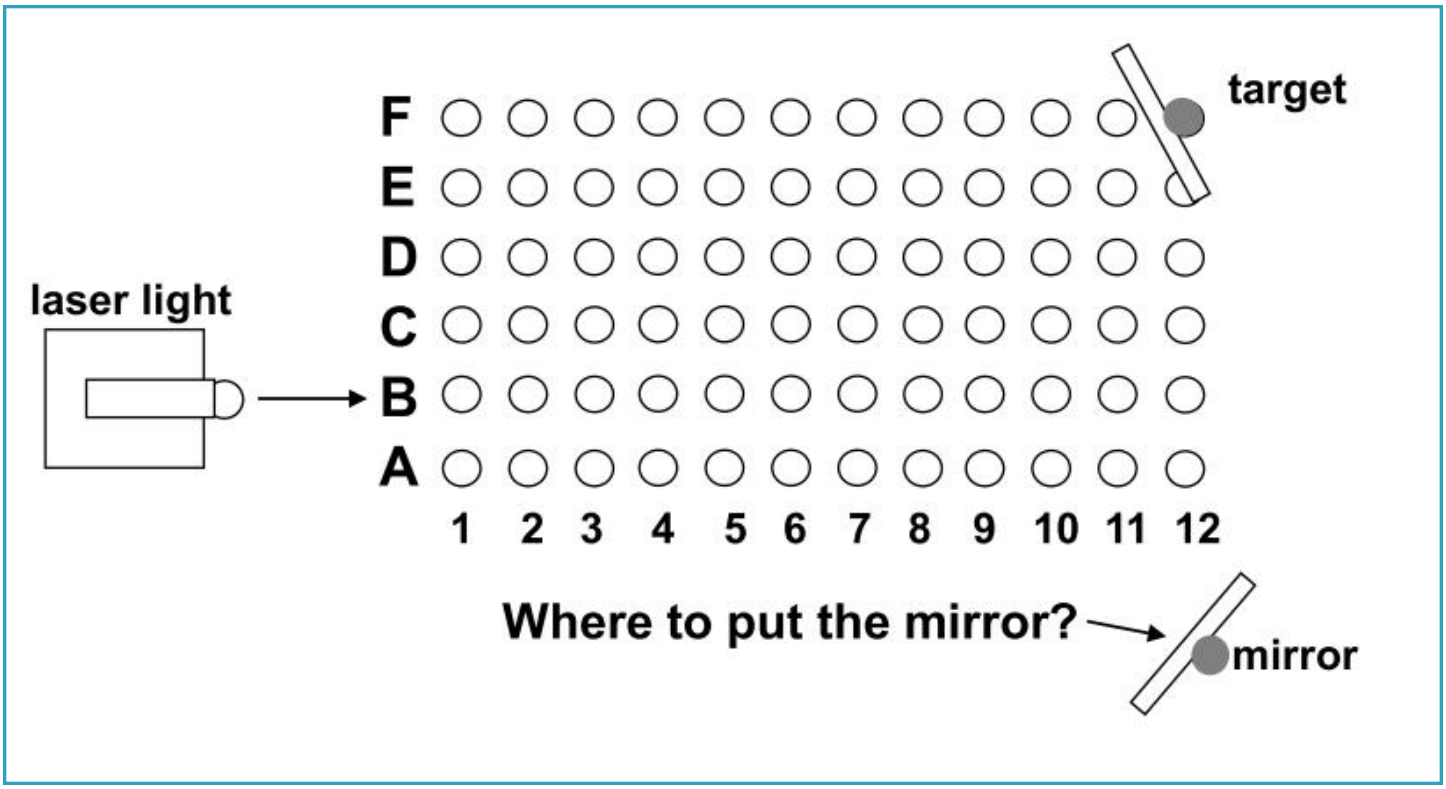
1 2 3 4 5 6 7 8 9 10 11 12



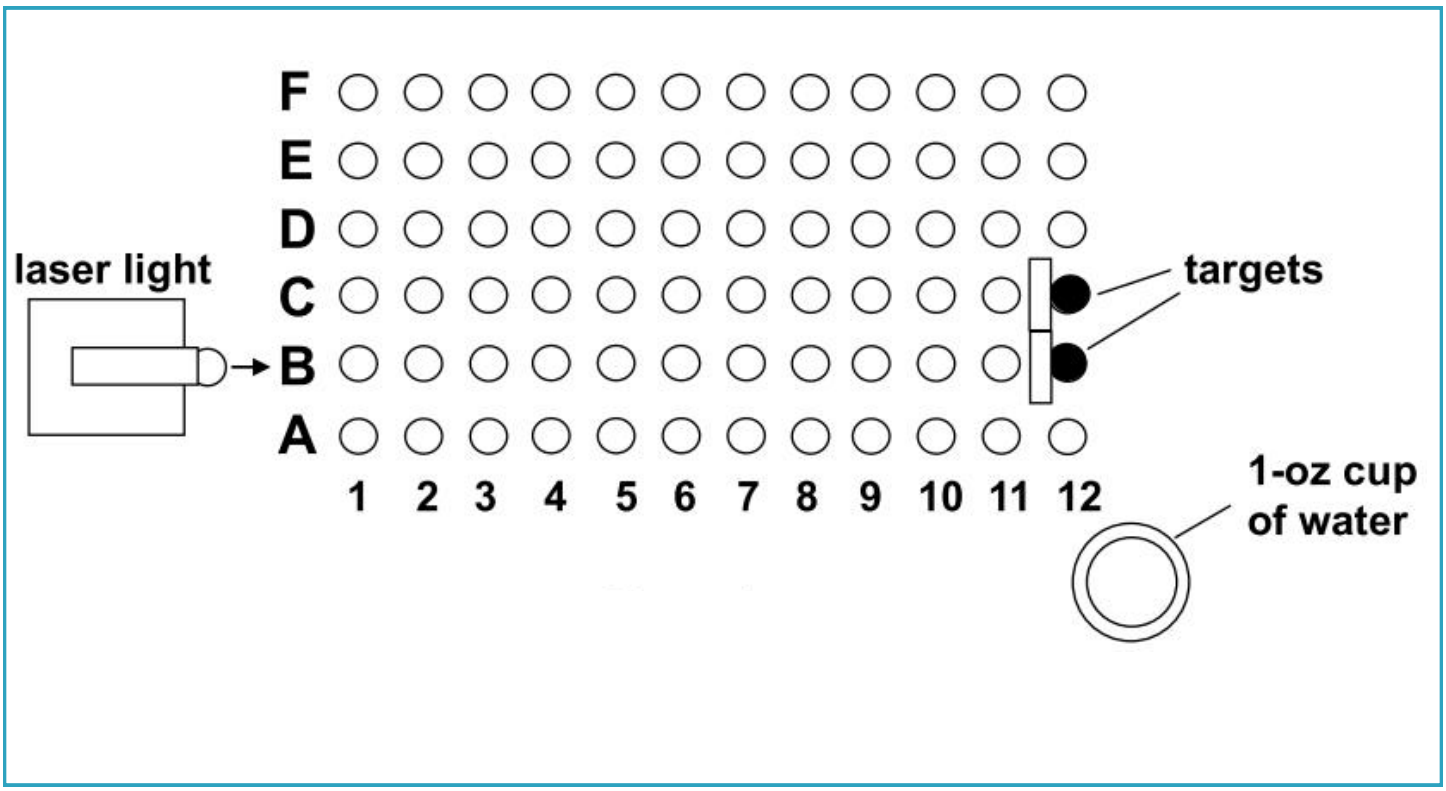
BLM 2


Where to put the target in column 12?
F
E
D
C
B
A
laser light
1 2 3 4 5 6 7 8 9 10 11 12
target

BLM 3


target
F
E
D
C
B
A
laser light
1 2 3 4 5 6 7 8 9 10 11 12
Where to put the mirror?
mirror

BLM 4


F
E
D
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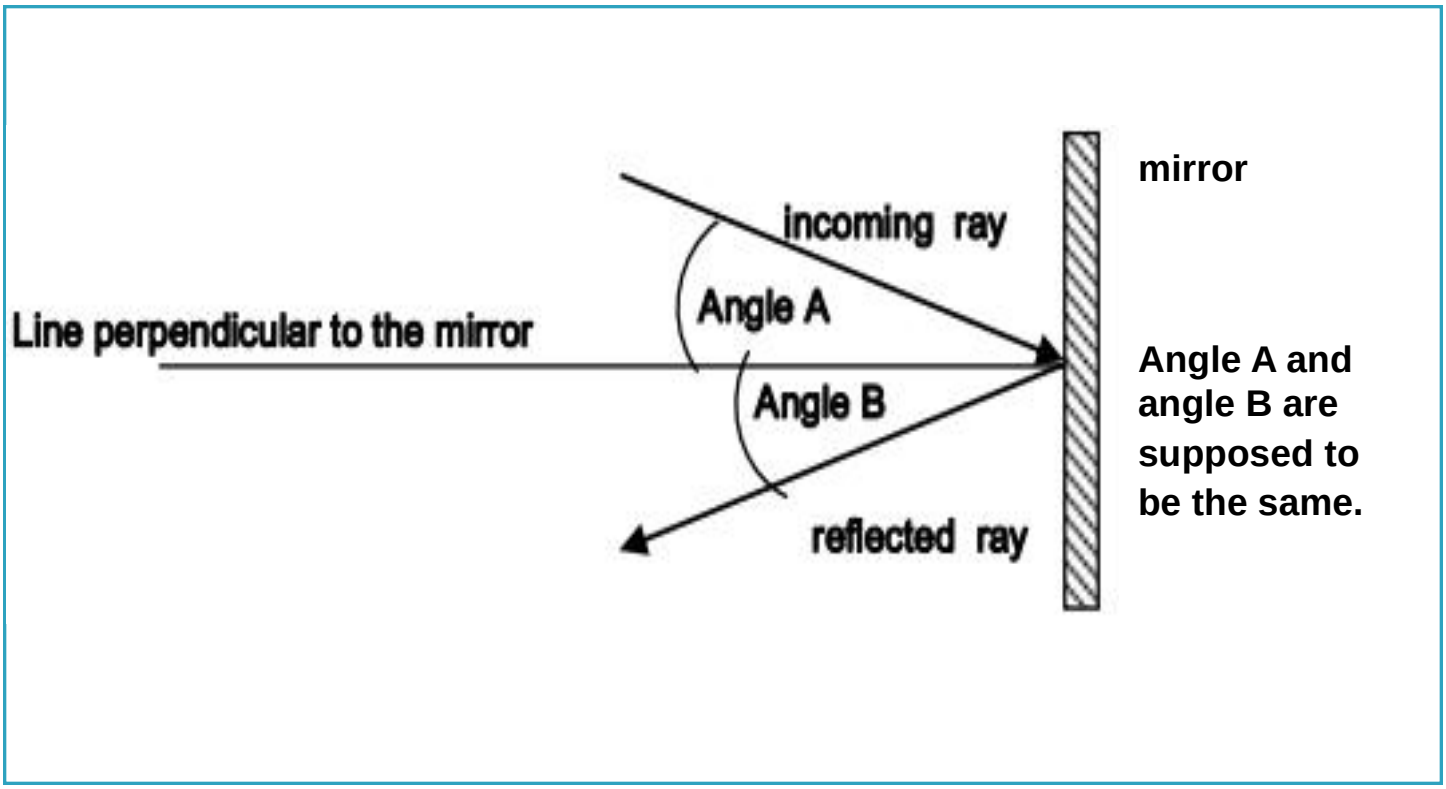
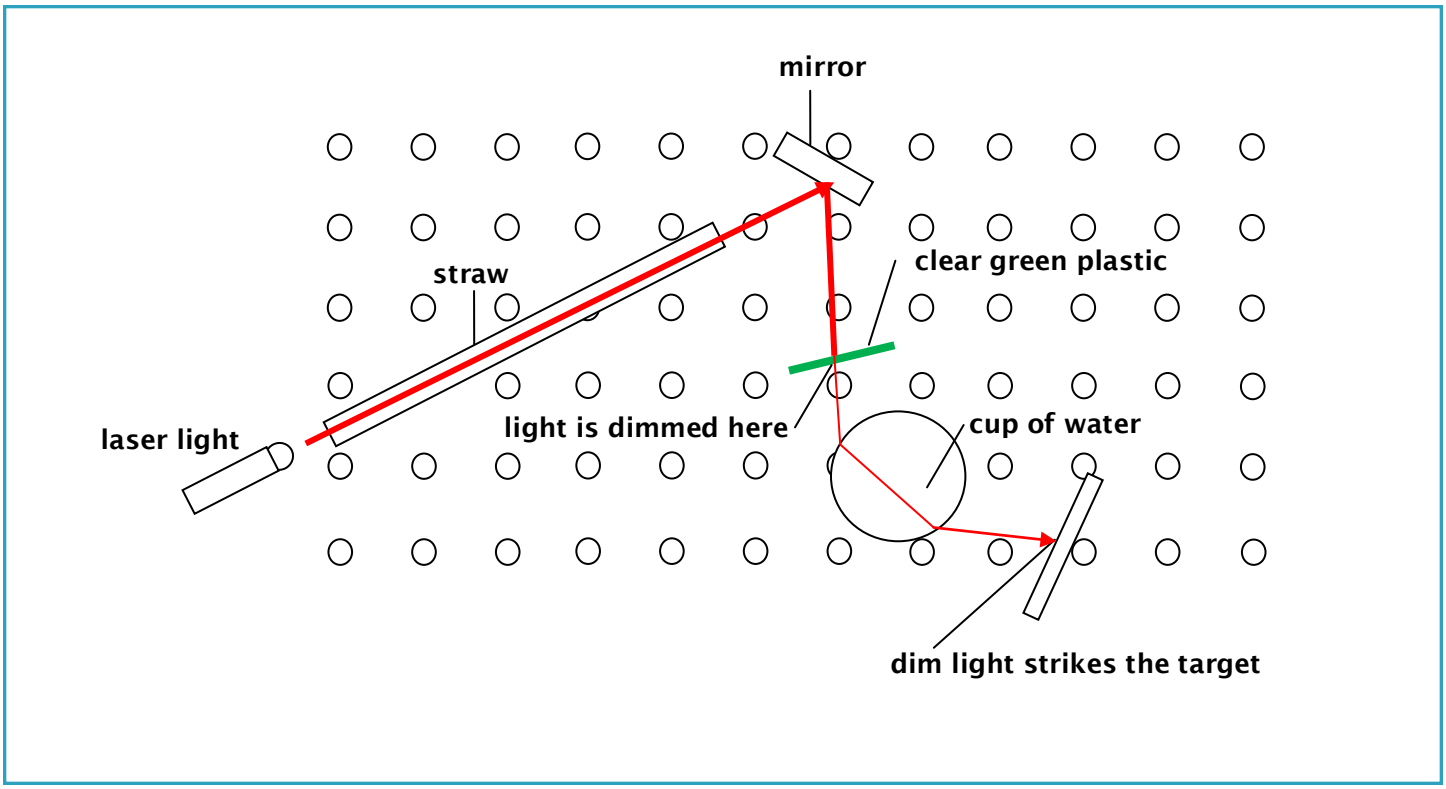
B
A
1 2 3 4 5 6 7 8 9 10 11 12
laser light
targets
1-oz cup
of water

BLM 5


mirror
incoming ray
Angle A
Line perpendicular to the mirror
Angle B
reflected ray
Angle A and angle B are supposed to be the same.

BLM 6


mirror
straw
clear green plastic
laser light
light is dimmed here
cup of water
dim light strikes the target

BLM 7

LASER POINTER SAFETY RULES

- Never look directly into a laser beam.
- Never point a laser beam at a person.
- Do not aim the laser at anything outside the light lab setup
- Never view a laser pointer through binoculars or a microscope.

Appendix

Common Student Preconceptions About This Topic

Children tend to think of light as a source or an effect, but not as something traveling through space. (From Driver, *Making Sense of Secondary Science*) "…Most 10-11-year-old children conceive of light as a source (such as an electric bulb), an effect (such as a patch of light) or a state (such as brightness). Children of this age rarely recognize light as a physical entity existing in space between the source and the effect that it produced…the fact that the path light takes is not directly visible presents special difficulties for children."

Background on Light's Path, Refraction, Absorption, and Reflection

Light travels in a straight line under what we consider to be normal circumstances, meaning through air or water. Light also travels in a straight line through a vacuum, which is not a normal circumstance for us, but is what occurs in outer space and allows light from the sun to reach the Earth.

However, light's straight-line path changes when it passes from one transparent medium to another, such as from air to water, or from air that is at one temperature to air at another temperature. This alteration in light's path is known as refraction. A common example of refraction due to a changing medium is the way a drinking straw in a glass of water looks when viewed from the side: the straw appears to be cut at the water's surface, with the submerged part shifted sideways compared to the part above the water. An example of refraction due to temperature changes is the way air appears to shimmer above a roadway's dark pavement on a hot, sunny day. The solid pavement, which absorbs the sun's heat and light energy, is very hot, and it heats the air just above it. A few feet up, however, the air is cooler, and so from a distance we can see the shimmering effect of refraction.

Reflection is another property of light, and it occurs because light can bounce off surfaces it encounters. This property of light is similar to the way a ball bounces when dropped on the floor. If light strikes a surface at right angles to its path, it will bounce back along the same path it originated from, just like a ball dropped to the floor will bounce up vertically. However, when light strikes a surface at an angle, it bounces off at the same angle but in the opposite direction, just as a ball thrown to the floor from an angle will bounce away at the same angle. This is why it is so easy to get sunburned at the beach. Not only does sunlight reach our exposed skin from the sky above, but it also reaches us by bouncing up to us from the light-colored sand and the ocean water's surface.

The most common example of reflection occurs with a mirror, which is a clear piece of glass backed by a flat, shiny surface. Other smooth and shiny surfaces are also good light reflectors, such as polished metal or water. Students may have seen their reflections in a lake or pond's surface if the

Appendix (continued)

water is smooth and relatively clean. They might also have seen bright spots of light reflected off car windshields while riding to school. However, in all of these examples not all of the light that hits these surfaces is reflected. Instead, some of the light is absorbed. In the case of a mirror, nearly all of the light is reflected and very little is absorbed. Similarly, when light strikes white or light-colored surfaces, more of the light is reflected than is absorbed. On the other hand, when light strikes dark objects, more light is absorbed than is reflected.

Absorption, therefore, is another property of light. Since light is a form of energy, what happens when light strikes a dark surface is that much of its energy is converted to heat or other invisible forms of energy (for example, ultraviolet or infrared light). That is why dark clothing, which absorbs more light than it reflects, feels hot on a sunny day.

Reflection and absorption are what allow us to perceive colors. This is because "normal" light is known as white light. White light is the product of all the colors of the visible spectrum (red, orange, yellow, green, blue, indigo and violet) blended together. When white light strikes an object, some of the colors that make up the light are reflected and some are absorbed. Different objects reflect and absorb different colors in different proportions, and what we see are the colors that are reflected and not the ones that are absorbed. The paint on a yellow pencil, for example, reflects yellow light and absorbs other colors. Similarly, if you look through blue-colored plastic food wrap, everything you see has a blue tint to it, because blue light passes through the plastic while most of the other colors are absorbed.

Laser Pointer Safety

Laser pointers in this kit are Class 3R 5mw diode lasers, wavelength 630 - 680 nm. These laser pointers are not likely to cause permanent retinal damage but may cause a few minutes of spots in the field of vision and flashblindness similar to looking directly at a flash when a picture is taken. Momentary exposure to a laser pointer, such as might occur from an inadvertent sweep of the beam across a person's eyes, poses no danger. However, longer exposures can cause longer lasting symptoms.

Always supervise children using laser pointers. You may wish to post these rules when students use laser pointers:

- Never look directly into the laser beam.
- Never point a laser beam at a person.
- Do not aim the laser at reflective surfaces outside the light lab setup
- Never view a laser pointer through binoculars or a microscope.