LESSON 2: Reflection of Light

Purpose and Key Question

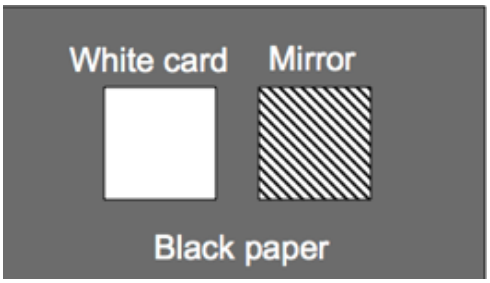
In the *Waves and Sound* unit you learned that water waves can reflect from barriers. Although we did not discuss it, sound waves can also reflect from surfaces like the walls in a room, or from mountains, giving rise to *echoes*. Since light is also a form of wave motion, it is not surprising that light can also reflect from surfaces, both shiny (like mirrors) and non-shiny (like paper). In this lesson you will investigate ***how*** light reflects from these surfaces, and how reflection from shiny surfaces gives rise to mirror images.

1. ***How does light reflect from shiny and non-shiny surfaces?***
2. ***How do you see an image in a flat mirror?***

Predictions, Observations and Making Sense

Part 1: What do you see?

Consider a small mirror and white card sitting on a black piece of paper, as shown to the right. Imagine the black paper was placed in the center of a table. Two students stand at opposite ends of the table.



The lights are turned off in the room. One student turns on a flashlight and aims it at the mirror and card, as shown in the following picture. Watch the movie **(UL L2 Mov1)** to see what the setup looks like.

Now consider what each of the two people would see when the flashlight person shines the light on the card and mirror. Assume all other lights are turned off.

CQ 2-1: What will the flashlight person see?

A. The mirror will be bright and shiny and the white card will be bright white.
B. The mirror and white card will both appear dark.
C. The mirror will be bright and shiny, but the white card will appear dark.
D. The mirror will appear dark, but the white card will appear bright white.

Why do you think so?

CQ 2-2: What will the opposite person see?

A. The mirror will be bright and shiny and the white card will be bright white.
B. The mirror and white card will both appear dark.
C. The mirror will be bright and shiny, but the white card will appear dark.
D. The mirror will appear dark, but the white card will appear bright white.

Why do you think so?

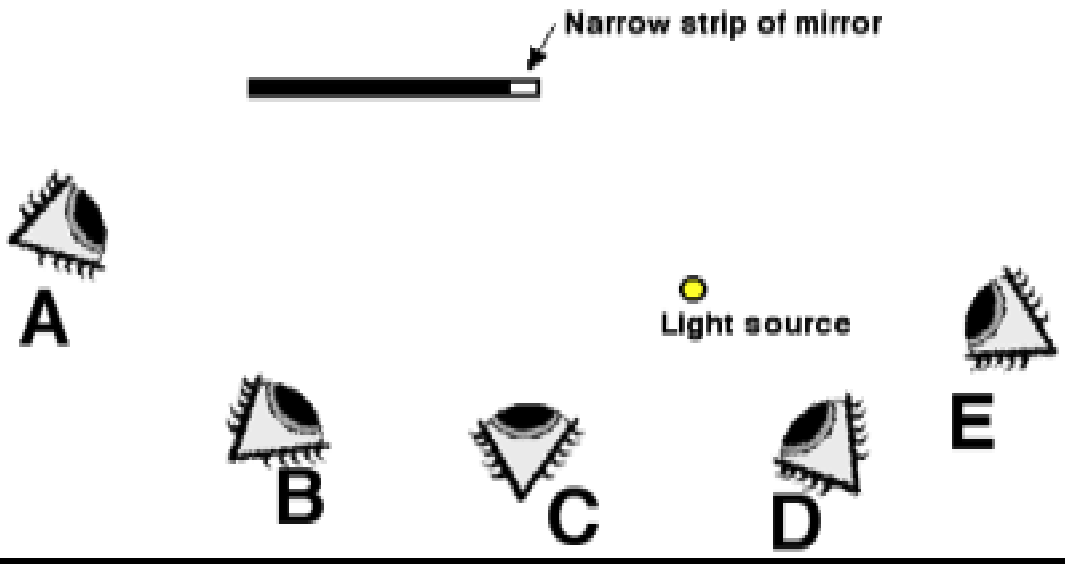
To check your predictions, watch the movie **(UL L2 Mov2)** to find out what is actually seen from the two positions. Discuss the results with your team.

To understand what happened in the movie, we need to investigate what happens to light when it is striking both a flat, shiny surface (mirror) and a smooth, non-shiny, white surface (white card).

Part 2: Reflection of light from a flat, shiny surface (mirror)

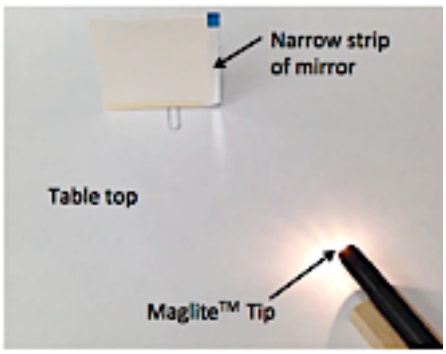
Suppose you had a small, flat mirror and covered up all of it except for a narrow strip. Imagine that you put a point source (tip of Maglite™) on the table as shown below in the **top view** diagram.

CQ 2-3: From which one of the positions do you think you would be able to see the image of the light source in the narrow strip of mirror?



Explain your reasoning.

To check your idea, watch the movie **UL L2 Mov3,** showing what happens when a Maglite™ is moved along a table top. You can observe the narrow strip of mirror from all the positions in the above diagram.

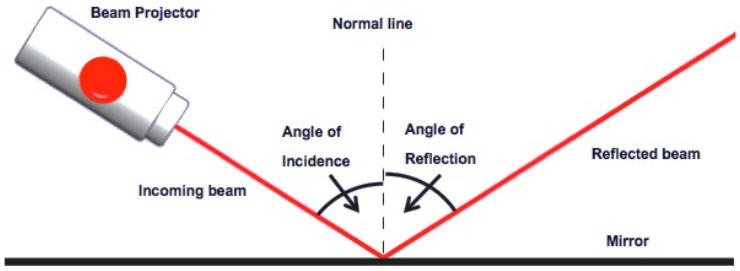


From which of the positions can you see an image of the light source **when looking at the strip of mirror**? Why do you think this is?

In order to 'see' the image of an object in a mirror, light from the object that reflects from the mirror must come into your eye. That raises the question, how does light reflect from a mirror?

Do you think there is any particular rule for how light reflects from a shiny surface, and, if so, what do you think it is?

In a moment you will check your thinking by watching a movie of a simulation. The setup, shown on the next page, is one in which a narrow beam of light (red line) is aimed toward a mirror and reflects from it. (The narrow beam effectively shows us how a single light ray behaves.)



Before you watch the movie, we need to define some terms.

Normal line: This is a line drawn perpendicular (at right angles) to the mirror at the point where the light beam strikes the surface of the mirror. (It is the dashed line in the picture above, which is vertical only because the mirror surface is horizontal. In general, the normal line can be drawn in any direction, depending on the orientation of the mirror surface.)

Angle of Incidence: This is the angle between the incoming beam (the 'incident' beam) and the normal line.

Angle of Reflection (shown with a question mark above): This is the angle between the normal line and the reflected light beam.

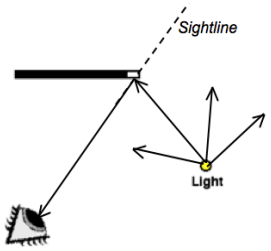
Watch the movie **UL L2 Mov4** from the PhET 'Bending Light' simulation.[1] In the movie, the angle of incidence of the incoming beam is changed. A protractor is included so that you can observe the angles of incidence and reflection, and see how they compare.

For all cases, how does the angle of reflection compare to the angle of incidence?

[1] You can run and download the simulation at http://phet.colorado.edu/en/simulation/bending-light. However, this simulation does not provide a mirror. Instead, the simulation shows what happens when a light beam strikes the smooth surface of a transparent material. Some light always reflects from such a surface, and that is what is shown in the movie.

A statement of how light behaves when it strikes a shiny surface like a mirror is called the **Law of Reflection**. When drawing light ray diagrams involving a mirror, you should always draw the reflected light ray so that the angle of reflection (approximately) equals the angle of incidence.
If light from an object strikes a mirror and then enters your eye, you will see the image of the object in the mirror. When the light enters the eye, your eye-brain system determines where the reflected light 'seems' to have come from, and it is in this direction that the eye 'sees' the image of the object. To determine which direction this is, we extend a light ray entering the eye backwards behind the mirror. This backward extended line is called a *sightline*.

For example, in the diagram to the right, many light rays leave the source, only one of which reflects from the small strip of mirror into the eye. Since the light entering the eye comes directly from the small strip of mirror, the eye-brain system 'sees' the image of the light in the direction of the dashed sightline shown by extending the light ray back behind the mirror.



However, if your eye is positioned so that no light from the object reflecting from the mirror can enter your eye, then you will not see its image in the mirror. Furthermore, if there is no light from any other nearby objects that can reflect off the mirror and enter your eye, the mirror surface should then appear very dark (black) when you look at it.

Part 3: What happens when light strikes a white, non-shiny surface?

Most objects are not shiny, like mirrors, but instead are non-shiny. For example, consider a white card.

CQ 2-4: What do you think happens when light strikes a white card?

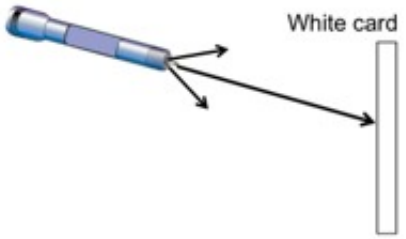
A. Light reflects from white card in one direction, the same way that it reflects from a mirror.
B. Light reflects from the white card in many directions, quite different from the way it reflects from a mirror.
C. Light does not actually reflect from the white card; it just spreads out on the card and illuminates it.

To check your idea, watch the movie **UL L2 Mov5** that will provide evidence supporting one of these answers. In the movie, light from a flashlight is aimed in the direction of a white card. A second white card sits alongside the flashlight. The only way the second white card can be illuminated is if light striking the first card is actually reflected in all directions, and some of that reflected light strikes the second card. To see if this actually happens, the first white card is alternately lifted up out of the light beam and then put back down. Watching what then happens to the second card should enable you to draw a conclusion.

What happens to the second card when the first card is illuminated by light from the flashlight?

What can you conclude after watching the video? Which of the three responses to CQ 2-4 does the evidence support?

Below is part of a light ray diagram representing light from a Maglite™ striking a white card. Complete the diagram by showing what happens to the light after striking the white card.



Your instructor will review the diagram with the class.

Summarizing Questions

S1. Consider the two clicker questions asked at the beginning of this lesson, CQ 2-1 and 2-2. You should now be able to explain what happened.

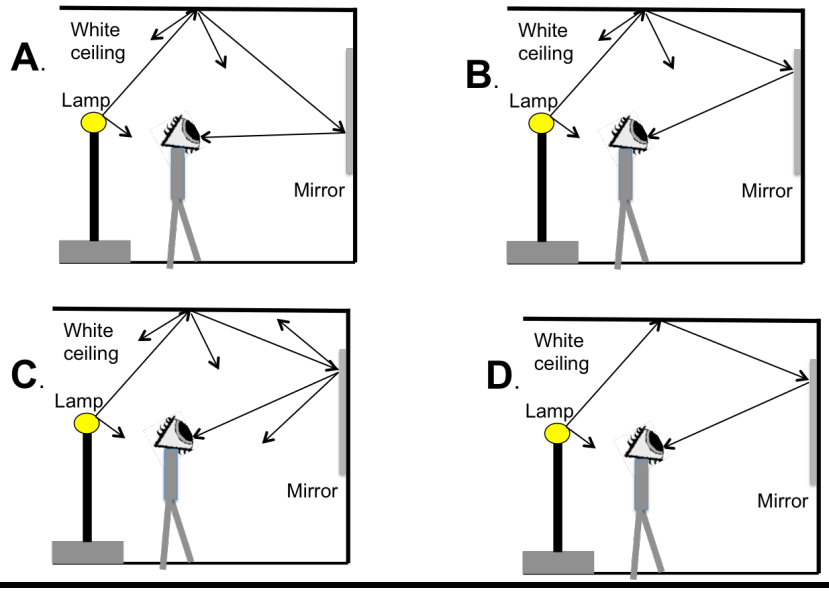
(a) Draw light rays on the diagram to show why the opposite person is dazzled when looking at the mirror. (Assume the small gray rectangle at the center of the table represents the mirror.) Also draw a *sightline* to show in what direction this person sees the image of the flashlight.

(b) Assuming there are no other lights in the room, explain why the flashlight person sees the mirror as being a 'black' surface.

(c) Explain why both persons can see the illuminated white card. How would your light ray diagram be different?

S2. Below are four possible light ray diagrams showing light going from a lamp to a white, non-shiny ceiling, to a mirror on the wall, and then to an observer. The observer can see an image of the ceiling in the mirror.

CQ 2-5: Which light ray diagram best represents how light behaves? What is problematic about the other three light ray diagrams?



On the appropriate diagram, draw a sightline to show in which direction the person sees the image of the ceiling.