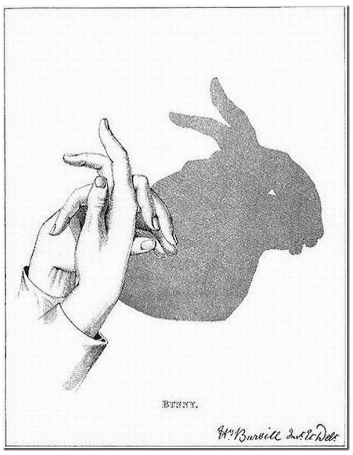
Activity: Explaining Patterns of Light and Shadow

Purpose

It is fun to make patterns of light and shadow on a wall by using objects as 'blockers'. Such patterns can be understood by using a model to show how light travels when it leaves a source (such as a light bulb, or the Sun), heading toward a screen (such as a wall). In this activity you will use such a model to explore patterns formed by pinholes and shadows. (Pinholes are tiny openings in an otherwise opaque[1] card or thin sheet.)



The key question for this activity is:

How can a model for light help us understand pinhole and shadow patterns?

Collecting and Interpreting Evidence

You will need:

- 2 Mini-Maglite™ flashlights
- Black pinhole card (4.5″ x 4.5″) with stand
- Small black card (2″ x 2″) with stand
- White foam board to act as screen with 2 blue foam supports
- Ruler or straight edge for each group member
- Regular light bulb and holder
- Wooden mini-Maglite™ holder

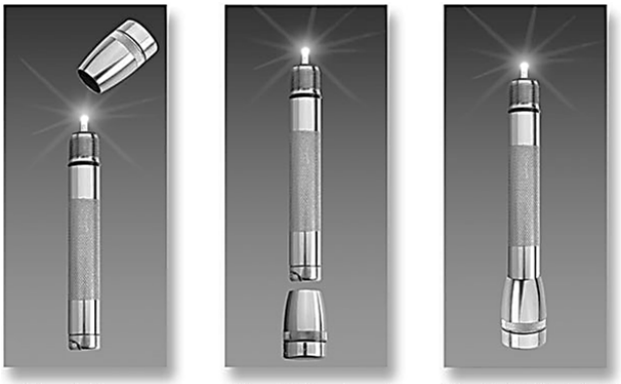
A basic model of light

Before we start investigating patterns, we introduce the basic model for light that we will use.

[1] The definition of opaque is "not letting light through: not transparent." Retrieved August 16, 2016, from http://www.merriam-webster.com/dictionary/opaque.

Set the Maglite™ up so that it is in ***candle mode*** by following the three steps shown in the figures to the right.

Set the Maglite™ on the table so that all group members can easily view it.



Step 1: Unscrew flashlight head | Step 2: Place head down on table | Step 3: Set flashlight into head

Stare at the point source for a few seconds. Describe the appearance of the light as it leaves the tip of the bulb.

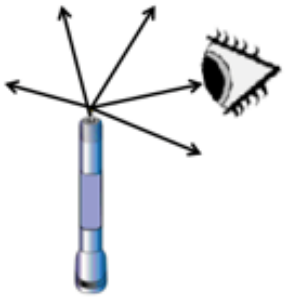
After staring at the point source for a few seconds, describe how your eyes feel.

You could probably 'feel' something going on with your eye. This is evidence that as you stared at the bulb, light coming from it entered your eye allowing you to see it.

Please recap your Maglite™ when not in use.

The Light Ray Model

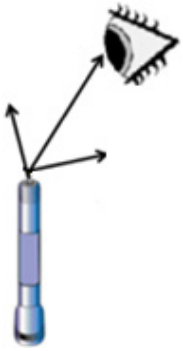
The model we will use in this activity is known as the ***light ray*** model. This model is based on the idea that light moves in straight lines that can be represented by arrows. Thus we can draw a **light ray diagram** like that shown to the right, to represent what is happening when a person looks at the Maglite™. Note that this diagram already illustrates two important aspects:



1) Light from the point source travels outward in **straight lines** in all directions;
2) For a person to 'see' the point source, at least some of this light (i.e. at least one light ray) traveling outward from the point source must enter the eye.

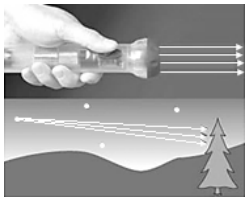
Light rays are always drawn with an arrow showing the direction in which the light ray travels ***from*** the light source ***to*** the object that the light strikes or enters (e.g. an eye). Note that the diagram above also shows some other light rays not entering the eye to illustrate that the light from this source goes outward in all directions.

To prevent our light ray diagrams from becoming too overwhelming, we will draw the path that only a few particular light rays take as they interact with various objects (such as a person's eye). To show that light travels in all directions from a light source, you will draw two shorter light rays that leave the light source in different directions as shown in the figure.



Types of light source

The Maglite™ you are using is a particular type of light source, known as a point source, because all the light rays coming from it seem to come from a single point. All light sources can be categorized into one of four types, depending on how the pattern of light rays they produce.

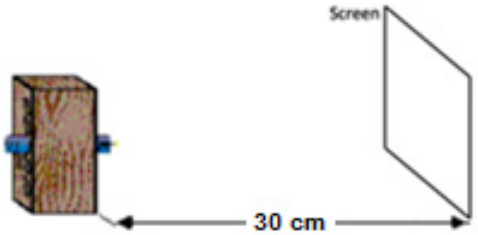
Types of light sources			
Single-ray source	**Point source**	**Extended source**	**Parallel-ray source**
			
There are no real sources that produce a single light ray, but a thin beam from a laser is a good approximation of one.	A point source is very small and emits light rays in every direction.	An extended source, such as a regular light bulb, produces light from its entire surface. In this case ***every point on the surface acts as a point source***, so an extended source is like a whole bunch of points sources stacked together.	Certain sources, such as focused flashlights and movie projectors, produce a bundle of rays that are essentially parallel to each other. Rays from a very distant source, such as a star, are very nearly parallel.

In this activity, we will mainly use point sources as they produce simple patterns of light and shadow for us to investigate.

Exploration #1: What happens when a pinhole is placed between a light source and screen?

Now we are ready to start exploring the patterns that can be formed using a pinhole and a point source.

STEP 1: Place the Maglite™ in location #3 of the wooden holder. Adjust the position of the Maglite™ so that only the bulb is protruding from the opening. Stand the piece of white foam board 30 cm away from the front edge of the wooden holder. This will be your screen.



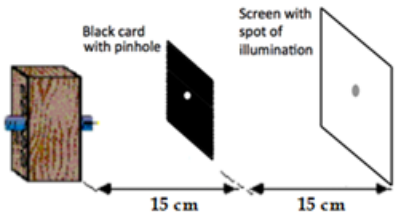
With the room lights off, you should observe that the screen is fully illuminated by light coming from the tip of the Maglite™. (You can ignore small variations in the screen illumination, which could be caused by small imperfections in the Maglite™ bulb.)

Draw light rays on the diagram below to show how light from the point source reaches, and therefore illuminates, the entire screen. (You are seeing the screen because this light is reflecting back from it into your eyes, but do not try to show this in your diagram.)

In constructing this drawing, we assume you are looking at the Maglite™ and the screen from the side (***side view***); hence, we only show the edge of the screen in the light ray diagram. We utilize side views because it is easier to draw a two-dimensional diagram than a three-dimensional one.

STEP 2: Look at the black card with pinhole and make sure the hole is opened. If not, use a small object to make it a clear hole, but not too large.

Place the black card with pinhole halfway between the tip of the light source and the screen as shown in the figure. Make sure you observe a spot of illumination on the screen.



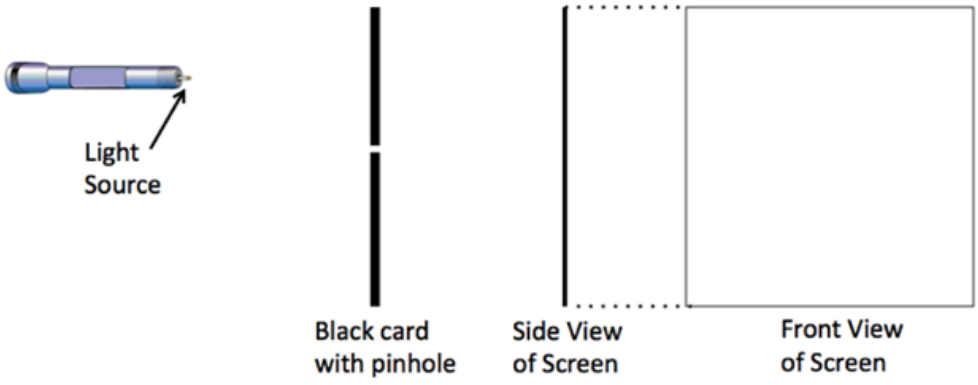
Try the Maglite™ in each of the other numbered locations in the holder. Make sure you are keeping the distance from the black card to the tip of the Maglite the same.

Describe what happens to the spot of illumination on the screen when the flashlight is moved up ward? What about when it is moved downward?

Explain why you think the spot of illumination on the screen behaves this way.

Now support your explanation by drawing a light ray diagram. A side view diagram of the light source, the black card with pinhole in its center and the screen is provided below. To the right of the diagram is a front view of the screen (looking directly at it). On this diagram:

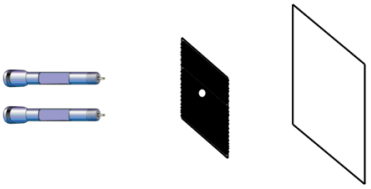
- **Use a straight edge** to draw a light ray showing how light goes from the source, through the pinhole, and to the side view of the screen. (Your light ray should end at the side view of the screen.)
- Draw two additional light rays leaving the light source and striking the card away from the opening, suggesting that they are blocked from reaching the screen.
- Finally, draw a spot of light on the **front view**[2] of the screen to show where it actually appears. (Line it up with where your light ray hits the side view of the screen.)



[2] The front view of the screen is what you would see if you were viewing the screen while standing behind the Maglite™.

Check your diagram with at least two other groups and try to resolve any differences.

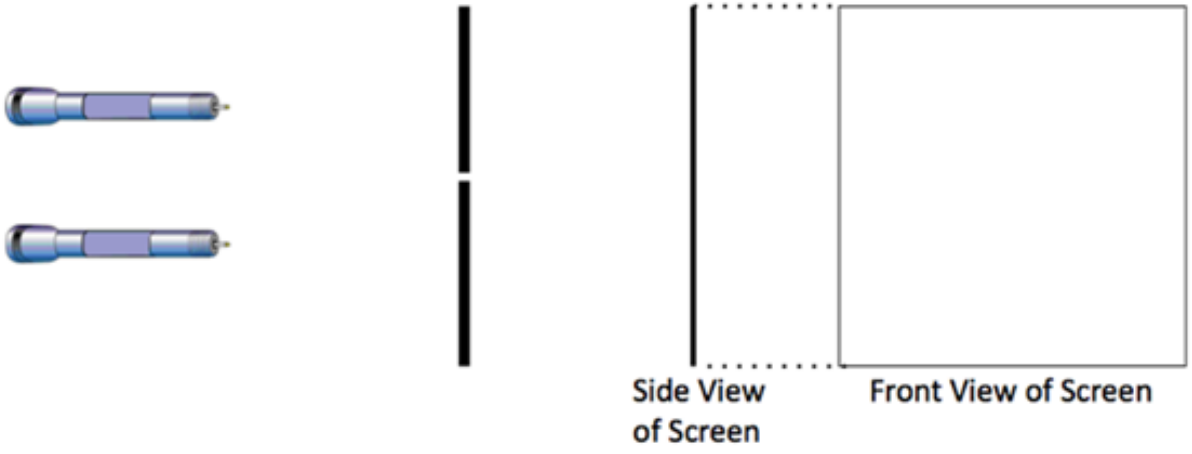
STEP 3: Imagine that you held two Maglite™ flashlights, one above the other, as shown in the picture. (**DON'T DO IT YET**!)



What do you predict you would see on the screen now? (A single spot of light again, two distinctly separate spots, a line of illumination, or something else?) Explain your reasoning.

Try it by placing two Maglites™ in hole #2 and hole #3 in the wooden block! Describe what you observe on the screen.

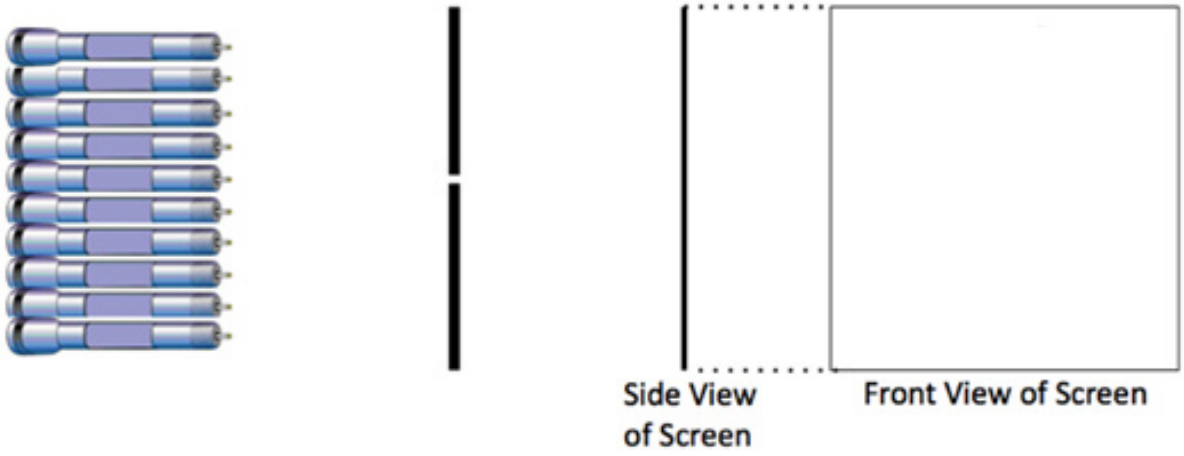
Use a straight edge to draw light rays on the diagram below to show how, and where, the two spots of illumination appear on the screen. (Remember to include at least some rays that are blocked from reaching the screen by the card.)



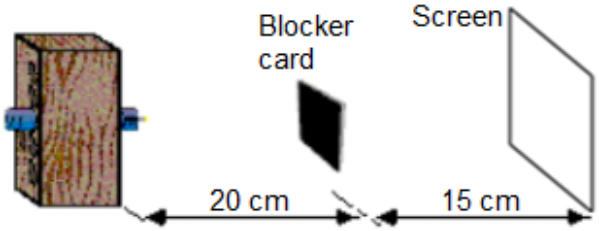
Now suppose you were to cover the **top** Maglite™. Do you think either of the spots of illumination on the screen would disappear? If so, which one (top or bottom)? Why do you think so?

Now try it by blocking the top Maglite™ with a finger. (Be careful not to block the bottom one.) Observe and record which (if either) of the two spots of illumination on the screen disappears. Is that what you predicted? If not, explain why it happened.

STEP 4: Now **imagine** that you lined up ten Maglite™ flashlights, one above the other, so that each was almost touching the next one. On the diagram below, draw light rays to show your thinking and sketch what you think you would observe on the screen. (For this diagram, draw only light rays that pass through the pinhole from each light source.)



Exploration #2: How can we explain the shape and size of shadows?

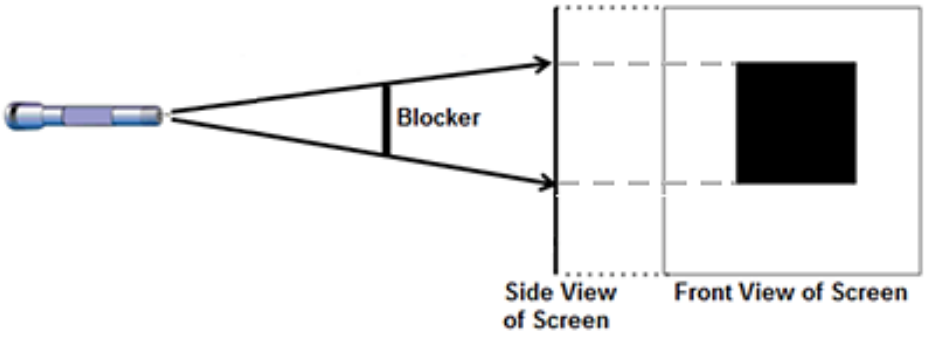


STEP 1: Place the Maglite™ in location #3 of the wooden holder. Adjust the position of the Maglite™ so that only the bulb is protruding from the opening. Stand the white foam board 35 cm away from the front edge of the wooden holder. The center of the card should line up approximately with the tip of the Maglite™. You should observe a shadow on the screen. (If possible, block the light coming from the Maglite™ of neighboring groups.)

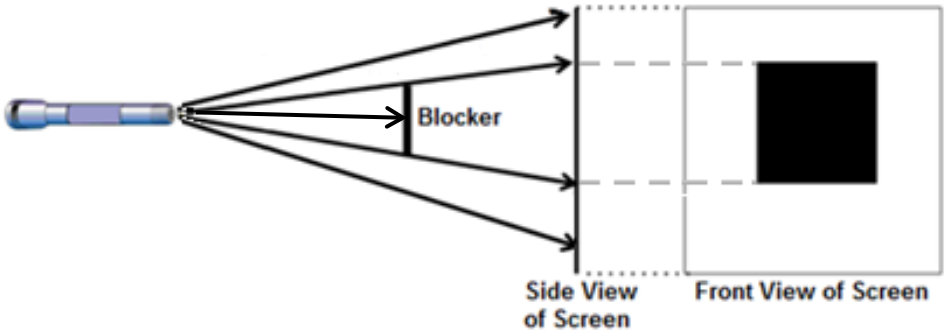
How does the shape of the shadow compare to the shape of the blocker card? Are the edges of the shadow reasonably sharp or very blurred?

Write a couple of sentences to explain how you think the shadow is formed.

When drawing a side view light ray diagram to explain how a shadow is formed, the most useful light rays to draw are the two rays that leave the source and travel in straight lines just past the upper and lower edges of the blocker and then go to the screen. These **boundary rays** show where the upper and lower edges of the shadow region are and enable you to determine both the size and position of the shadow region on the screen (assuming a square-shaped blocker).



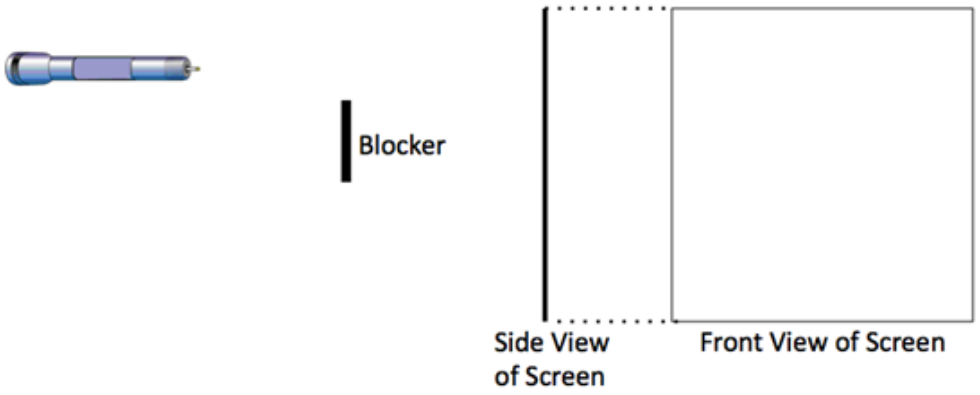
Drawing some other light rays shows where else the light reaches the screen to illuminate it, and where it does not.



STEP 2: Explore what happens to the position of the shadow as you move the Maglite™ flashlight up then down, keeping it the same distance from the blocker card.

Summarize your observations below.

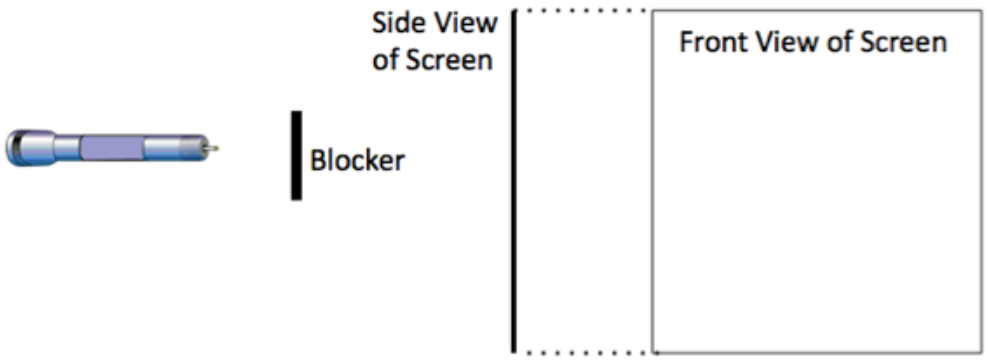
Draw light rays on the diagram below, including the boundary rays, to show how and where the shadow is formed when the Maglite™ is in the position shown. (Assume the shadow is approximately square in shape.)



STEP 3: Leave the blocker where it is and explore what happens to the size of the shadow as you move the Maglite™ closer to, then further away from the blocker card.

Summarize your observations below.

Draw a light ray diagram to show why the shadow is larger when the Maglite™ is closer to the blocker card.

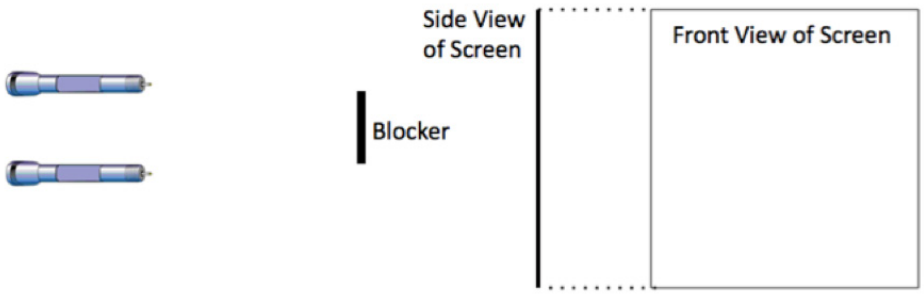


Summarizing Questions

Discuss these questions with your group and note your ideas. Leave space to add any different ideas that may emerge when the whole class discusses their thinking.

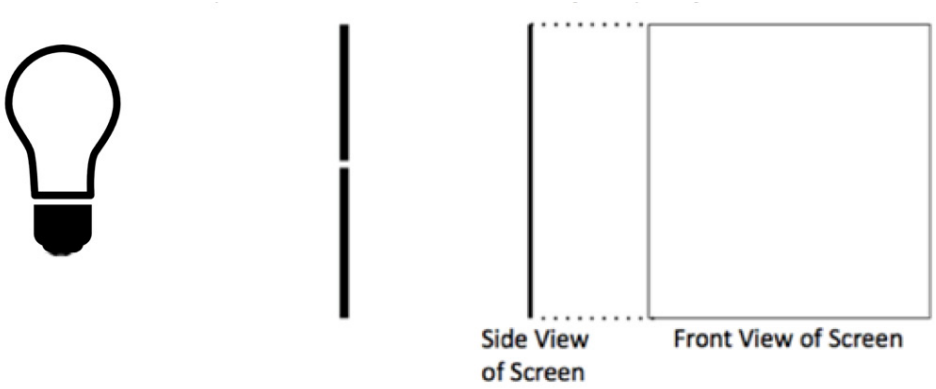
S1. A student in another class claimed that if the Maglite™ flashlight were placed a very long distance away from the blocker card, then (assuming it could still be seen) the shadow on the screen would actually be **smaller than the blocker card itself**. Do you agree or disagree with this student? Explain your reasoning and use the figure provided below to draw a light ray diagram illustrating your thinking.

S2. Now form a shadow pattern using your blocker and two Maglites™. Adjust the positions of the Maglites™ so the whole pattern fits on the screen. Sketch what you see on the front view of the screen below, paying careful attention to the relative shading. Add light rays to the diagram to show how this pattern is formed and explain what is happening below the diagram.



S3. Set up your pinhole and screen again, but use a regular light bulb as your light source. What do you observe on the screen? (If it is not clear, try moving the screen closer to the pinhole.)

Talk with your group and perhaps other groups and together try to come up with an explanation for your observation. (Remember, each point on the surface an extended source acts like a single point source.) Draw a light ray diagram to show your thinking.



Participate in a whole class discussion to go over your answers to the Summarizing Questions.