Physics of Imagineering | **In-class assignment #3**
September 22, 2015 | **Light and Optics**

Goals

1. To observe how light moves.
2. To learn how to draw light rays in order to determine the location of images.
3. To understand some of the visual "tricks" used at Disneyland.

Equipment:

Notebook (draw diagrams directly inside), ruler, protractor, box of optical elements, laser ray box, flashlight, Cards with holes punched

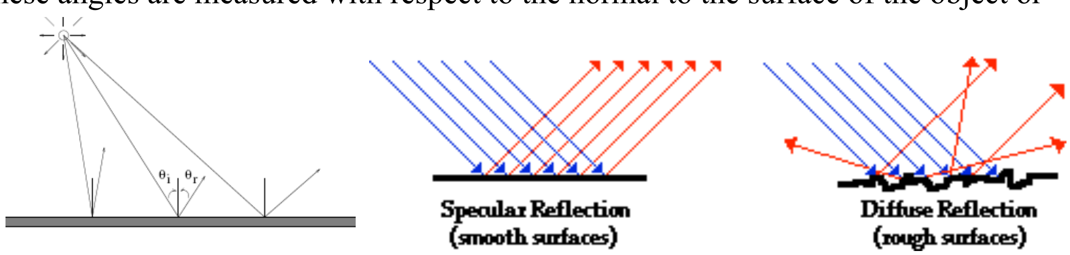
How does light move?

Light moves in straight lines (just like a particle) unless it encounters a barrier or boundary. This is useful for understanding how light travels because we can represent light by lines called "rays". The rules light obeys under these situations are introduced below. These rules can be derived from Maxwell's equations of electromagnetic radiation (take physics 432 to see this). Answer all questions and draw all diagrams in your notebook. Each page in your notebook should have a different diagram and answers to all questions regarding that diagram. It should also include any notes or interesting things you observe.

1. Aim a flashlight to point at the wall. Place one card with hole about 10-20 cm from the light. Where do you have to put the other card with hole so that the light still falls on the wall? Draw a diagram in your notebook. Does this agree with the statement "light travels in straight lines"? Why?

Reflection

Barriers – When light encounters any barrier (any object) some light will bounce (reflect) off of that object. Light reflects in two ways: diffuse or specular reflection. Specular reflection is the type we associate with mirrors and the angle of incidence equals the angle of reflection, $\theta_i=\theta_r$. These angles are measured with respect to the normal to the surface of the object or barrier.



2. Place a plane mirror on a clean page in your notebook. Trace the location of the mirror. Aim a laser beam at the mirror and trace the path of the beam (with a ruler). Measure the angles of incidence and reflection. Are they what you expect?
3. Alter the incidence angle of the laser beam. What happens to the reflected beam as you alter the angle of the incident beam?
4. Place a convex circular mirror on a clean page in your notebook. Trace the location of the mirror. Aim the laser ray box at the mirror and trace the paths of the beam. Does it behave as you expect? Do rays incident on this mirror converge or diverge?
5. Place a concave circular mirror on a clean page in your notebook. Trace the location of the mirror. Aim the laser ray box at the mirror and trace the paths of the beam. Does it behave as you expect? Do rays incident on this mirror converge or diverge?

Images

An image is formed where light rays converge. If the light rays converge on the same side of the mirror as the incident light, then the image is real and the distance from the mirror to the image is positive. If the light rays converge behind the mirror, then the image is virtual and the distance from the mirror to the image is negative. The distance from the mirror to the image is always measured along a line that connects the image to the object, as is the mirror to object distance.

6. On a different page in your lab notebook, place the plane mirror near the center and trace its location. Draw a dot on the page to serve as your object. Site along the edge of the paper looking at the image of the dot. Draw the ray that leads from the object's image to your eye. Continue this light ray back to the object. Repeat for at least 1-2 more rays. Does the light behave as you expected? What is the focal length for a plane mirror? Measure the image and object distances. How are they related?
7. Place an object at the location of the image. Replace the mirror with a piece of glass that both reflects and can be seen through. Observe from many locations at different angles, does the original object's image always line up with the object placed at the image location?
8. On a different page in your lab notebook, place the convex circular mirror and trace its location. Draw a dot on the page to serve as your object. Site along the edge of the paper looking at the image of the dot. Draw the ray that leads from the object's image to your eye. Continue this light ray back to the object. Repeat for at least 1-2 more rays. Does the light behave as you expected? Do the reflected rays converge at a point? Is that point behind the mirror or in front of it? Measure the image and object distances. How are they related?
9. On a different page in your lab notebook, place the concave circular mirror and trace its location. Draw a dot on the page to serve as your object. Site along the edge of the paper looking at the image of the dot. Draw the ray that leads from the object's image to your eye. Continue this light ray back to the object. Repeat for at least 1-2 more rays. If you cannot see an image, use the law of reflection to draw some rays from the object and their reflections. Does the light behave as you expected? Do the reflected rays converge at a point? Is that point behind the mirror or in front of it? Measure the image and object distances. How are they related?

Judging distance

There are three main ways we judge the distance to an object we cannot reach. The first, and most reliable, is our stereo vision. We receive different input from each eye and our brains put that together to tell us about the distance to an object. The second is used for judging far distances is atmospheric attenuation. The atmosphere makes far away object look murky or indistinct (see http://psych.hanover.edu/Krantz/art/aerial.html). The final method is based on knowing the size of an object (see http://psych.hanover.edu/Krantz/art/rel_size.html).

10. Center your nose above the castle on the next page. Focus your eyes on the castle. Put your thumb in front of your nose. Continue to focus on the castle. What do you see? Now change your eye's focus to be on your thumb. Now what do you see?

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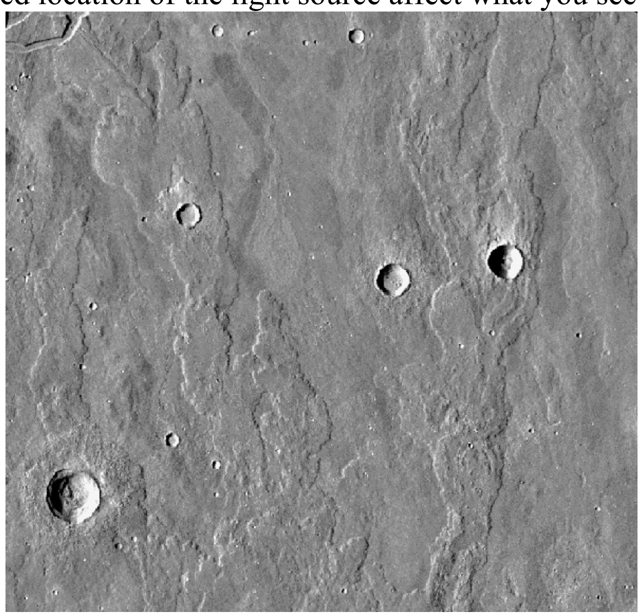
11. On a flat image, like a picture or a television screen, our stereo vision doesn't work because the images are actually the same distance from us. In these cases, we will likely be using size to tell us the distance. Go to http://www.123opticalillusions.com/pages/opticalillusions19.php. Is the blue side on the inner left back or the outer left front? Can you make it switch? This is an example of 3D confusion in a 2D image.
12. Look at the image below. This shows impact craters and a volcanic flow on Mars. Do the circular features look like craters (holes) or bubbles? What happens if you turn the page at look at the image from the side or upside-down? Where is the light source for this image? How does the perceived location of the light source affect what you see?



13. When we see things, we are only estimating size. What we are really seeing is an **angular size**. When a 6 foot (180 cm) tall man is 10 feet (300 cm) away, what is his angular size? To determine this, draw a scale figure in your notebook and measure the angle with a protractor. Can you calculate the angle using trigonometry? Calculate the angle for the same man 20 feet (600 cm) away.
14. Assume you are standing on the sidewalk about 10 feet (300 cm) away from a multistory building. Draw this situation in your notebook. What is the angular size of the first story of the building (assume a story is 10 feet tall)? The second story? Third? Why?
15. Google "forced perspective" to find images that show what happens when we get our brains to confuse size and distance. Pick a favorite image. Either print it out or write down the link. Describe the image and why you picked it.