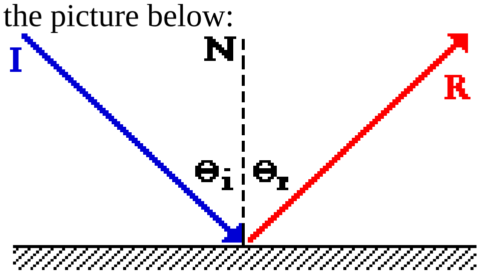
Floating Coin Optical Illusion

Description: The floating nickel box is an optical illusion using two concave parabolic mirrors. The nickel seems to float and students are encouraged to touch the nickel only to find that it is an optical illusion.

Physics Principles:
- Reflection
- Curved Surface Mirrors

Reflection and Flat Mirrors:
- Light rays from a point source spread out (diverge) in all directions as the light is emitted from the object.
- A certain distance away from the object, they strike a smooth, reflecting surface, like a mirror. The rays are reflected from the surface at an angle size relative to the that is the same as the angle of the incident ray, as seen in the picture below:



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- The light rays are reflected and continue in straight line paths.
- Your eyes and brain cannot discern that the rays are reflected and thus an image appears at a point in space where the light rays entering your eye appear to converge to a point. In the case of a flat mirror, this point is behind the mirror. This is the virtual image, which appears to be the same distance away as the actual object in front of the mirror.
- See a more thorough description with ray diagrams from: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l2c.html

Curved Mirrors:
- A curved mirror is actually part of a small section of a sphere. This means that a flat mirror is actually a spherical mirror with an infinitely large radius of curvature.
- A *flat or plane mirror* has a flat surface and the virtual image appears the same distance and the same size as the actual object.
- A *concave mirror* is formed when the surface of the mirror is turned in and the virtual image appears farther away and larger than the actual object (as long as the object is place inside of the focal point of the mirror).
- A *convex mirror* is formed when the surface of the mirror is turned out and the virtual image appears closer and smaller than the actual object. Because the focal point is virtual and behind the mirror, it does not matter what distance you place the object from a convex mirror, the virtual image will always appear closer and smaller than the actual object.
- A flat mirror would have a *center of curvature* infinitely away from the mirror. For a concave mirror, the center of curvature is closer and in front of the mirror. For a convex mirror, it is behind the mirror.

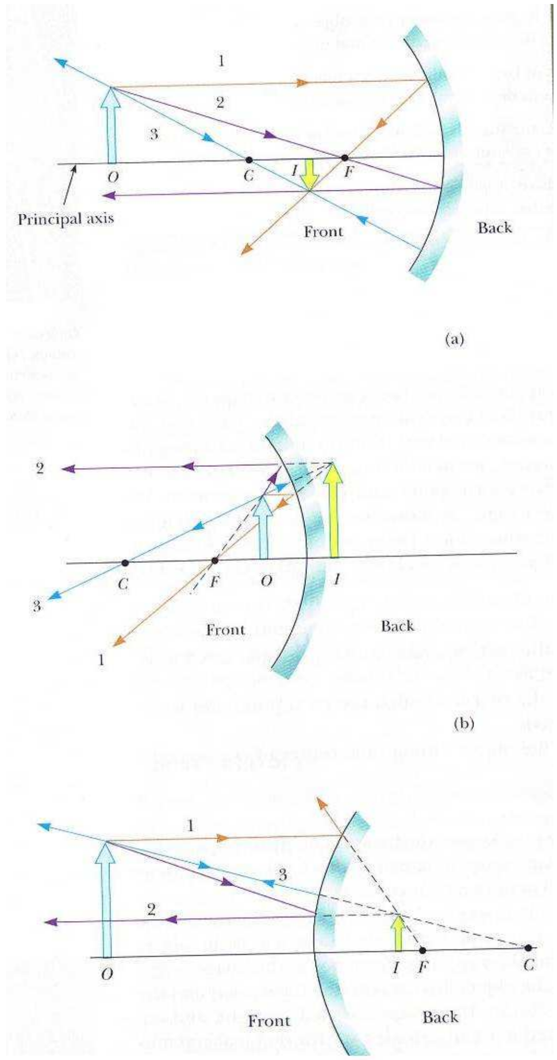
- The *field of view* (how much of a scene you can observe) is wide for a flat mirror, and smaller for a concave mirror. The field of view for a convex mirror is wider yet than a flat mirror.
- The virtual image in a flat mirror is as far behind the mirror than the actual object is in front of the mirror. In a concave mirror, the virtual image is farther behind the mirror, and in a convex mirror, the virtual image is closer to the mirror, as compared to a flat mirror.
- If we consider an object far enough away from a curved mirror, we can assume the incident light on the mirror is parallel to the central axis (extending through the center of curvature).
- When the parallel light rays hit a curved mirror, the angle between the reflected ray and the normal (perpendicular) is the same as the angle between normal and the incident ray.
- For a concave mirror, this means that the light rays on either side of the center of curvature will converge towards one another and where the reflected rays cross is the *focal point* of the mirror (and the distance from the center of the mirror is the *focal length*).
- If you place an object beyond the focal point of a concave mirror, the light rays will converge and intersect in front of the mirror forming a real image that is inverted and smaller than the actual object.

How it Applies to this Kit:

- See a complete sketch of how the mirrors are set up in this kit at: http://www.mip.berkeley.edu/physics/pdfs/'G'handout.pdf (page G+55+20)

Questions to Investigate:

- Have your students try to grab the coin they see in the box.
- Is this a real image or a virtual image of the actual object?
- Draw ray diagrams that correspond to concave (and convex) mirrors.
- Using the mirror equations (http://dev.physicslab.org/Document.aspx?doctype=3&filename=GeometricOptics_MirrorEquation.xml) calculate the image position or focal length of the mirrors.
- Surveillance mirrors in stores and banks want to have the largest field of view possible, so what curvature do these mirrors have?
- In each of the photographs on the next page, have the students identify if the mirror is convex or concave and if it is concave, if the object is inside or outside of the focal point. Have them draw the corresponding ray diagrams. (**Answers**: *Top image*: concave, outside of the focal point; *Middle image*: concave, inside of the focal point; *Bottom image*, convex).



Photos and ray diagrams from *Serway and Beichner*, 2000 pp. 1148.

<u>Online Resources:</u>

- PhysicsLAB Resource Lesson on Spherical Mirrors (be sure to also see Related Documents at the bottom of the page and select each subtopic for more classroom lab and worksheet ideas): http://dev.physicslab.org/Document.aspx?doctype=3&filename=GeometricOptics_SphericalMirrors.xml
- The Physics Classroom curved mirror tutorial: http://www.physicsclassroom.com/Class/refln/U13L3a.html
- An interactive applet for concave mirrors (move the object distance and determine where and what type of image you see): http://micro.magnet.fsu.edu/primer/java/mirrors/concave1.html

References:

Cummings, K, P.W. Laws, E.F. Redish, and P.J. Cooney, 2004: *Understanding Physics, Part 4*, John Wiley & Sons, Hoboken, NJ, 159pp.

Griffith, W.T., 1992. *The Physics of Everyday Phenomena: A Conceptual Introduction to Physics*, Wm. C. Brown Publishers, Dubuque, IA, 487pp.

Serway, R.A and R.J. Beichner, 2000. *Physics for Scientists and Engineers*, Vol. 4, 5th ed., Saunders College Publishing, Philadelphia, PA, 183pp.