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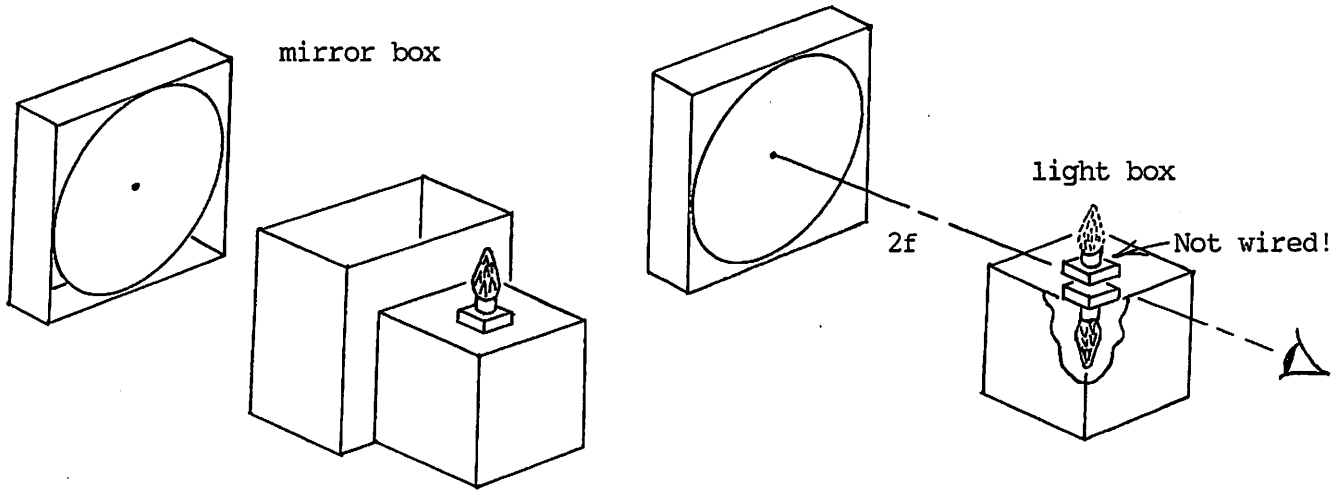
Light and a real image - a real image via reflection.

Long considered one of the greatest demonstrations of all time (if done correctly), this demonstration is a clear introduction to the definition of a real image, especially compared to the virtual images studied with flat mirrors. The importance of the curved, concave mirror, discovered by Isaac Newton, is fully appreciated here. Nearly a century ago this demonstration was called "The Phantom Bouquet" and later, "The Phantom Light Bulb". The demo does involve illusion (an aerial image) and secrecy for maximum effect. The diagram illustrates my set-up and the pieces needed. The light box isn't sold anymore but can be made. The expensive item is the commercially available ~16" dia., 32 cm focal length, spherical, concave mirror.* (This mirror has several other important uses, thus making it well worth having.) The light box is necessary; the mirror box is optional, but highly recommended. Plans for making both are included.

Diagram:



Presentation: (a) This is my way of doing this demo; you may prefer a different way. Because it's an illusion, any prior knowledge of it would ruin the effect you are looking for. Therefore, it must be kept a secret. Locate the set-up in a place (on a high desk or counter through a doorway) where a student can walk straight to it and leave easily.

(b) Plug in the cord from the light bulb inside the box. Align the set-up using a half-sheet of white paper as a screen above the empty socket on top of the box. With the alignment completed, unplug, place a bulb in the top socket, and cover the light box opening with a box.

(c) As students enter the classroom, keep them from poking around the set-up. When all are seated, close the door and have them focus on the set-up and its secrecy; they are never to discuss this demo with anyone outside of this classroom! They will understand when it's over. Their instructions are simply to unscrew the bulb on top, observe its effect in the mirror, screw the bulb back in for the next person, and quietly sit down. (The bulb won't be too hot to handle,and no electrical shock is involved.)

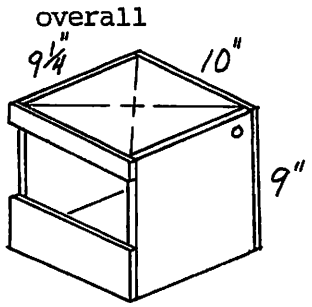
(d) Have them file out into the hallway, remain quiet, and then come to a spot on the floor near the doorway one by one when called. They are to walk straight in, unscrew the bulb, etc. The teacher calls them to the spot and follows them in to prevent them from touching the set-up and its alignment, and steers them toward their seats. Always call the classclown last.

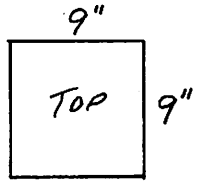
* Science Kit, Tonawanda, NY, (800) 828 - 7777

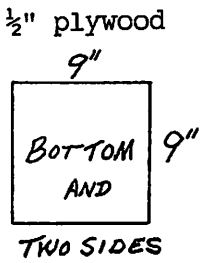
(e) When all are seated again, close the door and discuss the need for secrecy. Now explain that they weren't really tricked; something is really there. Place the screen on top of the empty socket and view the real image due to the concave mirror. They will be amazed.

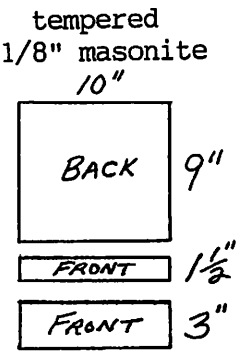
(f) Now let them file out again and repeat the process. Back in the room, I start the geometric optics diagram that explains what they just saw. They will never forget this demo, and most will keep the secret.

Plan for the light box:









Assembly of light box: (a) Cut out the plywood top, bottom, and sides. Countersink the side pieces slightly for #6 x 1¼" dry wall screws.

(b) Center and attach the two lamp sockets to the top board, top and bottom, with #8 x 1" RH screws at 90° with each other.

(c) Loosely attach the side pieces to the top and bottom boards. Tighten them later.

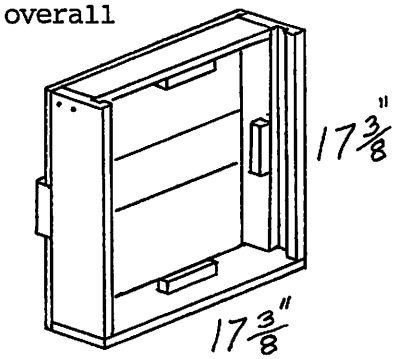
(d) Cut out the masonite back and two front pieces. Attach the back piece with #6 x 5/8" PH screws as square as possible; start with one corner. Work around the other three corners, tightening as you go. When finished, you should have a rigid, square box.

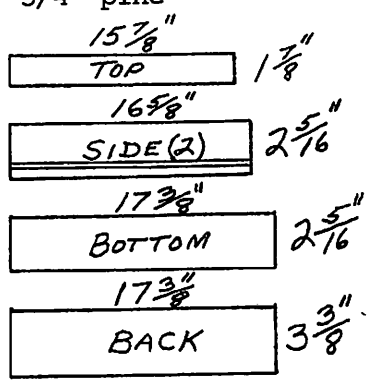
(e) Paint the box inside and out flat black. Then attach the two painted, front, masonite pieces with #6 x 5/8" PH screws.

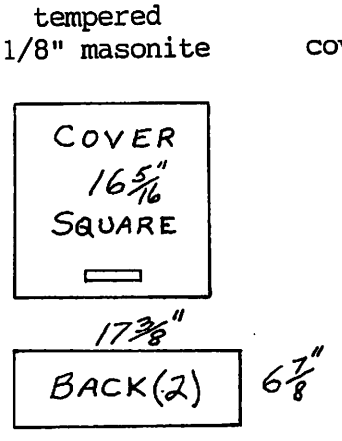
(f) Drill a tight, lamp cord hole in the upper corner of a plywood side piece. Wire the bottom socket only.

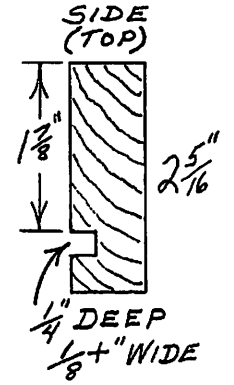
(g) Purchase two 25W de'cor bulbs, white.

Plan for the mirror box:









Assembly of mirror box: (a) Cut out the pine boards for the top, sides(2), bottom, and back. Cut the grooves for the cover in the side boards. TEST!

(b) Countersink the bottom, back, and side boards slightly for #6 x 1 5/8" dry wall screws.

(c) Attach the top, side, and bottom boards loosely with screws, as square as possible. Tighten later.

(d) Center and attach the pine back board with #6 x 1 5/8" dry wall screws.

(e) Cut out the masonite back pieces and attach with #6 x 5/8" PH screws.

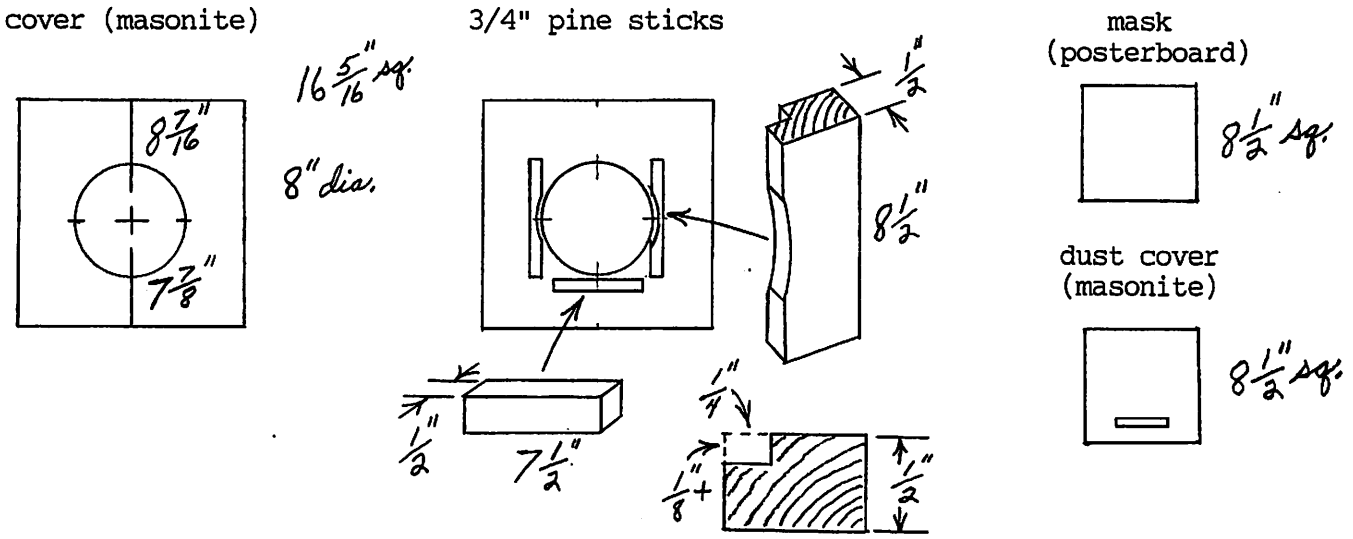
(f) With the box laying flat on its back, carefully place the concave mirror in the box face up. Place and attach the stops on all four sides. Remove the mirror and paint the inside of the box flat black.

(g) Cut out a masonite cover to slide up and down, with a handle on the bottom of the cover.
(h) Finally, with the box face down, replace the mirror face down against the stops. Now the difficult part. You don't want the mirror to shift around and wear off the paint and silver at its center. You need the pine back board to apply a little pressure. Does the board just touch the back of the mirror or is very close? If there is a space, add a cardboard shim(s) until the gap is closed. The final "layer" or shim should be a piece of Dr. Scholl's Moleskin with the soft side against the mirror. Screw down the back board, to apply some pressure, until any shifting stops. Go no further!
(i) You may wish to add a carrying handle on top of the box for convenience.

The cover as a mask holder for other curved, concave mirror studies.

Other important demonstrations using this concave mirror can be performed if the masonite cover is modified to hold different cardboard masks. An 8" dia. aperature works well, increasing the mirror's resolution in the process; the intensity (brightness) is still very high. Note that the mirror's center is <u>not</u> the center of the masonite cover, but is a little lower. Cut out the 8" dia. hole. Next, cut out six, blank, cardboard (posterboard) masks (for later use) and the smaller, masonite (dust) cover; glue a handle on the cover. Carefully position the three 3/4" pine sticks (holder) on the large cover and test the holder with the masks and dust cover to see that nothing binds; make adjustments if needed. Attach the sticks with small FH screws through the back of the board. Now you are ready for additional, interesting demos with this concave mirror. See "Light - studies with a concave mirror" on the next page.

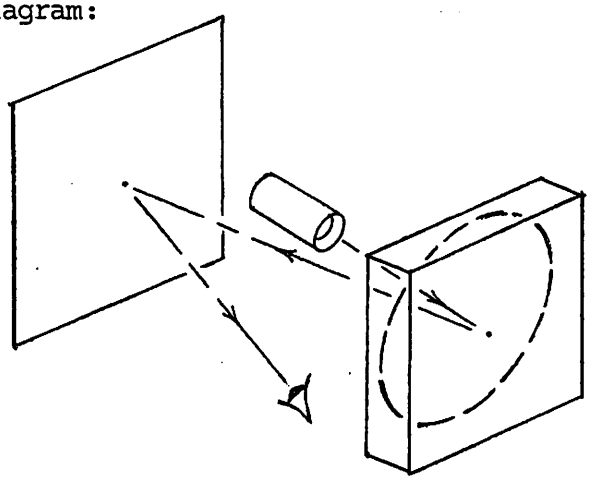
Plan for modifying the masonite cover:



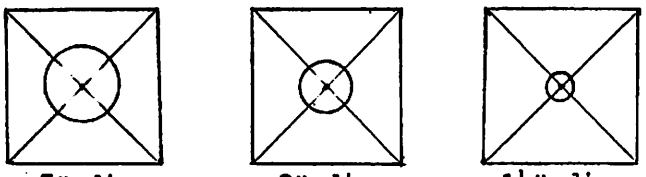
Light - studies with a concave mirror. You may take these studies in any order that you wish. The diagrammed arrangement will be used most of the time; only distances and masks will vary.

Materials: light source (object), mirror, screen (image), masks

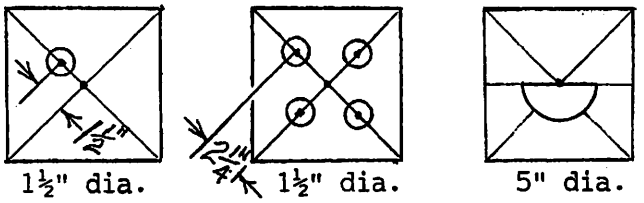
Diagram:



(b) masks



(c) masks



(a) Real images ("running the series") - Keeping the mirror stationary, move the light source (object) slowly outward from between F and C, at C, and beyond C. Move the screen to locate the real image each time.

(b) Resolution (removal of sperical aberration) - With a focused, real image on the screen, insert the cover with its 8" dia. aperature. Note the immediate clarity of the image. Continue with the center-holed masks of 5" dia., 3", and 1½". (Cut the holes in the posterboard with a carton knife.) Each time the image should appear "sharper" (more focused) or in higher resolution, but slightly dimmer (less intensity).

(c) Huygen's principle - any point (small area) on a concave mirror is a source of light (object) to form a real image. The principle is used by off-axis optics on telescopes like solar filters, etc. Make up a mask with one off-axis aperature as in the diagram, insert it, and view the image. Is it like the image from the 1½" dia. center-holed mask?

An extrapolation - Now cut four holes in another mask as in the diagram. Remove the one-hole mask and insert the four-hole mask. How does the image appear now? Now quickly pull the light source back so you see four separate images on the screen. Here's the drama. Slowly return the light source to its original position, watching the four images slowly come together to form one. You've just observed the essence of true focusing, bringing all points (areas) from the mirror together to form one image. Neat! Having just learned an important lesson, what will happen to the image if we "cut off" half of the mirror? Will we get half an image? Make up a mask with a semicircle as in the diagram. Cut a 5" dia. semicircular hole in the lower half of the mask. Insert the original, 5" dia. center-aperatured mask. Add the semicircular mask to it. If the two masks don't match exactly, remove the centered mask, and insert the semicircular mask separately. Did you make the connection with the previous study? Notice that only the intensity (brightness) is less.

(d) Solar furnace (solar energy) - On a bright, sunny day around noontime, aim the mirror at the sun with a small piece of paper inserted at the focal point; in a short time it should catch fire. Warning! For safety reasons, this demo should only be performed by an experienced teacher, not students. Severe burns can result. Hands (fingers) should never be held near the focal point. When inserting the paper at the focal point, the intensity of the sun's image is blinding (harmful!). So always observe the paper at the focal point out of the corner of your eye for as short a time as possible; don't stare at the hot spot. If you are careful, this demo can be performed safely. Because it is dramatic, it's a student favorite.