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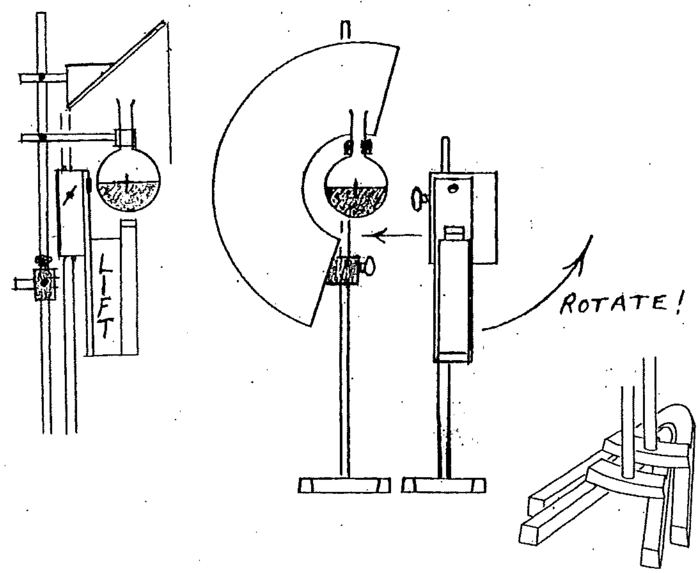
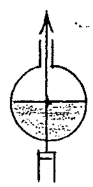
Critical angle "magic", especially in water - is a topic quite well illustrated in books but not easily demonstrated in real time. Most often, with many associated problems, it is attempted using an aquarium tank. The three aspects of internal reflection, i.e., partial, critical angle, and total, are not convincing. However, there is a better way, requiring only a large (500 ml) RB flask and a laser (1.). True, a beam spreader for the laser, a "halo" screen, and a pivoting laser "arm" need to be constructed to complete the apparatus, but the instructions provided will simplify the task.

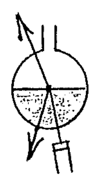
1.



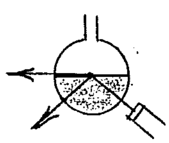
The principle: With a laser beam beneath the center of a half-filled flask of water aimed straight up, the beam will travel straight up through the glass bottom and the water, and then straight up the neck. (Minor surface reflections will occur, of course.)



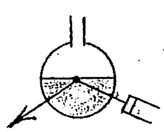
With the laser beam rotated to a different angle, the beam will divide into a partially transmitted beam and a partially, internally reflected beam.



Continuing to rotate the beam will result in the partially transmitted beam exiting the water parallel to the surface of the water; at this point, the critical angle will have been reached, between 48° and 49° .

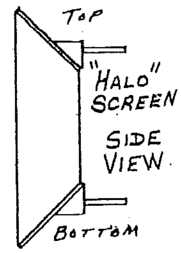


Rotating the beam still further will exceed the critical angle, and all of the original beam will be reflected internally, or total internal reflection will have been achieved, with absolutely no transmission possible.



If aligned properly (carefully), all of these aspects will be clearly demonstrated by this apparatus and may even dazzle you.
I designed the set-up to be assembled on two different ringstands that can be positioned one behind the other (1.). Warning: never try to attach everything to one ringstand; the results are disasterous! The water in the flask must be kept perfectly placid, no ripples, throughout the demonstration.
As you may have observed from (1.), the pivot (screw) of the laser "arm" is directly behind the center of the water's surface (and the flask) throughout the demonstration but must not touch the flask. At the start, the laser is positioned directly below the center of the flask and must rotate upward along the "centerline" of the flask. Because of the flask's size, a "lift" beneath the laser must be part of the laser "arm" to center it under the flask.

Obviously, the "halo" screen must be a "3-D" unit to catch the beams and be seen by the audience at the same time. The problem is solved with a 45° tilt in a circular pattern (2.). To make the beam's "dot" show as a "ray" (line) on the screen, requires a beam spreader, a special lens. 2.

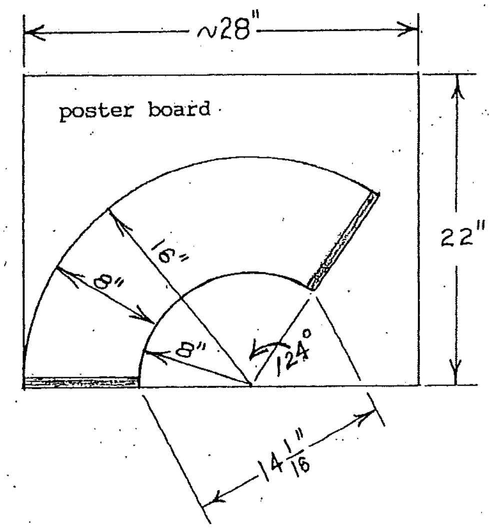


Note that the "halo" screen and the half-filled flask are attached with clamps on one ringstand while the rotating laser "arm" unit is attached to the other (1.)

Construction: (a) The "halo" screen is cut from a 22" x 28" sheet of white poster board (3.) A pair of 45° pine blocks with 4" long, 3/8" dia. dowels inserted and a pair of 8" x 3/4" x 3/16" sticks attached will be glued to the ends of the screen (4.)

To make the 45° pine blocks, cut a 3" sq., 3/4" thick pine board, drill 1" deep dowel holes, glue in the dowels, and finally cut the 45° diagonal. Attach the sticks with glue to the diagonal faces using clamps. The "rough" side (back surface) of the poster board makes a better screen surface so glue the 45° blocks to the shiny (front) surface.

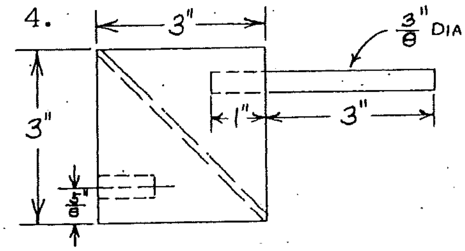
3.



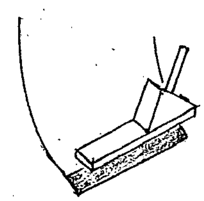
The "top" 45° block is attached to the ringstand with a right angle clamp, but the "bottom" 45° block requires the construction of a special pine block holder, 2½" x 5/4" x 5", and using two different-sized thumb screws (5.). The 17/32" hole is for the ringstand rod and the 3/8" hole is for the dowel.

Attach the half-filled flask to the ringstand with a flask clamp. It should be centered in the 3-D screen.

4.



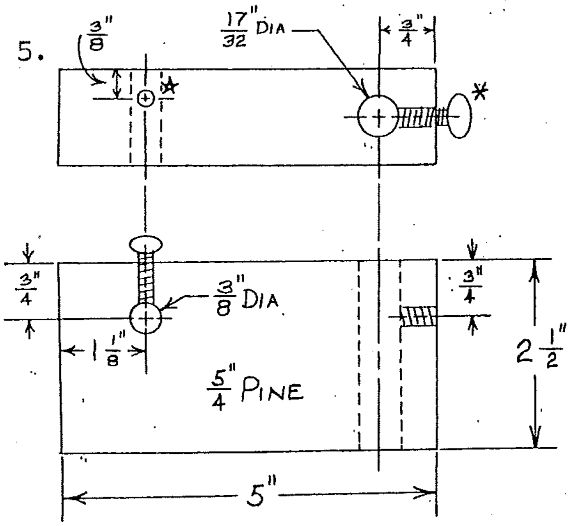
(b) The pivoting laser "arm" unit requires the most thought on the builder's part because of the choice of the laser to be used. A plan for the basic unit is provided; however, further details must be figured out by the builder. To start with, I'm assuming that most teachers will choose the popular laser pointer (pen laser); if not, they (you) must adjust. The basic unit looks like (6.), with a 5/4" pine block that attaches to the second ringstand with a thumb screw; it, also, has a small piece of plywood attached to it, the "shield". Attached to this unit is the rotating, plywood "arm" that carries the laser. Given are possible dimensions, but change if necessary.



The next complication is the size and shape of the "lift" block that will be needed under the laser. This requires some thought; you must consider distances (clearances, no touching!) between the parts and proper alignment for the whole apparatus to work well. Note that during this demo, the laser must be kept on, from start to finish, during the rotation. Therefore, the "lift" block must accommodate a "turned on" laser somehow.

(c) The beam spreader, a special lens, is easily made from a short piece of glass stirring rod glued to something held in the laser beam's path before it strikes the flask; it changes the beam's "point" to a "line" (streak) which is essential in this demo. The spreader must be attached to the laser, "lift" block, or pivoting laser "arm" somehow.

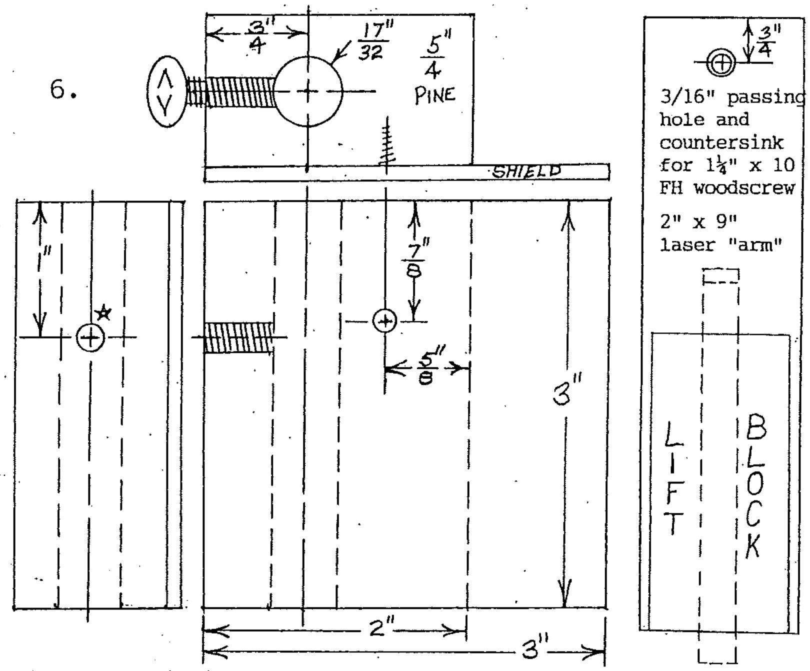
5.



☆ (a) use 5/32" bit
(b) press-screw 3/16" x 24 x 3/4" thumb screw

✳ ¼" x 20 x 3/4" thumb screw

6.

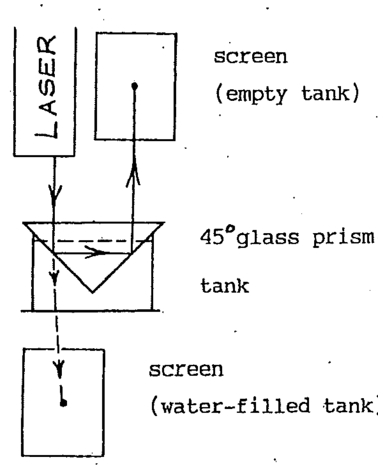


☆ For ¼" x 20 x 3/4" thumb screw, drill pilot hole 3/16" or 13/64"; "press fit" threads using soap or wax.

Assembly and presentation: Arrange the "halo" screen and half-filled flask on one stand and the pivoting laser "arm" with laser on the second stand. Carefully slip the laser unit on its stand in behind the flask without anything touching. Center the pivot point (screw) with the water's surface. Adjust the beam spreader for best effect. Start with the laser beam on the bottom and aimed straight up. Slowly, smoothly rotate the "arm" and laser upward observing the partial transmission on the screen above and the partially reflected beam on the screen below. Keep rotating until that "magic" point (the critical angle) is reached when all of a sudden the partial transmission ray disappears and only the reflected ray remains and brightens considerably due to total internal reflection. Also, observe the changes in the brightness of each ray throughout the rotation. Several lessons are possible with this special demonstration.

Finally, the screen is stored flat between two strong pieces of corrugated cardboard taped together. The 500 ml flask is stored in a special wooden box, fully filled, and stoppered (no evaporation!) at room temperature. For the demo, I empty it to the halfway mark. After the demo, I immediately refill it. You may totally change the water but do it quickly. This entire procedure is meant to prohibit any dried-on waterspots from accummulating on the inside of the flask and ruining its clarity.

Addendum: Different critical angles for different boundary conditions; for example, from glass to air vs from glass to water. Set a 45° glass (acrylic?) prism in an empty tank (beaker?). Arrange the tilted screens above and below. Aim the laser beam straight down to the prism. The beam should end up on the upper screen. Fill the tank with enough water to cover enough of the prism. Now the beam ends up on the lower screen. Show the simple math using Snell's Law that explains the change in the critical angle. $\sin i_{CA} = n_2/n_1$



empty tank: $\sin i_{CA} = 1 \text{ (air)}/1.52 \text{ (glass)} = 0.658 \quad i_{CA} = 41^\circ$

water-filled tank: $\sin i_{CA} = 1.33 \text{ (water)}/1.52 \text{ (glass)} = 0.875 \quad i_{CA} = 61^\circ$