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Shooting Fish in a Barrel: A Demonstration of the Refraction of Light

Walter Trikosko
Stephen F Austin State University, wtrikosko@sfasu.edu

Shooting Fish in a Barrel: A Demonstration of the Refraction of Light

Walter Trikosko, Stephen F. Austin State University, Nacogdoches, TX

This is not a treatise on optics or the index of refraction. It is merely a demonstration that will surprise and engage many of your students. We have all put a pencil in a beaker of water and observed how it appears to bend.[1] Not so much fun or engaging, is it? Why not illustrate this optical effect by taking your students spearfishing? *Simulated* spearfishing, to avoid the financial and legal ramifications.

I intercepted a quiver of 30-in long aluminum shaft arrows that were on their way to the dumpster because, if for no other reason, my office could always use more junk in it. The arrows had part of the fletching missing and dull target points, which made them ideal for this project. I stripped the remaining fletching and adhesive from the shaft, made a facsimile of a speargun, and took the students spearfishing.

Here is how to make your own speargun. Obtain a 3-ft piece of pine (1 x 4 in) and a pack of screw eyes (#14 x 1-1/16 in) with approximately 3/8-in inside diameter eyes at your local home improvement store. I chose the 3/8-in eye size because the diameter of the arrow shafts was 0.30 in. Yours may be different. Lay out the pattern in Fig. 1 on the pine board, cut it out, then round and sand the edges smooth. Insert the screw eyes along the top edge at about 1, 4, 9, and 20 in from the front end of the speargun. Make sure that the eyes all line up since the arrow is powered by gravity alone and must slide through the screw eyes freely (like an arrow through Penelope's 12 axe heads).

I was lucky to find the discarded aluminum arrows. If you aren't so lucky, you can purchase ¼-x-48-in solid fiberglass rod ($5) used for kite making from http://www.intothewind.com. Go ahead and get a vinyl end cap ($0.15) to put on the end of the rod to protect the aquarium. You can pay a little more and get a 0.240-x-32.5-in pultruded carbon tube ($6.09) that slides even easier from http://www.goodwinds.com. Cut the rod to a length of 30 in (76 cm). I would avoid using a wooden dowel. Although they are readily available in the correct size, they will easily warp and bind in the eye screws, especially after getting wet. Keep in mind that since this is propelled by gravity alone, the rod must be smooth and light enough not to break the aquarium after sliding down the gun.

Fill a small aquarium with water and add a "fish." The fish could be a coin or a lump of waterproof modeling clay (not Play-Doh®) shaped like a fish. The speargun needs to be inclined steeply enough for the arrow to slide easily, so place the fish accordingly. Insert the arrow shaft through the screw eyes and have the shooter hold it in place with his thumb. Set the notch at the front of the speargun on the edge of the aquarium and have your students aim for the fish (Fig. 2). Lifting the thumb allows the arrow to slide down the speargun. The last couple of screw eyes should be spaced so as to hold the arrow in place after it hits the fish or the bottom of the aquarium. The gravity-propelled arrow moves slowly enough to follow visually, whereas a power-propelled arrow moves far too fast to track and would probably shatter the aquarium. Breaking the aquarium glass, although exciting, is not the lesson we wish to demonstrate here.

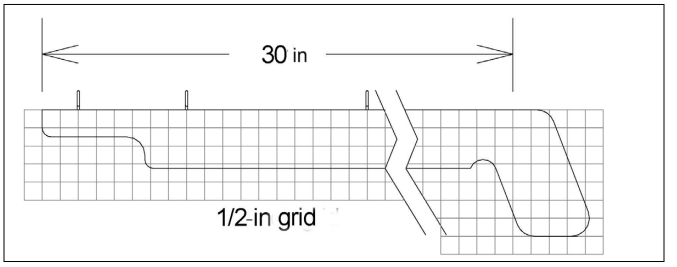

Fig. 1. Pattern for laying out the speargun.

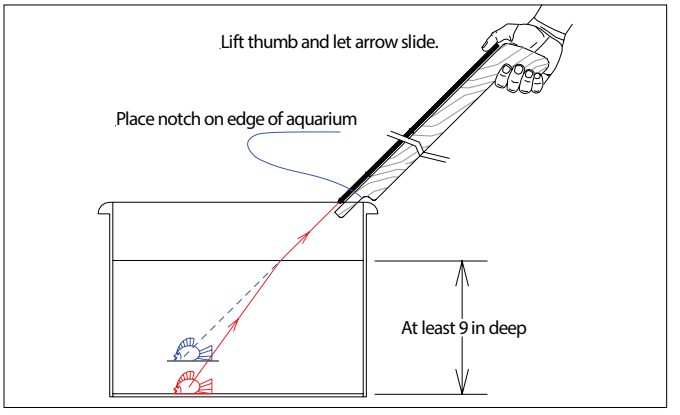

Fig. 2. Diagram showing a spearfisher who will miss the target. The location of the actual fish is shown in red, as is the ray of light from the fish that aligns with the arrow after refraction, while the fish's image and path of the arrow that hits the image (but misses the actual fish) is shown in blue. The arrow is guaranteed to follow a straight line path through the surface of the water because it hits the bottom of the tank before the back of the arrow has left the last two screw eyes atop the speargun.[1]

Just like the pencil of old, the arrow appears to bend when it enters the water, missing the fish. With a little practice most of the students will learn how to compensate for the refraction and hit the fish. You could even make a "Survivor" game out of it; hit the fish and eat, miss the fish and go hungry. Either way, the demonstration drives the point home.

Reference

1. R. A. Serway and C. Vuille, *College Physics*, 9th ed. (Brooks/Cole, Boston, MA, 2012), pp. 783 and 803.

Walter L. Trikosko *is an associate professor of physics at Stephen F. Austin State University.*
wtrikosko@sfasu.edu