Home Science Activity: Moving Arrows

Watch arrows appear to flip direction thanks to refraction of light.

Learning Intentions

Students will recognize the refraction of light at the surfaces of different transparent materials, such as when light travels from air to water or air to glass and be able to apply this understanding to vision and humans' development and function of lenses in glasses, microscopes and telescopes.

Hypothesis

Using the principles of refraction, can your students develop a hypothesis for why this occurs? You could get into Snell's Law (see the Activity 7 from FLEET Schools resource Light: Reflection, refraction, diffraction, How to find a rainbow), but it is sufficient here to understand how light reflects off an object and refracts (changes direction) when it enters a different medium, in this case water. Light will refract toward the normal when it enters a medium that is denser, for example from air to water. When light enters a medium that is less dense, for example from water into air, it will refract away from the normal.

The normal line: This is the imaginary line (drawn as a dotted line) drawn at 90° to the surface of the two substances (in this case air and water). See Figure 2 below.

Materials

- a piece of paper
- a pen or marker
- a glass (round)
- Jug of water

Teacher Notes	Teaching Notes: Running the activity
What is happening: Light reflects off your arrows (or fish, or dragons) and travels toward your eye, but as it enters the water it will change direction (refract) and then refract again as it enters the air. See FLEET Schools resource on refraction and Snell's Law (link). When you view the arrows through the glass from a distance beyond the focal point the arrows are reversed because the light reflecting from the left of the arrow is now on the right; the light reflecting of the right side of the arrow is now on the left. See Figures 1 and 2 below. What is happening here is in some way similar to how your eye works. Light passing through the lens of your eye refracts to a focal point, that, if you have perfect vision, will be on your retina at the back of	**Method** Draw an arrow pointing in one direction on the piece of paper. Hold the paper right behind the glass of water so you can see the arrow. Slowly, move the paper backwards. What happens to the arrow? Alternatives: Draw two arrows on a card pointing the same direction, one above the other (or two colourful fish, two dragons…whatever). Place the card behind the empty glass at the correct distance from the glass. Pour in the water until the water only comes above the level of the bottom picture and not the top one. Observe what happens to the picture you see through the water.

your eye. Our brain then processes and interprets this image. The image at the focal point of your eye will also be upside down, but your brain is clever and works with your ears to know which way is up and corrects this so we perceive it to be the right way up. If you are near-sighted your focal point will be at a point before the retina and for long-sighted people the focal point will be at a point behind the retina. This is why people with this vision impairment have blurred vision. It can be corrected using lenses that shift the focal point to where it should be at the back of the retina.

Extended thinking – more stuff for students to do and think about

Once they have played with Experiment 2, get students to experiment with different shaped containers and develop a hypothesis about what they think the effect will be and why.
For example, try using a square or rectangular container (one with flat sides). What do you predict will happen? Will the arrow reverse?

Get students to draw a ray diagram with light enter a square glass of water and compare it to the ray diagram in Figure 2 above.

Think about how light travels in a straight line and will refract when it enters a different medium on an angle. The greater the angle it enters the greater the angle of refraction. Light hitting the new medium straight on (at 90° to the surface) won't refract. Look at the angle light will enter water sitting in a round glass compared to a square glass. In a glass with straight sides, the arrow or image should not reverse, if you are directly in line with the image behind the glass.

More refraction fun can be had with the Appearing coin activity.

Results

In the first version, if you move the paper back far enough you should see the arrow change direction. In the second version, you should see your arrow (or your fish, dragons, etc) change direction, but only the bottom image that you view through the water.

What do you think causes the picture appear to flip, change direction? Think refraction, which is how light will change direction when it enters a medium of a different density. For example, from air to water such as occurs in our experiment.

Think about the shape of your glass and compare it to the shape of a corrective lens in glasses or a magnifying glass.

Draw ray diagrams to illustrate what is happening to the light as it travels from your arrows through your glass of water, out of the glass and to your eye.

Experiment 2. Make your own magnifying glass

The round shape of the water glass is also acting like a magnifying lens and will make the image you view through the water bigger or smaller depending on the distance it is from the glass. But explaining that is for another experiment. In the meantime, have some fun with this easy activity below.

The concept of refraction is employed to make magnifying glasses or microscopes, telescopes and the lenses for people's glasses to enable them to see clearly. You can make your own magnifying glass using a droplet of water. A droplet of water will have a spherical shape above the surface it is resting on that will act as a lens.

Check out the Babble Dabble Do site for more detailed instructions and videos on this.

	Extended thinking Find the distance of the arrow from the glass where it is reversed. Now move your eye closer to the glass. Does the same reversing arrow effect happen? That is, does the arrow revert back to facing the correct way? What is happening? By placing your eye before the focal point, the image should appear as it does on the paper (not reversed). Check the small upward facing arrow to the right of the focal point in Figure 2. This is where your eye will need to be to see the arrow point the correct way. Can you explain to your class and teacher why, when you place your eye before the focal point that you see the arrow (image) the right way around?

Figures

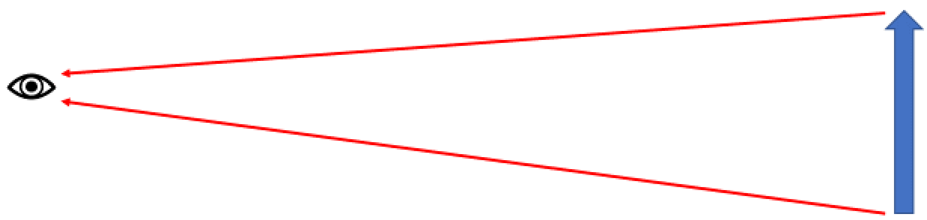

Figure 1. How you would see the arrow without it refracting through a glass of water. You would see it the right way up – as you drew it on the paper.

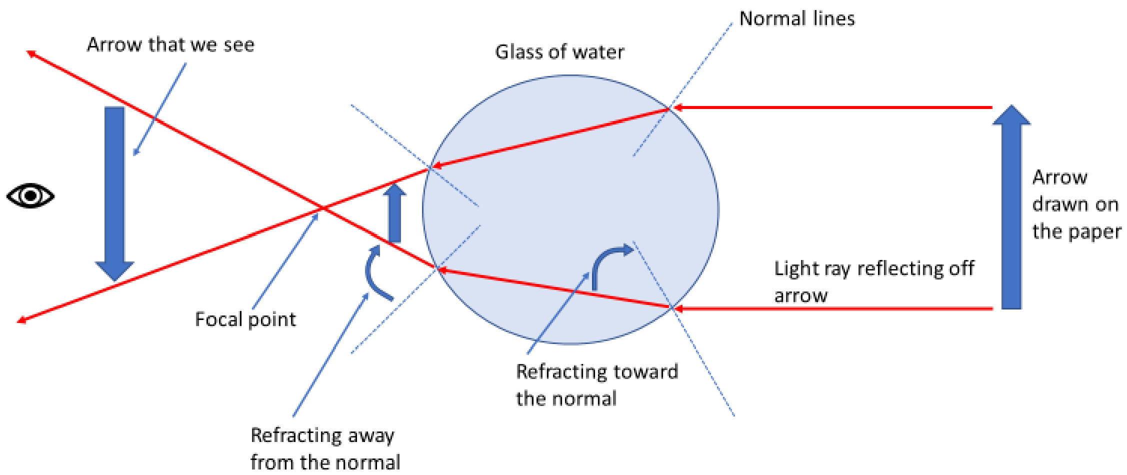

Figure 2. How does the arrow change direction once the glass is filled with water? Follow the light ray from the top of the arrow drawn on the paper as it travels in a straight line through the air toward the glass of water, through the water (where it refracts away from the normal) and then out into the air (where it refracts again this time toward the normal). Notice where the ray of light is when it reaches your eye and compare this to the ray of light that left the bottom of the arrow. The ray of light from the top and bottom of the arrow are reversed once they reach your eye, which is why you see a reversed or arrow facing the opposite direction.