Activity 6. Appearing coin

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Learning Intentions
The activity investigates refraction and its applications in the real world. By the end of this activity, students should be able to:

draw a diagram to show how the light coming from the coin changes direction (refracts) as it moves from water into air
explain that this refraction of light makes the coin appear to be in a different place than it really is
be able to define refraction and understand how the concept is applied to technologies.

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Before the activity:
This activity builds on students' knowledge of light and reflection. Students can get an initial understanding of refraction from FLEET School resource, Light: reflection, refraction, diffraction
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Your hypothesis
There are two parts to this activity and series of questions and hypotheses that should be made as they go.
Question: Why am I unable to see the coin when there is no water in the bowl?
Hypothesis 1. What will happen when I fill the bowl with water?
Hypothesis 3. What will happen when I shine the laser light or insert the skewer down the straw to try and hit the coin?
Question: Why was real position of the coin not where it appeared to be?
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Materials

a bowl
a coin
a jug of water
A partner helps here

Extension

Straw
Laser light or skewer
Blutack

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<tr><td>Teacher Notes</td><td>Teaching Notes: Running the activity</td></tr>
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What is happening?
Light travels in a straight line, but it will change direction when it passes through different materials such as from air to water. This change in direction is called refraction and it is what makes something appear to be in a position it is not.

In our example of the appearing coin, as light reflects off the coin in the bottom of the bowl and exits the water, it changes direction (refracts). This change in direction
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Method
Place the coin in the bowl. Lower yourself so that you can no longer see the coin in the bowl.

Go to Table 1, Appearing coin, and answer the first two questions.

Now it is time to add water. Return to your position where you were unable to see the coin. Pour the water into the bowl. This is where the partner comes in handy to pour
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enables the light to enter our eyes and makes the coin visible. See Figure 2 below.

While not necessary to understand for this activity, when light moves from one medium to another of different density, the speed of light will appear to change. The apparent change in speed is dependent on the medium it travels through. The constant (the c in $E = mc^2$) is the speed of light in a vacuum.

Technically the speed of light does not change, because as it passes through the medium it interacts with the atoms in that different media, changing direction with each interaction, which affects the time it takes to pass through the particular media.

Why does the coin appear where it isn't?
Remember that light travels in a straight line. If you take the refracted light that reaches our eye from the coin, and trace it back in a straight line it will land in the bowl where the coin appears to be (rather than where it actually is). See Figure 2.

Applications of refraction
Think correctional lenses in glasses, microscopes, telescopes, cameras – anything with a lens.

Ask students what they think our world might be like if we had not worked out refraction and applied it to these technologies. How much of our world would we not understand if we had not be able to view it down a microscope – think bacteria.

Would we still think the Sun revolved around the Earth if we did not have the telescope?

What about rainbows? Without refraction we would be unable to witness one of nature's wonders. See Activity 7, *How to find a rainbow* that takes students on a deeper exploration of refraction, and they get to build a rainbow finder.

the water in for you, while you keep your eyes where you can't see the coin.

Keep pouring the water into the bowl (don't overflow the bowl – messy).

What do you notice? What happens to the coin?

This should be the whoa moment when the coin magically becomes visible.

Complete the final questions in Table 1.

Extension
This activity is a bit like spear fishing. Take the straw and cut it in half, give the other half to the partner.

Place the coin in the middle of the bowl.

Use the Blutak to stick the straw to the side of the bowl. The partner sticks their straw on the opposite side of the bowl.

Use the straw as an aiming tool. Look down the straw and move the straw around until you are looking at the middle of the coin. That is, the straw is aimed at the middle of the coin.

Hypothesis time: If you have a laser light or skewer and you shine the light down the straw or insert the skewer down the straw that is aimed at the middle of the coin, what do you predict will happen? Go to Table 2, Coin fishing, to complete your hypothesis.

Now test your hypothesis. Shine the laser light down the straw or use the skewer and insert it into the straw and down into the water. You are trying to spear the coin.

What happens? Did you hit where you aimed? Describe your observation in Table 2.

Imagine if you were trying to spear a fish for dinner. What would you have to do with your aim to make sure you did not go hungry?

	Answer the rest of the questions in Table 2, Coin fishing.

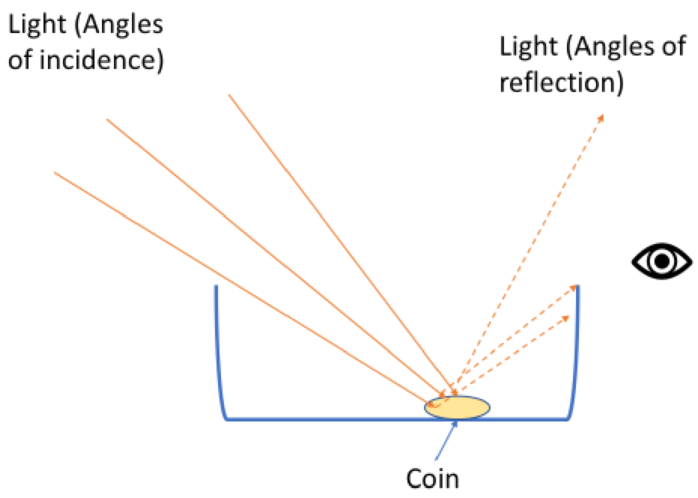


Figure 1. As light reflects off the coin in a bowl without water, there is no refraction and if our eye is positioned below where the reflected light passes, we cannot see the coin.

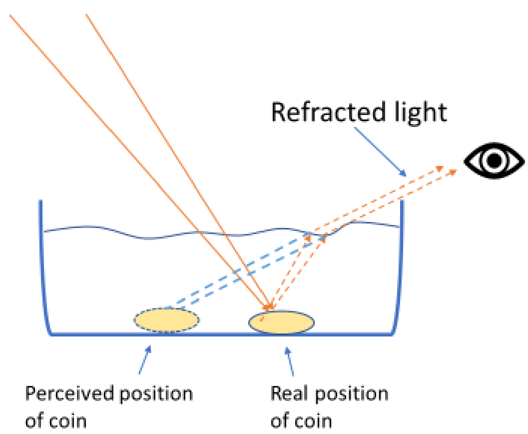


Figure 2. When light reflect off a coin in a bowl of water, it refracts (changes direction) away from the normal. The change is direction enable the light to enter our eye and make the coin visible, but the refraction makes the coin appear in a different position.

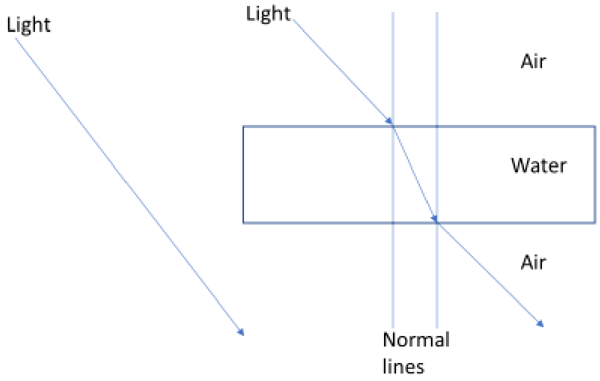
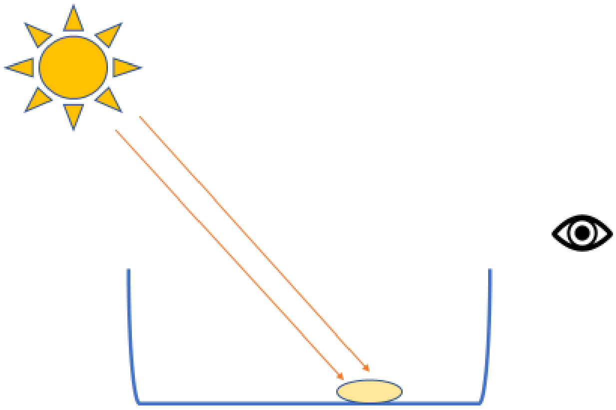


Figure 3. As light passes from one medium to another it will change direction (refracts) and slow down, or more accurately take a longer route from its point of entry to the point of exit and therefore appear to have slowed down. In this case because water is denser than air it refracts toward the normal line. As it exits the water into the air it will refract away from the normal line.

See Tables 1 and 2 on the following pages.

Table 1. Appearing coin

Describe why you are unable to see the coin?
Complete the diagram below to show what happens to each ray of light reflected off the coin that means you are unable to see the coin when there is no water in the bowl. 
Describe your observations when the water was poured into the bowl
Complete the diagram below to show what happens to each ray of light as it reflects off the coin and then exits from the water to the air. Show how the light refract to enable us to see the coin when the bowl is full of water. Note: For simplicity the refraction of the light as it enters the water is not shown, only the refraction of the light as it exits the water as that is the part crucial to understanding why the coin appears.

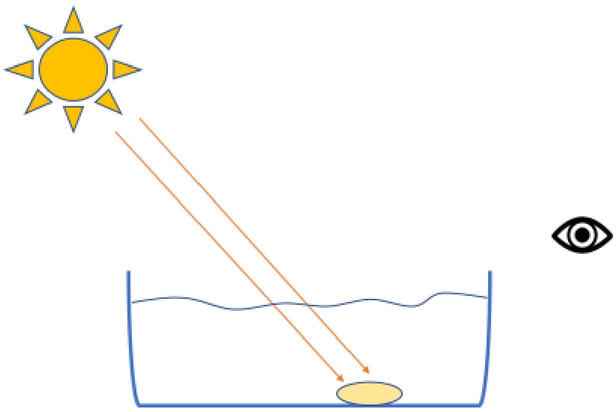
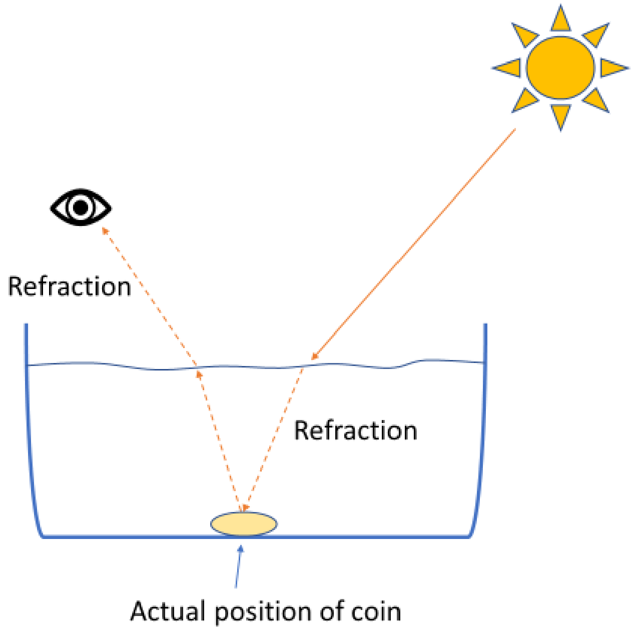


Table 2. Coin Fishing

Your hypothesis: what is going to happen when you shine the laser light or insert the skewer down the straw to try and hit the coin?
What did you observe when you shone the laser light or inserted the skewer down the straw to try and hit the coin?
Your explanation: Why do you think the coin was not where it appeared to be?
Complete the diagram to include the coin where it appears to be and the light rays that illustrate this effect. Use what you learned from the appearing coin to help here. Note: Here the refraction of the light as it enters the water is included, which is what would have happened in the appearing coin diagram.



Define refraction
Can you list examples where refraction is used to develop technologies?

Acknowledgement: This activity was created by Tristan Fuhrer and Nicholas Chang Wollmann from McKinnon Secondary College, in collaboration with FLEET