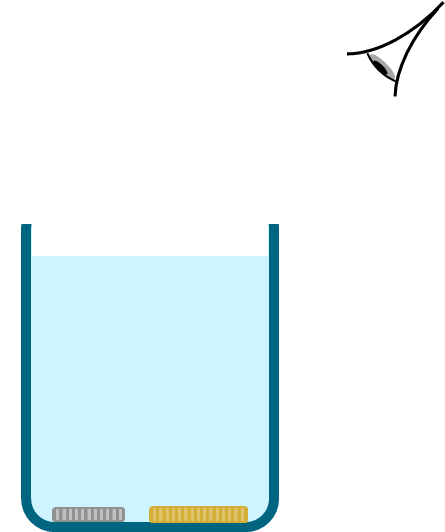
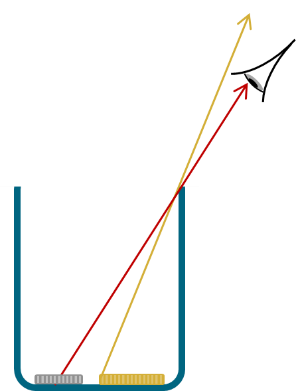
**On the bottom**



There are two coins on the bottom of a mug.

Tyler can see a silver coin.

He cannot see the gold coin.

Tyler fills the mug with water.

The coins do not move.

Tyler does not move.

**Predict**

What will Tyler be able to see at the bottom of the mug?

**Explain**

Why do you think he will see this?

|  |
| --- |
| **Carry out the investigation** |

**Observe**

Describe what you can see when the mug is full of water.

**Explain**

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

*Physics > Big idea PSL: Sound, light and waves > Topic PSL3: Making images > Key concept PSL3.2: Refraction and lenses*

|  |
| --- |
| **Response activity** |
| **On the bottom** |

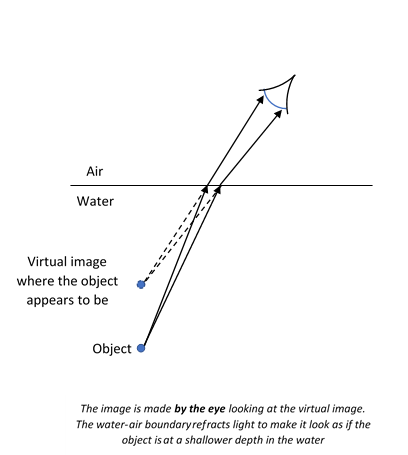
**Overview**

|  |  |
| --- | --- |
| Learning focus: | All light from each point of an object that passes through a converging lens is bent (refracted) to a corresponding point in a sharp image. |
| Observable learning outcome: | Explain why water can appear shallower than it really is. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Refract, refraction, apparent depth |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic question:

* Diagnostic question: How deep?

**What does the research say?**

A common strategy for teaching students about refraction is to demonstrate examples of refraction phenomena and to explain the observations using ray diagrams that show how light is bent by glass blocks. In this approach students may use a ray box to explore how light travels through a parallel sided glass block to understand the nature of refraction. They change the angles of incidence to establish: a change of direction only occurs at an interface; light travelling perpendicular to the interface is not refracted; and light bends towards the ‘normal’ when entering more dense medium and vice versa (Tear, 2011).

In order to understand how ray diagrams explain refraction: students first need to understand that light is emitted in all directions from each point on the source (Rice and Feher, 1987; Dedes and Kanstantinos, 2007; Galili and Hazan, 2000; Andreou and Raftopoulos, 2011); and the idea that rays *represent* the direction light travels in (Andreou and Raftopoulos, 2011).

A *virtual image* formed by refraction is not really an image – it is not a *real* image. As with observing reflections in a plane mirror, it is important to recognise that the observer is an inherent part of the optical system (Galili and Hazan, 2000; Andreou and Raftopoulos, 2011) and that the real image which we observe is formed on the retina of the eye. As with plane mirrors, it is helpful to use dashed, ruled lines to work out where each ray of light appears to come from; it is here that the object is seen to be because the image formed on the retina is exactly the same as if the object *were* here. The ray diagram shown here is used ‘to find where the object appears to be’.

**Ways to use this activity**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think will happen, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now carry out the practical**.**

* Place two coins at the bottom of a mug, at opposite edges.
* With one coin towards the observer, the observer moves backwards until they can no longer see the coin that is closest to them in the mug. They do not move from here.
* Without moving the mug or the coins in the mug, a partner carefully fills the mug with water.
* The observer should see a change in what they see inside the mug.

After the practical each group should be given the opportunity to change, or improve their explanation. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

**Equipment**

For each student/pair/group:

* Cup
* Two coins
* Beaker of water

**Technician notes**

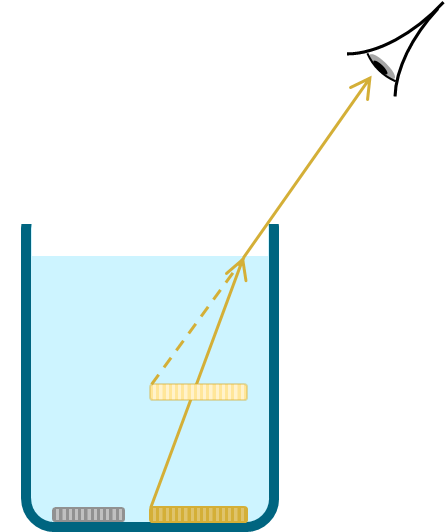
Any opaque cup with straight sides can be used.

Coins, or tiddly-winks could be stuck to the bottom of the cups if they are to be used repeatedly for this experiment. If stuck down the coins should be opposite each other and close to the edge of the bottom. Any loose coins or washers can be used so long as they sink in water.

**Health and safety**

Water can spill and cause a trip hazard.

Using drinking cups may tempt some students to take a drink from them.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

The gold coin will come into view because light from the coin is refracted at the surface of the water.

Both coins appear to be higher up in the water and the mug appears shallower than before the water was added. This is because the light from the bottom of the mug is refracted at the surface of the water. The bottom appears to be where it would be if the light had reached Tyler’s eye is a straight line.

A good explanation should include a diagram.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Andreou, C. and Raftopoulos, A. (2011). Lessons from the history of the concept of the ray for teaching geometric optics. *Science and Education,* 20**,** 1007-1037.

Dedes, C. and Kanstantinos, R. (2007). Teaching image formation by extended light sources: the use of a model derived from the history of science. *Research in Science Education,* 39**,** 57-73.

Galili, I. and Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education,* 22(1)**,** 57-88.

Rice, K. and Feher, E. (1987). Pinholes and images: childres's conceptions of light and vision. *Science Education,* 71(4)**,** 629-639.

Tear, C. (2011). Sound, light and waves. In Sang, D. (ed.) *Teaching secondary physics.* London: Hodder Education.