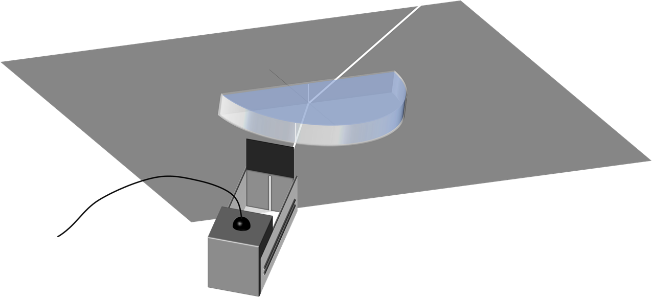
**Turning expectations**

A clear plastic semi-circular box is filled with a liquid.

It can be used to investigate how different liquids refract light.

Two different liquids are compared.

Light travels slower in the second liquid, which is optically more dense.

**Predict**

How do you think the second liquid will refract light differently than the first?

**Explain**

Why do you think the light will refract in this way?

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| **Observe how the second liquid refracts, compared to the first.** |

**Observe**

Measure the angles of refraction for the same incident ray refracted by each liquid in turn.

**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 PSL6: Wave properties of light > Key concept PSL6.1: Refraction and dispersion*

|  |
| --- |
| **Response activity** |
| **Turning expectations** |

**Overview**

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| Learning focus: | Light has wave properties, which allows it to be refracted at a boundary between one transparent medium and another in which it travels at a different speed. |
| Observable learning outcome: | Compare the refraction of light at the boundary of different pairs of transparent media. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Refract, refraction, wavelength, wavefront, angle of incidence, angle of refraction, normal |

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

* Diagnostic question: Liquid refraction

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| **B** | **BRIDGING**  This activity explores ideas that are usually taught at age 16-19, to build a bridge to later stages of learning. |

**What does the research say?**

Wavefront diagrams can be used to explain how light is refracted, but students struggle to interpret these. They find it hard to visualise how the wave pattern moves out from the source, or relate it to a photograph [or a real wave] (Knight, 2004).

Wosilait et al. (1999) suggest that the process of developing a wave model of light should begin by using the context of water waves. This gives students the opportunity to develop and consolidate their understanding of wavefront diagrams by articulating what happens at different points in space as a wave moves forwards (Knight, 2004). This understanding could then be extended to explain refraction.

As with mechanical waves, the speed of a light wave is determined almost entirely by the medium it is passing through. The higher the optical density of a transparent medium, the slower the speed of light through it. Changing the speed of a light wave does not alter its frequency.

Explanations of refraction should include rays, but also include wavefronts and ideas about changing speed and therefore changing wavelength (Sengoren, 2010).

**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, or watch a demonstration. You will need to decide whether it is better for each group to carry out the practical and risk some unexpected observations, or to demonstrate the activity so that everyone *observes* the same thing.

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 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 a demonstration:

* Ray lamp and slit
* Collimating lens for ray lamp
* Power supply
* Refraction cup filled with water
* Refraction cup filled with glycerol
* A3 sheet of plain paper
* Protractor

For each student/pair/group:

* Ray lamp and slit
* Collimating lens for ray lamp (not essential)
* Power supply
* Plain paper
* Protractor
* Refraction cup
* Access to water and a light-coloured cooking oil or glycerol

**Technician notes**

A *refraction cup* is a protractor shaped container, with sides that can hold a liquid. Liquids can be compared that have very different refractive indexes, which mean they refract the same incident ray by measurably different angles. The same experiment does not work with glass and acrylic (Perspex) blocks because they each have almost the same refractive index.

The second liquid need a significantly higher refractive index than the first one. Water should be used as the first liquid.

|  |  |
| --- | --- |
| Suitable liquid | Refractive index |
| Water | 1.33 |
| Glycerol (Propane- 1,2,3-triol) | 1.47 |
| Cooking oil | 1.46 – 1.47 |

**Health and safety**

Glycerol (ethane-1,2-diol) is classified as harmful and should not be used in this investigation. Instead use glycerol (Propane- 1,2,3 Triol). A light-coloured cooking oil may be used instead of the glycerol, although this should be trialled in appropriate light levels to ensure the rays of light are all clearly visible.

Steps should be taken to contain spills to avoid slip hazards.

Glycerol should not be disposed of down a sink (see the relevant CLEAPSS HazCard for disposal advice).

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**

With an angle of incidence is 30o, the angle of refraction will be about 42o for water and 47o for glycerol or cooking oil.

Light travels more slowly in glycerol (or cooking oil) than in water, so at the liquid-air boundary there is a bigger change in speed when light emerges from glycerol. Refraction is caused by the change of speed of light at a boundary and the bigger the change of speed, the more the light is refracted.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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