**How deep?**

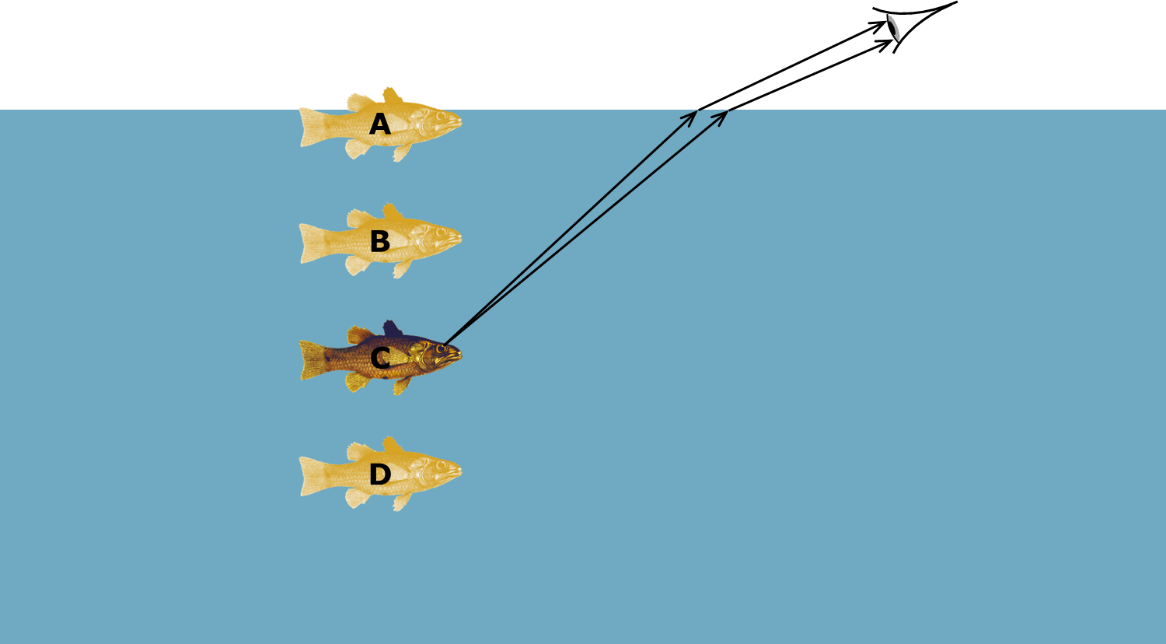
A fish is swimming near to Leah’s boat.

It is hard to know how deep the fish is.

Light from the fish refracts at the surface.

Leah looks at the fish.

Where does the fish appear to be?



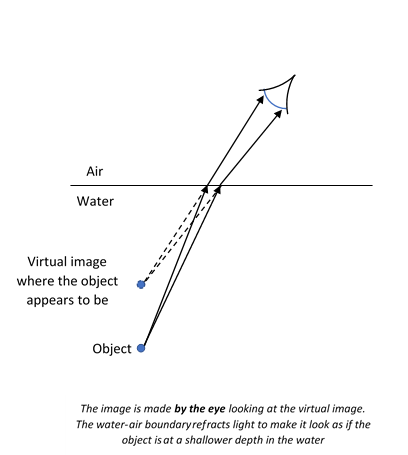
*Physics > Big idea PSL: Sound, light and waves > Topic PSL3: Making images > Key concept PSL3.2: Refraction and lenses*

|  |
| --- |
| **Diagnostic question** |
| **How deep?** |

**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. |
| Question type: | Simple multiple choice |
| Key words: | Refract, refraction, apparent depth |

**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 question**

Students should complete the question individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

Answer B

**How to respond - what next?**

Many students think that a mirror forms an image that can be viewed as if the mirror were a photograph (Ceuppens et al., 2018; Galili and Hazan, 2000). Answer A suggests this misunderstanding is being applied to this question and that students think an image forms on the surface.

Answer C is not taking into account the role of the brain, which interprets light that forms images on the eyes’ retinas arriving in straight lines.

Answer D suggests students who know that objects appear at different depths in water and who are guessing. This may be the same reason why some students choose answer B.

If students have misunderstandings about why the fish appears to be at depth B, it can help to use structured discussion to guide the class through how we judge position. Looking at an object, each eye looks from a slightly different angle to the other. The size of the angle is translated by the brain into a position. Young babies learn this by trial and error as they reach out for objects. If when we look into water light enters our eyes at the same angle as it would from an object that is at a shallower depth (with no water), then that is where the object appears to be.

An informative exercise students can do in pairs is for one of them to hold a pencil horizontally by its tip, and the second student is challenged to touch (quickly) the other end of the pencil with a fingertip. When carried out with two eyes open, the second student rarely misses. With one eye covered up the task is much more problematic. This works instinctively unless there is something in the way that changes the direction of the light.

The following BEST ‘response activities’ could be used in follow-up to this diagnostic question:

* Response activity: On the bottom
* Response activity: Seeing the bottom

The first activity gives students experience of observing an underwater object appearing to be at a different depth when looked at from above the water.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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