**Bending bananas**

Refraction bends light as it moves from one transparent medium into another – because a transparent medium can change the speed of light.



*Each transparent medium has a refractive index.*

*The bigger the refractive index of a medium, the slower light travels through it.*

1. What is the rule for the refraction of light moving ***into*** water?

Pick ***one*** statement in each row to explain how.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | When light moves from air into water … | | | |
| 2 | … it slows down. | … it speeds up. | | … it continues at the same speed. |
| 3 | It changes direction at the boundary. | It changes direction through the water. | | It changes direction through the air. |
| 4 | It bends towards the normal line. | | It bends away from the normal line. | |
| 5 | Light continues in a straight line if the angle of incidence is 0o. | Light continues in a straight line if the angle of incidence is 90o. | | Light always bends as it moves from air into water. |

Refractive index of air = 1.0 Refractive index of water = 1.3 (water is optically more dense)

2. What is the rule for the refraction of light moving ***out of*** water?

Pick ***one*** statement in each row to explain how.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | When light moves from water into air … | | | |
| 2 | … it slows down. | … it speeds up. | | … it continues at the same speed. |
| 3 | It changes direction at the boundary. | It changes direction through the water. | | It changes direction through the air. |
| 4 | It bends towards the normal line. | | It bends away from the normal line. | |
| 5 | Light continues in a straight line if the angle of incidence is 0o. | Light continues in a straight line if the angle of incidence is 90o. | | Light always bends as it moves from air into water. |

Refractive index of air = 1.0 Refractive index of water = 1.3 (water is optically more dense)

*Physics > Big idea PSL: Sound, light and waves > Topic PSL6: Wave properties of light > Key concept PSL6.1: Refraction and dispersion*

|  |
| --- |
| **Diagnostic question** |
| **Bending bananas** |

**Overview**

|  |  |
| --- | --- |
| 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: | Describe rules for the refraction of light at a boundary between transparent media. |
| Question type: | Explanation story |
| Key words: | Refract, refraction, incident ray, angle of incidence, normal, refracted ray |

**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 an optically more dense medium and vice versa (Davenport, 2021).

In a study of (n=213) Greek students age 14-15, who had previously studied refraction, Fyttas et al. (2013) found that about half thought that light continued in a straight line at a boundary between air and glass, because glass is transparent. Significant numbers thought wrongly that light was wholly reflected at a boundary or that it was refracted the wrong direction. When answering questions about refraction most did not consider a general rule for refraction.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It is best done as a pencil and paper exercise.

Students should read the statements and follow the instructions on the worksheet. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*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 the 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.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

**Rule 1** (moving into an optically more dense medium, with a higher refractive index)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | When light moves from air **into** water … | | | |
| 2 | … it slows down. | … it speeds up. | | … it continues at the same speed. |
| 3 | It changes direction at the boundary. | It changes direction through the water. | | It changes direction through the air. |
| 4 | It bends towards the normal line. | | It bends away from the normal line. | |
| 5 | Light continues in a straight line if the angle of incidence is 0o. | Light continues in a straight line if the angle of incidence is 90o. | | Light always bends as it moves from air into water. |

**Rule 2** (moving into an optically less dense medium, with a lower refractive index)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | When light moves from air **into** water … | | | |
| 2 | … it slows down. | … it speeds up. | | … it continues at the same speed. |
| 3 | It changes direction at the boundary. | It changes direction through the water. | | It changes direction through the air. |
| 4 | It bends towards the normal line. | | It bends away from the normal line. | |
| 5 | Light continues in a straight line if the angle of incidence is 0o. | Light continues in a straight line if the angle of incidence is 90o. | | Light always bends as it moves from air into water. |

**How to respond - what next?**

The general rules, for how light refracts at a boundary between two transparent media, depend on the difference in speed that it travels in each.

(Light travels at its maximum possible speed of 3.00 x 108 m/s in a vacuum. The speed of light in air is the same, to three significant figures, and about three quarters of this speed in water.)

Often students do not use the general rules described here to work out how light refracts when it passes through a lens or a prism. Instead they make best ‘guesses’ based on what they expect to happen.

If students have misunderstandings about describing rules for the refraction of light at a boundary between transparent media, it can help to provide them with the opportunity to carry out hands on practical work in order to investigate what happens.

To consolidate understanding, they could also be given the opportunity to work in pairs or small groups to combine both rules into one short and accurate rule, using their own words.

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

* Response activity: Measuring refraction

**Acknowledgments**

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Image: Steve Buisinne from Pixabay.

**References**

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Fyttas, G., Komis, V. and Ravanis, K. (2013). Ninth grade students' mental representations of the refraction of light: didactic implications. *Mexican Journal of Physics,* 59**,** 133-139.