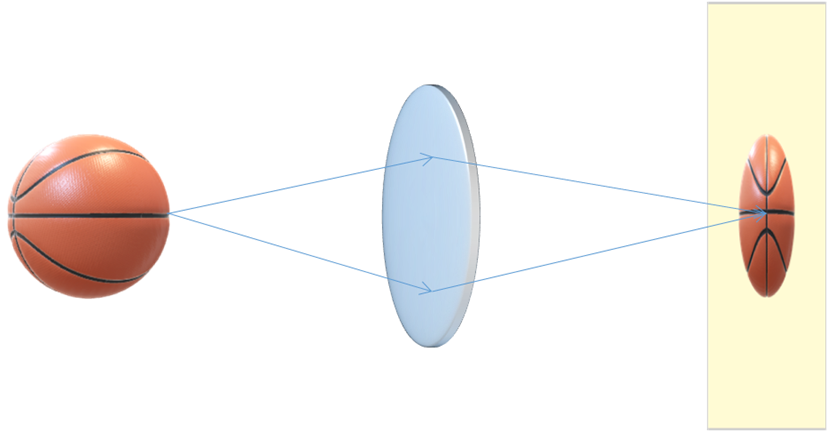
**Refracting rays**

A ray of light shows the direction light moves.

When light moves from air into glass it can refract.

It can change direction at the boundary between air and glass.

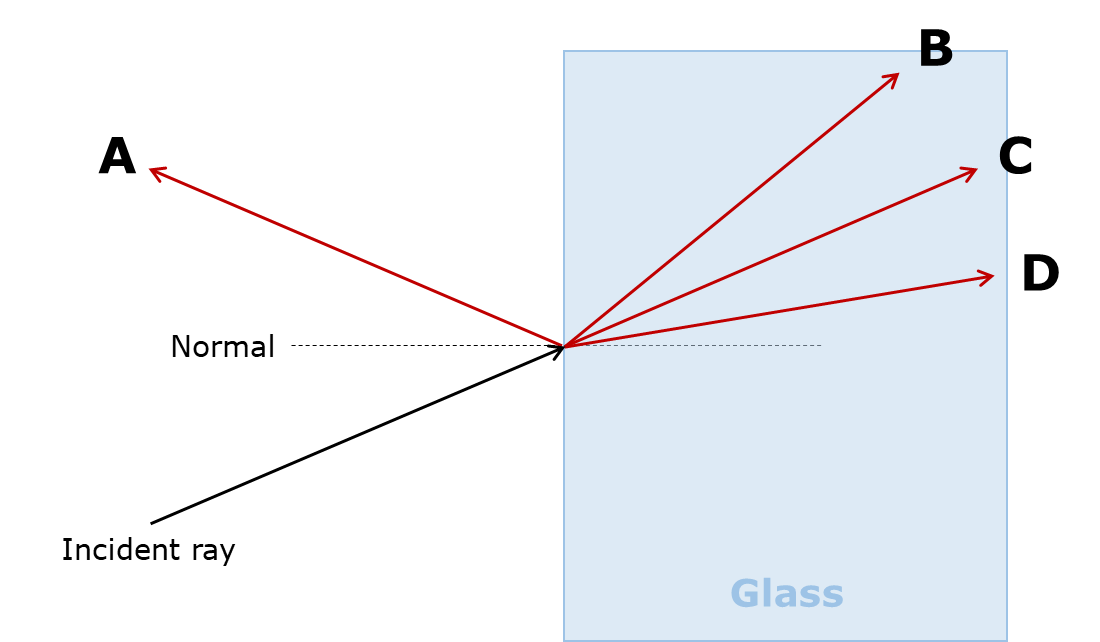
Light can also refract when it moves from glass into air.



A lens can refract light to form an image on a screen.

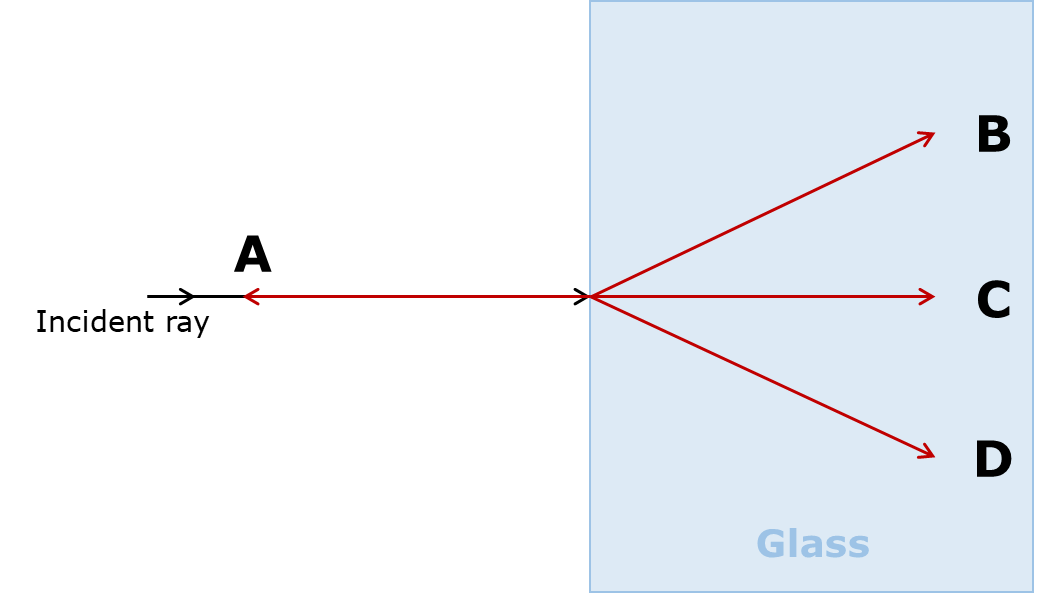
**1.** Which ray of light shows what happens at a boundary between

air and glass?



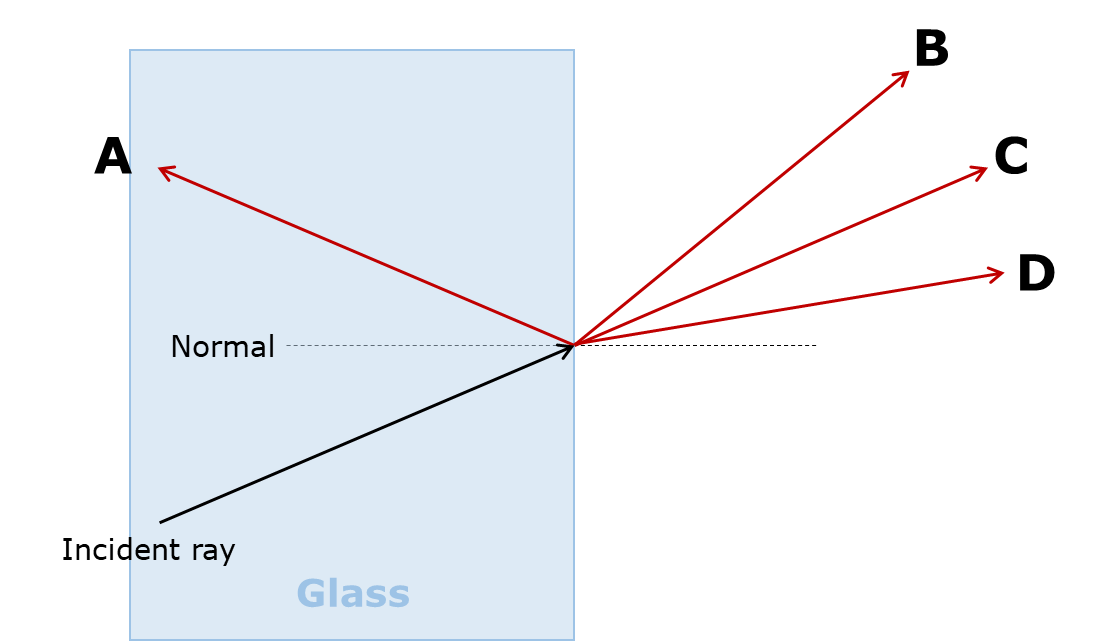
**2.** Which ray of light shows what happens at a boundary between

air and glass?



**3.** Which ray of light shows what happens at a boundary between

glass and air?



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

|  |
| --- |
| **Diagnostic question** |
| **Refracting rays** |

**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: | Use ray diagrams to show how light refracts at a boundary between transparent media. |
| Question type: | Simple multiple choice |
| Key words: | Refract, refraction, incident ray, normal, refracted ray, reflected ray |

|  |  |
| --- | --- |
| **P** | **PRIOR UNDERSTANDING**  This diagnostic question probes understanding of ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

**What does the research say?**

Galili and Hazan (2000) found over half of 14- to 16-year-olds (n=166) consider rays to be actual physical things that are the constituents of light, perhaps because it is rarely made explicit in teaching that rays are imaginary lines that show the direction in which light is travelling (Andreou and Raftopoulos, 2011).

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 significant numbers thought wrongly that light was wholly reflected at a boundary or that it was refracted the wrong direction. About half thought that light continued in a straight line at a boundary between air and glass, because glass is transparent.

**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**

1. D

2. C

3. B

**How to respond - what next?**

Light travelling perpendicular to the boundary is not refracted; and light bends towards the ‘normal’ when entering an optically more dense medium and vice versa.

The following are results of a study of (n=213) Greek students age 14-15, who had previously studied refraction (Fyttas et al., 2013):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Ray is reflected or diffused | Ray continues straight | Ray bends towards the normal | Ray bends away from the normal |
| 1. Moving into an optically more dense medium. | 21% (A) | 58% (C) | **13% (D)** | 9% (B) |
| 1. When the angle of incidence is 90o. | 33% (A) | **51% (C)** | - | 16% (B/D) |
| 1. Moving into an optically less dense medium. | 14% (A) | 57% (C) | 10% (D) | **20% (B)** |

N.B. The students were given the diagnostic questions used here, but without a choice of answer.

The most common misunderstanding is that light continues in a straight line because both the air and the glass are transparent.

In their earlier studies students are likely to have experienced rays of light reflecting and refracting at the surface of a glass block. The answers given in the study (Fyttas et al., 2013) suggest that students, who do not think light continues in a straight line, are largely guessing between the other options. This view is backed up by the fact that only 6% of students in the study were able to give a scientifically correct explanation for their choice.

If students have misunderstandings about how light refracts 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.

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

* Response activity: Measuring refraction

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), based on questions used by Fyttas et al. (2013)

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.

Davenport, C. (2021). Waves. In de Winter, J. & Hardman, M. (eds.) *Teaching Secondary Physics.* 3rd ed. London: Hodder Education.

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