**Refracting light**

Light can refract at a boundary between air and glass because it has the properties of a wave.



A light wave crosses the boundary between air and glass.

What happens to the light wave as it enters the glass?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Its speed becomes slower. |  |  |  |  |
| **B** | Its wavelength becomes shorter. |  |  |  |  |
| **C** | Its frequency is reduced. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Refracting light** |

**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 a wave model to explain how light refracts. |
| Question type: | Confidence grid |
| Key words: | Refract, refraction, frequency, wavelength, wavefront |

**What does the research say?**

The speed of a wave depends on the properties of the medium it is passing through and is independent of the wave’s frequency or the size of disturbance (amplitude). In a study of (n=598) students aged 15 to 16, Caleon and Subramaniam (2010) found that over 70% held the common misunderstanding that the speed of a mechanical wave depends on frequency. Studies by Tongchai et al (2011) of (n=324) senior high school students, Wittmann, Steinberg and Redish (1999) of (n=92) students enrolled onto a university physics course and Tumanggor et al (2019) of trainee physics teachers (n=35) all found similar results.

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 question**

Students should complete the confidence grid 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.

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**

Statements A and B are right, and statement C is wrong.

**How to respond - what next?**

Light moves through glass at a slower speed because glass is optically more dense than air. The frequency of the light wave remains constant, and the wavelength is reduced. This is because during the time of one complete wave (which remains constant) the wave travels forward a shorter distance.

A Some students may think that light travels at the same speed in glass as in air because they are aware that ‘all electromagnetic waves travel at the same speed, which is the speed of light’ and that the speed of light is ‘fixed at 3.00 x 108 m/s’. However, light and electromagnetic waves only travel at their fastest speed in a vacuum. In glass or in water the speed of light falls by about a quarter and a third respectively.

B As light waves slow, they move forward a shorter distance for each complete vibration, which means the wavelength is less.

C Often students make a false connection between the speed of vibration and the speed at which a wave moves forward. These students are likely to think that a slower moving wave has a lower frequency.

At the air-glass boundary there is no mechanism for changing the number of waves per second.

If students have misunderstandings about using the wave model to explain how light refracts, it can help to show them how water waves refract. You could use a ripple tank, or show video clips from the internet. With a ripple tank, perhaps make a slow-motion video recording using a smartphone and show this to the class using a visualiser.

Careful questioning should elicit understanding that:

* each line on a wavefront diagram represents the top of a water wave;
* across the boundary between deep and shallow water, the crests of a wave are each continuous;
* the part of each crest in deep water moves more quickly than the section of the same crest moving in shallow water;
* and when all of a wave crest has crosses the boundary, it swings round because, for a time, one end of the wavefront is moving faster than the other end.

To help consolidate understanding students could be asked to work in pairs or small groups to explain the refraction of light their own words.

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

* Response activity: Modelling refraction
* Response activity: Explaining refraction

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG), photograph by ajizai from Wikimedia Commons.

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