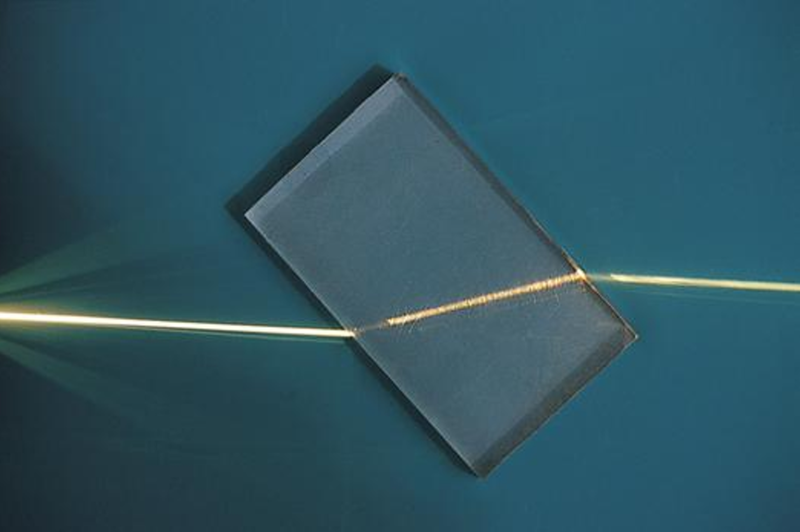
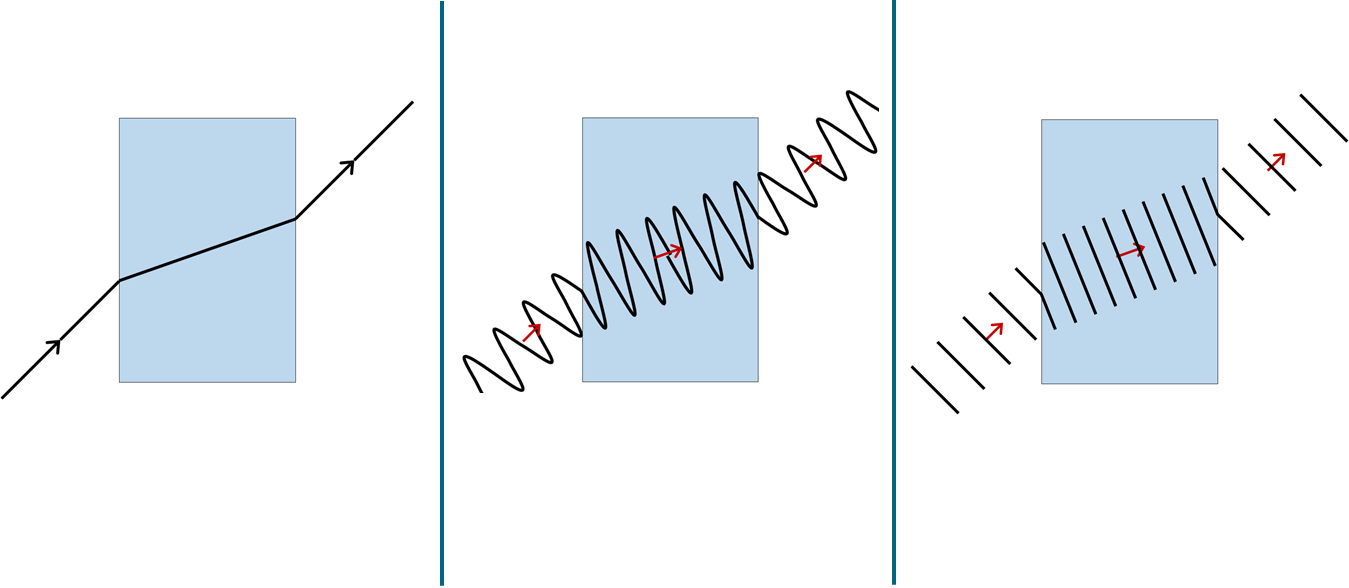
**Representing light**

Light can refract at a boundary between one transparent medium and another.



There are different ways to represent light.

Which is the best way to represent light to **explain how** it refracts?



**B** Wave diagram

**C** Wavefront diagram

**A** Ray diagram

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

|  |
| --- |
| **Diagnostic question** |
| **Representing 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: | Simple multiple choice |
| Key words: | Refract, refraction, wavefront |

**What does the research say?**

Fredlund, Airey and Linder (2012) found that even experienced undergraduate students tend to attempt to explain refraction using ray diagrams first, and wave theory only when this approach fails. They postulate that this is because ray diagrams are used more often and students are most familiar with them.

In a similar study in Turkey (n=175, age 17-19) Sengoren (2010) found that many students understood that wave theory was necessary to explain the refraction of light, but to try to explain refraction they were more likely to draw a sinusoidal wave bending at a boundary than they were to use a wavefront diagram.

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).

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 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 answer**

C

**How to respond - what next?**

Refraction can be explained using the wave nature of light.

As light moves into the glass block it slows down and each wave front of light moves forward more slowly. The wavelength of the wave in glass is less than in air (for light of a particular frequency).

Diagram C is the only one that can show how this happens. The change of speed of the wave in glass turns the wave because, for a time, one end of the wavefront moves more quickly than the other. Wavefronts can also explain why light waves do not refract if they meet a boundary at right angles.

Diagram A is the best one for *describing* how light is refracted in a glass block, but cannot be used to explain how the light bends at a boundary.

Diagram B shows an understanding that light has wave properties, but cannot be used to explain how the light bends at a boundary.

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

*Further guidance*

Historically some scientists thought of light as a stream of particles moving along light rays. Reflection can be explained using this model, but to explain refraction requires the wave properties of light. (The best model we now have is called wave-particle duality. In this model light is made of photons which can be thought of as little packets of waves.)

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

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

**References**

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