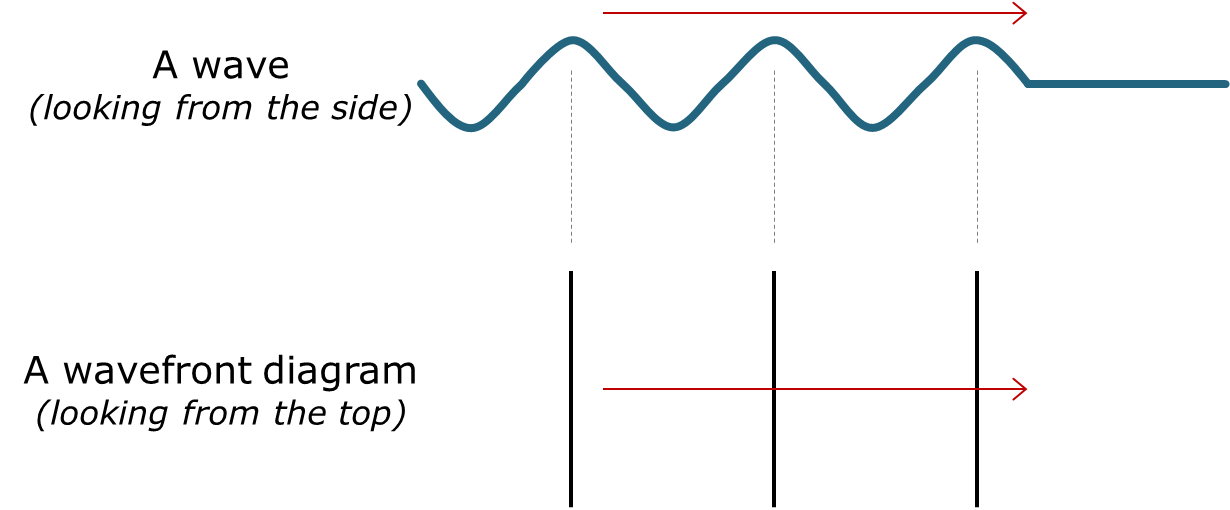
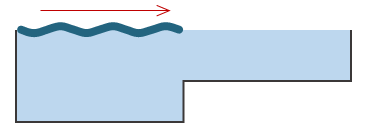
**Refracting water waves**

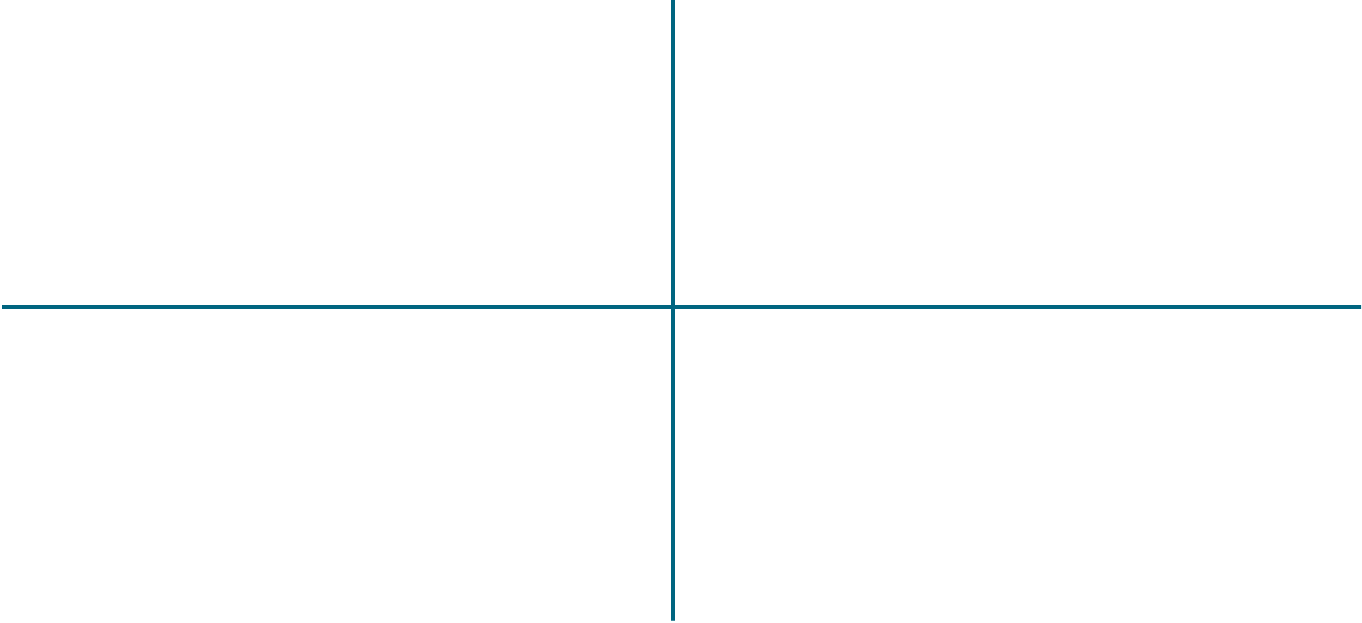
A wavefront diagram shows the crests of a wave.

It shows the tops of a wave from above.



As they move into shallow water, water waves slow down and refract.

Which wavefront diagram shows how water waves refract?

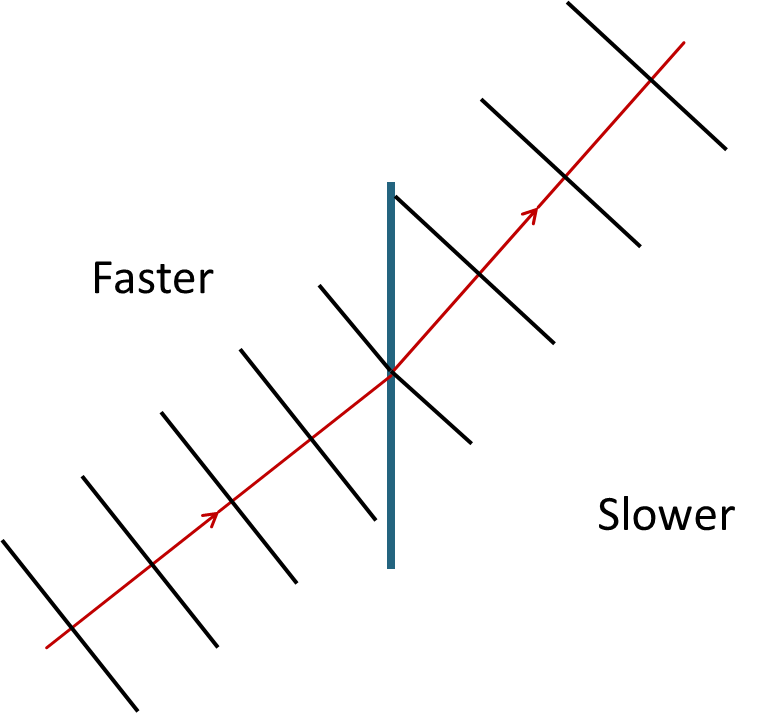
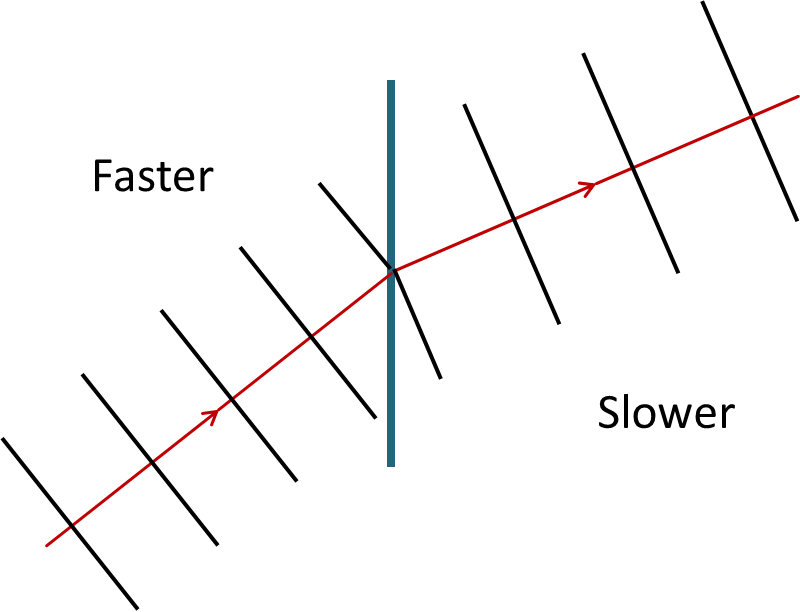
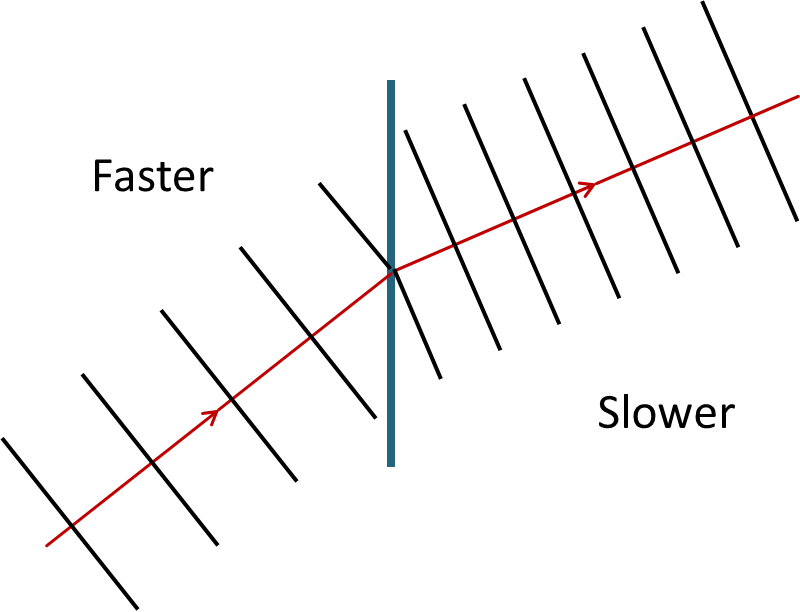
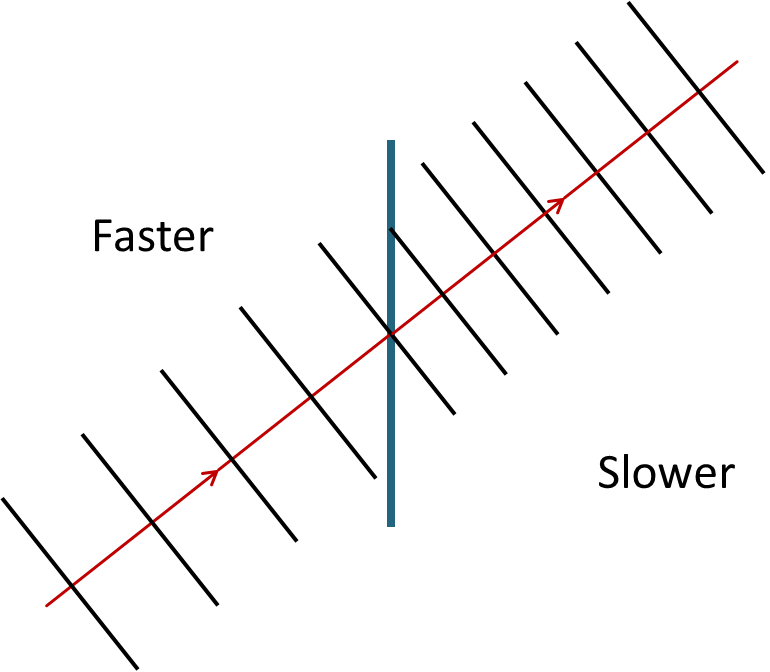


**A**

**D**

**C**

**B**



*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 wavefront diagrams to show how water waves refract. |
| Question type: | Simple multiple choice |
| Key words: | Refract, refraction, wavefront, crest |

**What does the research say?**

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).

Wosilait et al. (1999) suggest that the process of developing a wave model of light should begin by using the context of water waves. This gives students the opportunity to develop and consolidate their understanding of wavefront diagrams by articulating what happens at different points in space as a wave moves forwards (Knight, 2004). This understanding could then be extended to explain refraction.

In a study of (n=598) students aged 15 to 16, Caleon and Subramaniam (2010) found that over 70% held the common misunderstanding that wave speed 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. This can lead to the misunderstanding that the longer the wavelength of a wave after it is refracted, the slower the wave is travelling. The opposite is in fact true.

**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**

1. B

**How to respond - what next?**

As the water wave moves into shallow water it slows down and each wave front moves forward more slowly. The wavelength of the wave in shallow water is shortened.

Diagram B is the only one in which the top end of the wavefront travels at a steady speed in the deep water and the bottom end of the wavefront travels at a steady slower speed in shallow water.

Options C and D show each wave front further apart. Some students may think that the slower a wave, the fewer the number of wavefronts. They are linking the wrong ‘number’ on the diagram with speed or thinking wrongly that frequency of a wave decreases with speed.

Option C is consistent with the wave travelling faster in shallow water. In option D the direction of refraction is correct, and may have been remembered, but the separation of the wavefronts shows a wave that is moving faster in the shallow water.

Option A represents a common misunderstanding that light does not refract when it enters a different transparent medium. The incomplete wavefront at the boundary shows that a wave cannot travel straight on in this situation.

If students have misunderstandings about using wavefronts to show how water refracts, it can help to provide them with the opportunity to observe what happens in a real situation. 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 water waves using their own words.

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

* Response activity: Modelling refraction

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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