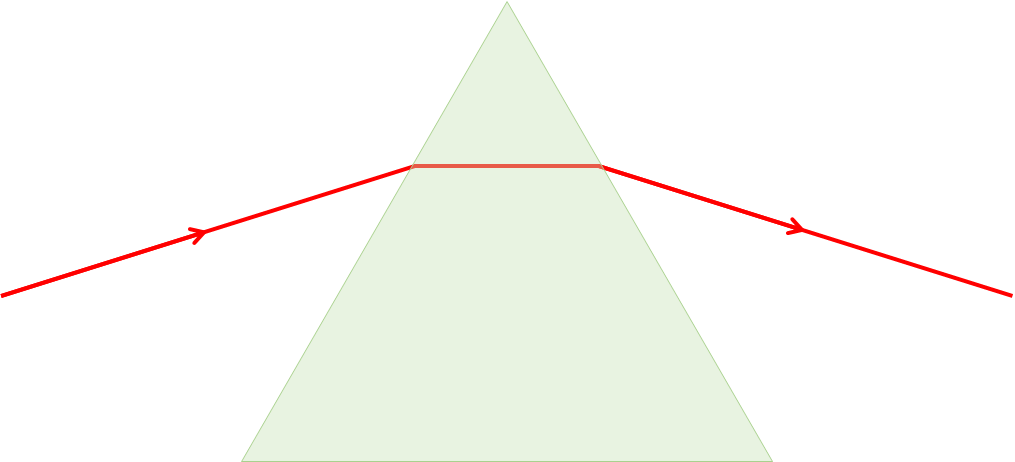
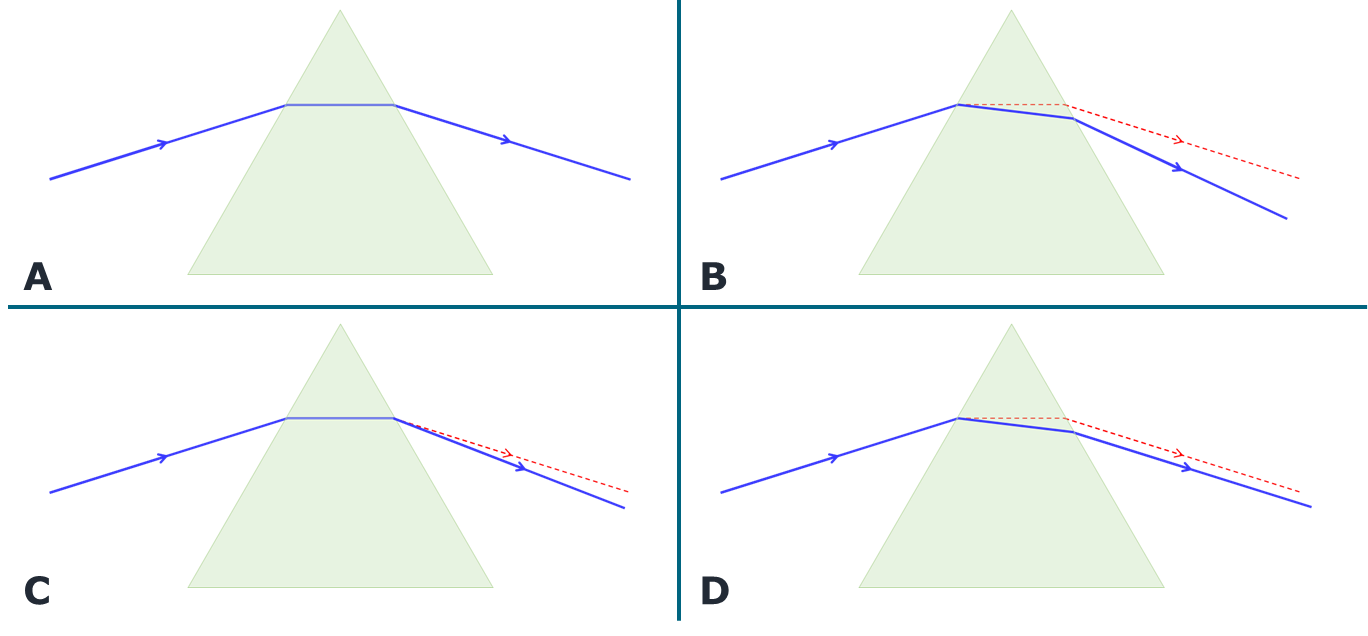
**Double refraction**

Red light refracts twice as it passes through this prism.



**a.** How does blue light refract through the same prism?



**b.** What is the best reason for your last answer?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | At each boundary blue light changes speed more than red light. |  |
|  |  |  |
| **B** | In both air and glass, red light moves faster than blue light. |  |
|  |  |  |
| **C** | In glass, blue light moves more slowly than red light. |  |
|  |  |  |
| **D** | All colours of light travel at the same speed. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Double refraction** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | The frequency of a light wave determines the colour of the light. When light refracts at a boundary, the size of the angle by which each different colour changes direction is different. |
| Observable learning outcome: | Predict how blue light refracts as it passes through a prism with three 60o angles. |
| Question type: | Two-tier multiple choice |
| Key words: | Refraction, refract |

**What does the research say?**

The speed of a mechanical 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.

For light waves, the higher the optical density of a transparent medium, the slower the speed of light through it. However, *the speed of light through a transparent medium is also affected by its frequency*.

All colours of light travel at the same speed in a vacuum, but the frequency of each colour determines how quickly it moves through other transparent media. This is because the way that light photons interact with particles in a medium is dependent on their frequency. This fact, that the speed of light in a transparent medium depends both on the medium *and* on the frequency of the light, distinguishes light waves from mechanical waves and is rarely brought to the notice of students. This lack of awareness can lead to confusion.

Explanations of refraction should include rays, but also include wavefronts and ideas about changing speed and therefore changing wavelength (Sengoren, 2010), which suggests that it could be helpful to scaffold answering questions about refraction using general rules based on wave theory and the speed of light in different media.

**Ways to use this question**

Students should complete the questions 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 follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

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**

a. B

b. A

**How to respond - what next?**

All colours of light travel at the ‘speed of light’ through the air, but blue travels slower than red light in this type of glass, which means that the change of speed of blue light is greater at each boundary. This leads to blue light refracting more than red, both as it enters the prism and again as it leaves (options B, A).

A, D Some students may think that all colours of light travel at the same speed in glass because all colours do travel at the same speed in air; or because they have learnt that for mechanical waves, the wave medium determines the speed of a wave and not frequency. For light waves, both the wave medium and the frequency of the wave affect its speed.

*This latter point is not commonly made clear to students and a lack of awareness of it can cause confusion in thinking about the properties of both light waves and mechanical waves.*

Part a: Options C and D are often selected by students who understand that colours of light are spread out by the prism and who are relying on recall. Option C in particular is what students, who have completed an experiment to observe a spectrum of light, may recall having observed, because the splitting of light at the first surface is often hard to discern.

Part b: Option C is correct, but option A is better to explain why blue light refracts more than red. The amount of refraction, and which colour refracts most, depends on the difference between the speeds of each colour of light in the media on either side of a boundary, rather than the speeds of each colour in one medium.

Some students are likely to generalise wrongly and think that all colours of light travel at the same speed in all media, or that red light always travels faster than blue.

If students have misunderstandings about predicting how blue light refracts as it passes through a prism with three 60o angles, it can help to draw their attention to the understanding that the speed of light travelling through a transparent medium is, unlike mechanical waves, dependent on both the medium *and* the frequency of the wave. This is because the mechanism by which a light wave propagates is different to that of a mechanical wave.

Light travelling through a transparent medium is slowed down by its interaction with atoms, and different frequencies of light interact with the atoms in a particular medium differently. The full explanation is beyond the scope of secondary science, but it is fairly straightforward to demonstrate how each colour interacts differently with a particular medium: for example, by shining red, blue and green light separately at a yellow surface in a darkened room. (Yellow appears black in blue light, red in red light and green in green light.)

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

* Response activity: Prism blues
* Response activity: Rainbow light
* Response activity: Making rainbows

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Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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