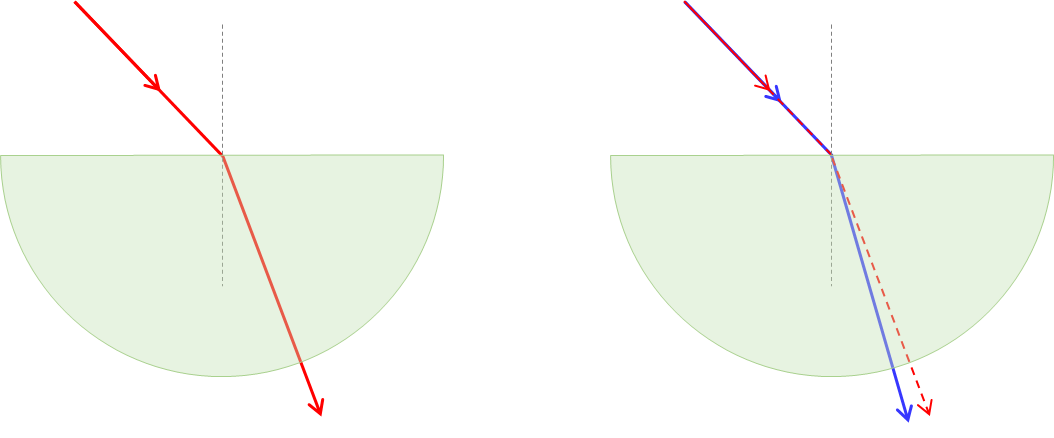
**Refraction blues**

Blue light has a higher frequency than red light.

It refracts more than red light when it enters a glass prism.



These statements are about the differences between red light and blue light.

What do you think about each one?

*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** | Blue light moves slower than red light in glass. |  |  |  |  |
| **B** | Blue light moves slower than red light in air. |  |  |  |  |
| **C** | The wavelength of blue light is shorter than that of red light. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Refraction blues** |

**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: | Explain why blue light refracts more at a boundary than red light. |
| Question type: | Confidence grid |
| Key words: | Frequency, wavelength, refraction |

**What does the research say?**

The speed of a wave depends on the properties of the medium it is passing through and, for mechanical waves, 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, and also 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 a general rule based on wave theory and the speed of light in different media.

**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 C are right; and statement B is wrong.

**How to respond - what next?**

Red and blue light, and all electromagnetic waves, travel at the same speed in a vacuum and at almost exactly the same speed in air (3.00 x 108 m/s). Blue light travels slower than red light in (most kinds of) glass. For light meeting a boundary at a particular angle: the greater the change of speed at the boundary, the greater the change of direction. The frequency of each colour of light remains constant, and each 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 red and blue light both travel at the same speed in glass because they have been taught that the speed of a *mechanical* wave is dependent only on the medium that it is travelling through, and not on its frequency. Light waves are different: moving from air into glass the speed of light falls by about a quarter, and it falls by different amounts depending on its frequency (colour).

B Some students make a false connection between the speed of vibration of a wave and the speed at which the wave moves forward. These students are likely to think that blue light moves faster in all media because it has a higher frequency.

C Some students have the misunderstanding that the slower a wave, the shorter its wavelength. These students are likely to think red light has a shorter wavelength than blue.

If students have misunderstandings about why blue light refracts more at a boundary than red light, 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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Images: Peter Fairhurst (UYSEG).

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