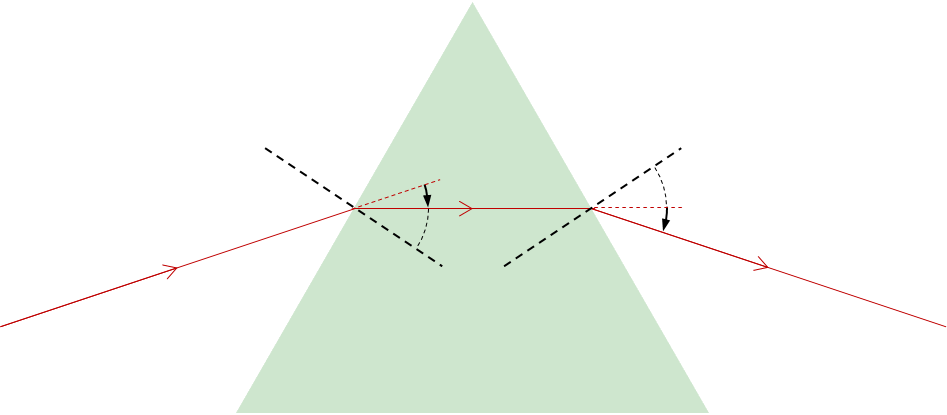
**Prism blues**

Moving from air into glass, red light refracts towards the normal line.

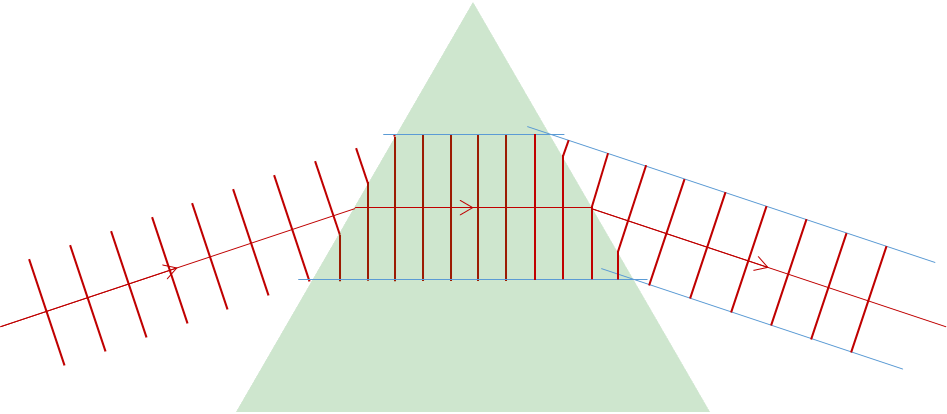
Moving from glass to air, red light refracts away from the normal line.



A wavefront diagram shows how red light slows down in glass.

It shows how red light speeds up again in air.

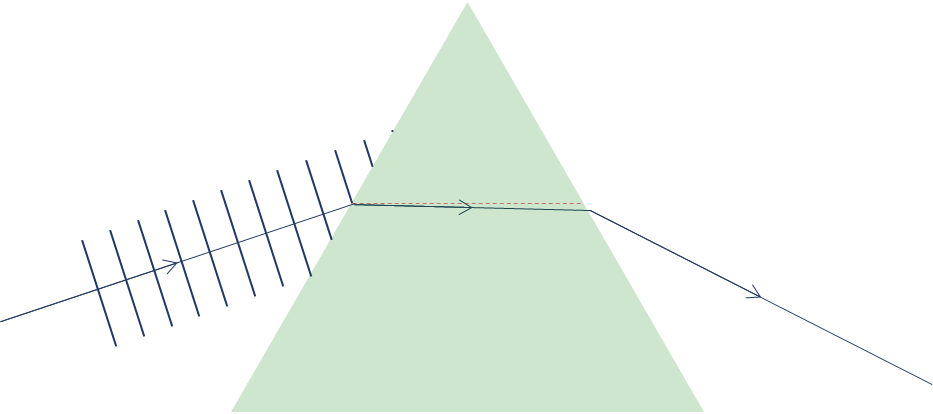
It helps to explain how a prism refracts red light.



* Draw rays to show the path of light through the prism.
* Draw construction lines to show the path of the edges of the wavefronts. These are parallel to the direction that light travels.
* Wavefronts are drawn perpendicular to the direction that light travels. (At right angles) Wavefronts join up at each boundary. They are equally spaced in glass or in air.

**To do**

Complete this wavefront diagram to show blue light moving through a prism.



**To answer**

* 1. Why does blue light refract more than red light as it enters the prism?
  2. Why does blue light refract more than red light as it leaves the prism?

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

|  |
| --- |
| **Response activity** |
| **Prism 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 red light refracts in the way it does through a prism with three 60o angles.  Explain why blue light refracts more at a boundary than red light.  Predict how blue light refracts as it passes through a prism with three 60o angles. |
| Activity type: | Application and practice |
| Key words: | Refract, refraction, normal line, wavefront |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: Prism rules
* Diagnostic question: Refraction blues
* Diagnostic question: Double refraction

**What does the research say?**

A common strategy for teaching students about refraction is to demonstrate examples of refraction phenomena and to explain the observations using ray diagrams that show how light is bent by glass blocks. In this approach students may use a ray box to explore how light travels through a parallel sided glass block to understand the nature of refraction. They change the angles of incidence to establish: a change of direction only occurs at an interface; light travelling perpendicular to the interface is not refracted; and light bends towards the ‘normal’ when entering an optically more dense medium and vice versa (Davenport, 2021).

In a study of (n=213) Greek students age 14-15, who had previously studied refraction, Fyttas et al. (2013) found that significant numbers thought wrongly that light was wholly reflected at a boundary or that it was refracted the wrong direction. About half thought that light continued in a straight line at a boundary between air and glass, because glass is transparent.

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. This is perhaps similar to the way, described by Bing and Redish (2012), that students often approach calculations – by quoting a remembered equation and (sometimes blindly) trying to fit in the given quantities, rather than by examining the situation to see what approach is most appropriate.

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, 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 activity**

This activity gives students the opportunity to practise applying their understanding and to clarify their thinking through discussion. To support this, students should complete the activity in pairs or small groups.

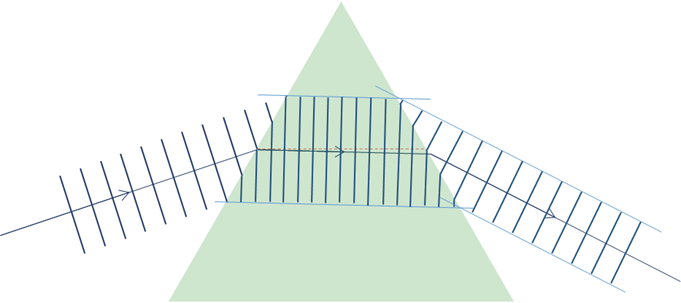
Listening to individual groups as they work often highlights any difficulties they might have. These can often be overcome, through a whole class clarification or redirection part way through the activity.

Asking students to share their answer is a useful check. Students could move around the classroom to look at the work of other groups to identify good points and points for improvement. Having done this, each group or individual student should be given the opportunity to complete their own improved diagram.

*Differentiation*

If some students are working with a teaching assistant, then a list of prompts, or prior training, for the TA could help to make this activity more purposeful.

**Expected answers**



The separation of wavefronts leaving the prism should be similar to the separation of those entering the prism, as blue light travels at the same speed in both situations.

The angles at which the rays refract on the diagram should enable this to happen.

(If the angle at which blue light emerges from the prism is different to this angle, then the separation of wavefronts will be changed. As this is not possible, there is only one angle at which blue light can be refracted.)

1. The speed of blue light is reduced more when it enters the prism than the speed of red light because it travels slower in glass than red light (and the same speed in air).

2. The speed of blue light is increased more when it leaves the prism than the speed of red light because it was travelling slower in glass than red light, and both colours travel at the same faster speed in air.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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