*Physics > Big idea PSL: Sound, light and waves > Topic PSL5: Measuring waves*

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| **Key concept (age 14-16)** |
| **PSL5.2: Speed of waves** |

**What’s the big idea?**

A big idea in physics is waves because it is the key to explaining how energy can be transferred from one object to another object by radiation, even when the objects are not touching. Waves carry information that can be detected by humans or manufactured detectors. Understanding waves helps us to communicate, explore the universe, and transfer energy to where we want it.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by building on the understanding of how the speed of a wave can be measured and of what changes can affect wave speed, in order to develop an understanding of the wave equation, v = f x λ.

****The conceptual progression starts by checking understanding of how the speed of a wave can be measured and the factors that can, or cannot, change wave speed. It then supports the development of understanding the relationship between wavelength and frequency of waves in a particular wave medium in order to enable understanding of the wave equation v = f x λ.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Speed of waves**

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| **Learning focus** | The speed of a wave is determined by the wave medium in which it moves and can be calculated by multiplying its frequency and wavelength. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Measure the speed of a wave using v = s/t.  **P** | Describe how the speed of a wave can, and cannot, be changed.  **P** | Describe how the frequency of a wave moving through a particular medium is related to its wavelength. | Explain why the speed of a wave is v = f x λ. | Calculate the frequency or wavelength of a wave using v = f x λ. |
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| **Diagnostic questions** | Slow motion | Faster spring waves | Two shakes | A wave equation | Changing waves |
| Spring waves | Slow wave |
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| **Response**  **activities** | Measuring spring waves | |  | Measuring wave frequency | |
|  | Measuring wave speed | |

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| Key: | | | | | | |
| **P** | Prior understanding from earlier stages of learning | | **B** | | Bridge to later stages of learning | |
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| **Slow motion** | | **Faster spring waves** | | **Spring waves** | | **Two shakes** | | **A wave equation** |
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| Simple multiple choice | | Two-tier multiple choice | | Two-tier multiple choice | | Simple multiple choice | | Two-tier multiple choice |
| **Changing waves** | | **Slow wave** | | **Measuring spring waves** | | **Measuring wave speed** | | **Measuring wave frequency** |
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| Simple multiple choice | | Confidence grid | | Predict, explain; observe, explain | | Application and practice - practical | | Application and practice - practical |

**What’s the science story?**

The velocity of a wave can be measured indirectly:

* Velocity of a wave = distance travelled / time
* Velocity of a wave = wavelength x frequency

**Earlier development of understanding (BEST 11-14)**

When applying their understanding to novel situations, students of all ages often revert to earlier misunderstandings. Before moving forward, it is worthwhile using diagnostic questions from earlier topics to check that students do not have any persistent misunderstandings that can form barriers to learning. Time spent consolidating the scientific understanding of earlier key concepts before moving forward can accelerate progression later.

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| **Key concept PSL4.1: Waves on water and ropes**  **Learning focus:** A transverse wave travelling across the surface of water (or along a rope) transfers energy, as particles of water (or rope) are successively made to vibrate at right angles to the direction in which the wave travels.  This key concept:   * Consolidates understanding that the medium through which a transverse wave is travelling does not move forward with the wave. * Develops the understanding of how particles move in a transverse wave in order to propagate the wave. * Develops an understanding that amplitude and frequency do not affect the speed of a transverse wave, and of why they do affect the rate at which transverse waves can transfer energy. |

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| **Key concept PSL4.2: A wave model of sound**  **Learning focus:** As a sound wave (longitudinal wave) travels it transfers energy, as particles of the medium through which it travels are successively made to vibrate forwards and backwards along the direction in which the wave travels.  This key concept:   * Consolidates understanding that the medium through which a sound wave is travelling does not move forward with the wave. * Develops the understanding of how particles move in a transverse wave in order to propagate the wave. * Develops an understanding that amplitude and frequency do not affect the speed of a longitudinal wave, and of why they do affect the rate at which longitudinal waves can transfer energy. |

**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 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 (2020) of trainee physics teachers (n=35) all found similar results.

In these studies (Caleon and Subramaniam, 2010; Tongchai et al., 2011; Wittmann et al., 1999), some students thought that bigger amplitudes sped up waves because the waves had more energy or more force, and others that they slowed down because it took longer for the wave to move up and down. Some thought that a smaller amplitude sped up the wave because smaller pulses slipped more easily through the wave medium.

Caleon and Subramaniam (2010) also found that it is common for students (72% in their study) to consider the terms in the equation for the speed of a wave, v = f x λ, to be three interdependent variables. This is wrong, as the speed, v, of the wave is fixed by the wave medium and is independent of frequency, f, and wavelength, λ. In other words, changes to frequency and wavelength do not affect the speed of a wave.

Students often treat the equation v = f x λ as a mathematical formulation without (necessarily) reference to the physics. For this reason, Caleon and Subramaniam suggest that an understanding that wave speed is determined solely by the properties of the wave medium, namely its elastic and inertial properties, is developed and consolidated before introducing v = f x λ. This is a focus of the BEST topic: PSL4 Waves.

To help consolidate understanding that the speed of a wave is independent of frequency and wavelength, Caleon and Subramaniam (2010) suggest developing a qualitative understanding of the equation v = f x λ first, before using it to calculate quantitative values. This approach supports students in understanding the physical meaning of each term and the relationships between them. It also helps move the analysis of a problem beyond a ‘brittle rote procedure’ and can promote insights that may simplify some more challenging problems (Redish and Kuo, 2015).

**Guidance**

A wave pulse is a short non-periodic wave, perhaps created by a single shake of a slinky spring.

**References**

Caleon, I. S. and Subramaniam, R. (2010). So Students Know What They Know and What They Don't Know? Using a Four-Tier Diagnostic Test to Assess the Nature of Students' Alternative Conceptions. *Research in Science Education,* 40 (3)**,** 313-337.

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Tongchai, A., et al. (2011). Consistency of students' conceptions of wave propogation: Findings from a conceptual survey in mechanical waves. *Physical Review Special Topics Physics Education Research,* 7(2)**,** 11.

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