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

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| **Key concept (age 14-16)** |
| **PSL5.1: Visualising 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 ‘particles’ in a wave move, in order to develop the understanding of how waves can be represented in displacement-distance and displacement-time graphs.

****The conceptual progression starts by checking understanding of amplitude and wavelength of transverse waves and how these are represented on displacement-distance graphs. It then supports the development of understanding how displacement-time graphs represent motion of ‘particles’ in transverse and longitudinal waves, in order to enable understanding of displacement-distance graphs of longitudinal waves.

**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: Visualising waves**

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| **Learning focus** | The motion of particles in a wave can be represented by a displacement-distance or a displacement-time graph, from which the wave’s amplitude and wavelength or time period can be found. | | | | |
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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** | | | | |
| Identify wavelength and amplitude on pictures of transverse waves. | Explain how a displacement-distance graph relates to the transverse wave it describes. | Explain how a displacement-time graph relates to the wave it describes. | Identify wavelength and amplitude on pictures of longitudinal waves. | Explain how a displacement-distance graph relates to the longitudinal wave it describes. |
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| **Diagnostic questions** | The right wavelength | Rope wave graph | New wave graph | Longitudinal measurements | Spring wave graph |
| Sound graph |
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| **Response**  **activities** |  |  | Oscilloscope graph | Explaining longitude waves | |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **The right wavelength** | **Rope wave graph** | **New wave graph** | **Sound graph** | **Longitudinal measurements** |
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| Simple multiple choice | Confidence grid | Confidence grid | Simple multiple choice | Confidence grid |
| **Spring wave graph** | **Oscilloscope graph** | **Explaining longitudinal waves** |  |  |
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| Simple multiple choice | Explanation story | Clarifying – demonstration |  |  |

**What’s the science story?**

All waves can be described in terms of their amplitude, wavelength, frequency and period. The amplitude of a wave is equal to the maximum size of the disturbance it makes. Wavelength (λ), measured in metre (m), is the distance from one wave crest (or wave trough) and the next.

**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. |

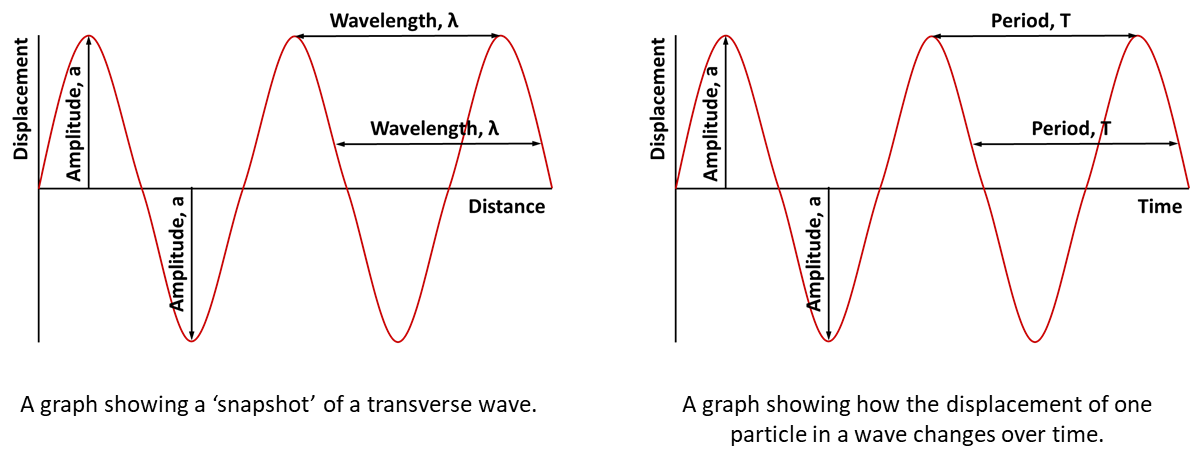
**What does the research say?**

The motion of waves is hard for students to understand because waves form from large numbers of small scale events, such as the up and down movement of water particles in a water wave and the backwards and forwards movement of air particles in a sound wave, that are quite different to the form and motion of the wave (Caleon and Subramaniam, 2010a). This is seen clearly when spectators in a sports stadium stand up and sit down in sequence to produce a *Mexican wave* moving around the stadium. In a mechanical wave the disturbance of one particle has a direct effect on the particles around it, causing them to move and progressively pass on the disturbance to adjoining particles. This process transfers energy through a medium, but without the transfer of any bulk substance.

There are two common ways to represent a wave in the form of a graph (Caleon and Subramaniam, 2010b). The first shows either a snapshot of a transverse wave, such as a wave on a rope, or the forwards and backwards displacement of particles in a longitudinal wave. The second graph shows how the displacement of one particle of a wave changes over time. On this graph the peak-to-peak separation on the graph is the time period of the wave. Caleon and Subramaniam (2010b) found that the majority of students aged 15 and 16 (n=598) do not clearly distinguish between these two representations.

Some students may think of a wave’s graph as a picture of the wave drawn to scale, which in most cases it is not. This way of thinking about graphs of waves can get in the way of understanding graphs of longitudinal waves and of interpreting displacement-time graphs.

In graphs that represent a wave, the vertical axis shows the displacement of either one particle or of all the particles in the wave. The amplitude of the wave is equal to the maximum displacement of a particle from its undisturbed position. It is common for students to identify the amplitude on a graph wrongly as the total peak-to-trough height.



*Two ways a graph is used to represent a wave*

About two thirds of students age 15 and 16 in Caleon and Subramaniam’s study (2010b) struggled to identify the wavelength of a longitudinal wave from a picture or description of its particles. They did not have any significant misunderstandings, but were unsure of how particle positions in a longitudinal wave related to wavelength. This may be because they are trying to make direct connections with the wavelength shown in the wave picture of a transverse wave. Tumanggor et al. (2020) found that about half of trainee physics teachers (n=35) had a similar uncertainty.

**References**

Caleon, I. and Subramaniam, R. (2010a). Development and Application of a Three-Tier Diagnostic Test to Assess Secondary Students' Understanding of Waves. *International Journal of Science Education,* 32:7**,** 939-961.

Caleon, I. S. and Subramaniam, R. (2010b). 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.

Tumanggor, A. M. R., et al. (2020). Using four-tier diagnostic test instruments to detect physics teacher candidates’ misconceptions: Case of mechanical wave concepts. The 5th International Seminar on Science Education, 2019 Yogyakarta, Indonesia Journal of Physics: Conference Series, Institute of Physics.