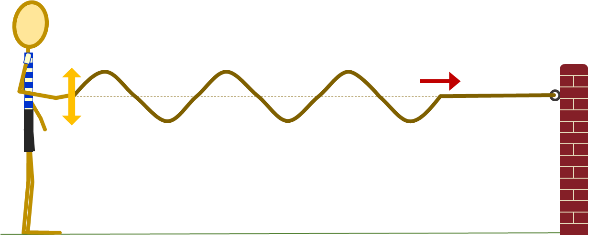
**Changing waves**

A wave is made on a rope.

**1.** What will happen if the **frequency** of the wave is **doubled**?



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

|  |  |  |
| --- | --- | --- |
| **A** | Wavelength will double. |  |
|  |  |  |
| **B** | Speed will double. |  |
|  |  |  |
| **C** | Wavelength will halve. |  |
|  |  |  |
| **D** | Speed will halve. |  |

**2.** What will happen if the **wavelength** of the wave is **tripled**?



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

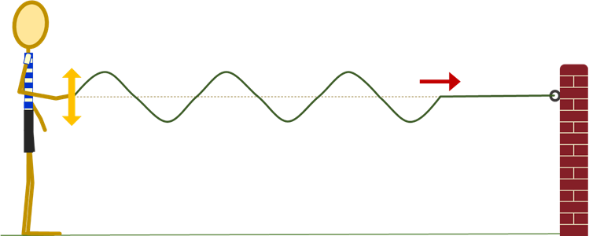
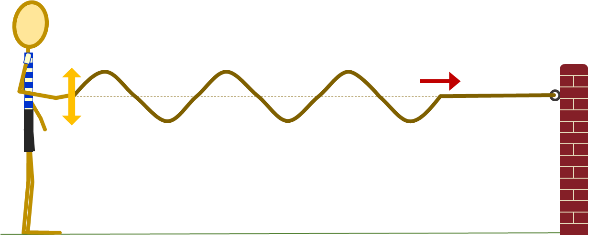
|  |  |  |
| --- | --- | --- |
| **A** | Frequency will triple. |  |
|  |  |  |
| **B** | Speed will triple. |  |
|  |  |  |
| **C** | Frequency will become three times smaller. |  |
|  |  |  |
| **D** | Speed will become three times smaller. |  |

**3.** What will happen if the **frequency** of the wave is **halved**?

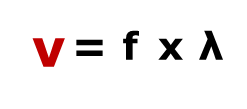


*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Wavelength will double. |  |
|  |  |  |
| **B** | Speed will double. |  |
|  |  |  |
| **C** | Wavelength will halve. |  |
|  |  |  |
| **D** | Speed will halve. |  |



**4.** What would cause the **speed** of the wave to **double**?



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

|  |  |  |
| --- | --- | --- |
| **A** | Doubling the frequency. |  |
|  |  |  |
| **B** | Doubling the wavelength. |  |
|  |  |  |
| **C** | Changing the rope. |  |
|  |  |  |
| **D** | Any one of the above. |  |

*Physics > Big idea PSL: Sound, light and waves > Topic PSL5: Measuring waves > Key concept PSL5.2: Speed of waves*

|  |
| --- |
| **Diagnostic question** |
| **Changing waves** |

**Overview**

|  |  |
| --- | --- |
| 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. |
| Observable learning outcome: | Calculate the frequency or wavelength of a wave using v = f x λ. |
| Question type: | Simple multiple choice |
| Key words: | Frequency, wavelength, wave medium |

**What does the research say?**

Caleon and Subramaniam (2010) 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 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).

Rearranging formulae is something that students can often find challenging (Boohan, 2016). The difficulty in students being able to use maths in physics may be that they can’t do the maths, but it could also be to do with students struggling with the way symbols in equations are used to make meaning differently in maths and physics (Redish and Kuo, 2015).

**Ways to use this question**

Students should complete the question 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 answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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**

1. C 2. C 3. A 4. C

**How to respond - what next?**

The key to these questions is understanding that speed of a wave is determined solely by the wave medium and that in the equation v = f x λ, v is a constant (for a particular wave medium).

1-3 In each of the first three questions, the speed of the wave is constant and does not change if either the frequency or wavelength are altered. This means that an increase in frequency or wavelength is accompanied by a proportionate reduction in wavelength or frequency respectively – and vice-versa.

A very common misunderstanding (about 70% of students in studies) is that speed is a variable in the equation v = f x λ. Students who think this are likely to believe, that in some situations, the speed of a wave increases or decreases if either the frequency or wavelength are changed.

A few students may select options for which a change in frequency results in a similar change in wavelength and vice-versa. These students have misunderstood the proportional relationship involved and are wrongly changing both variables in the same way, perhaps to ‘keep them balanced’.

4 In question 4, the speed has changed and the only way to cause a change in speed is to change the rope (wave medium). Doubling the speed will also double the wavelength, for a constant frequency, but the doubling of the wavelength is not the *cause* of the increased speed.

It can be common for students to revert back to earlier misunderstandings in novel situations, and it is likely that option D is the wrong answer chosen most often.

If students have misunderstandings about reasoning about using v = f x λ to deduce the frequency or wavelength of a wave, it is essential to check first that they understand that *all* waves moving through a *particular* wave medium travel at the same speed. Diagnostic questions from earlier in the learning progression for this key concept could be used to do this.

To develop and to consolidate understanding, it can help to ask students to work in pairs or small groups to define each term in the equation v = f x λ and to explain what causes each to have the value that it does. Answers should reveal that speed, v, is determined by the wave medium; frequency, f, by the rate of vibration that creates the wave; and wavelength, λ, by a combination of the wave speed and frequency of vibration.

It can be revealing to ask students to compare each of the following statements and comment about which one more accurately describes the physics of a wave:

* ‘wave speed is equal to wavelength multiplied by frequency’ and
* ‘wave speed is found by multiplying wavelength by frequency.’

Students could also be challenged to formulate their own statements about v = f x λ that more fully describe the physics of a wave – perhaps along the lines of: ‘the unchanging speed of a wave in a particular wave medium can be found by multiplying the measured wavelength of a wave in that medium by the measured frequency of the same wave.’

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

* Response activity: Measuring wave frequency

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Boohan, R. (2016). *The Language of Mathematics in Science: A guide for teachers of 11-16 science* Hartfield, Herts: Association for Science Education.

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.

Redish, E. F. and Kuo, E. (2015). Language of physics, language of math: Disciplinary culture and dynamic epistemology. *Science and Education,* 24**,** 561-590.