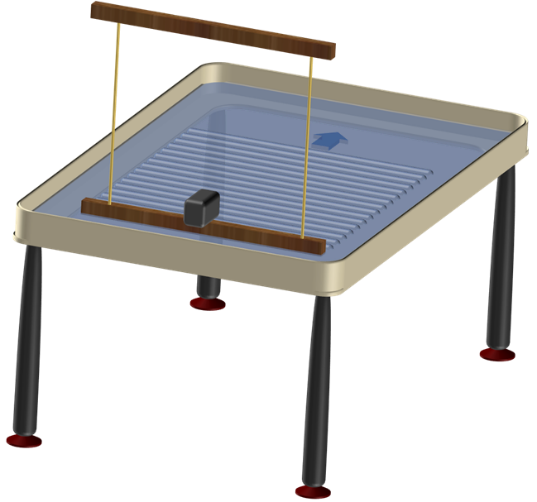
**Measuring waves frequency**

****A ripple tank uses a vibrating bar to make a wave.

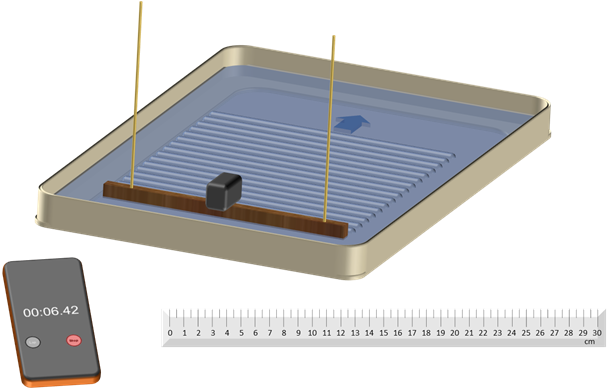
*Held with a clamp and stand.*

The bar hangs on elastic and dips into the water.

An electric motor makes it vibrate up and down.

**How can the frequency of a wave be measured accurately?**

**Safety:** Water spills can make the floor slippery and should be wiped up immediately.

**Apparatus**

* Ripple tank and accessories
* Timer
* Ruler
* Mobile phone with slow-motion video capability

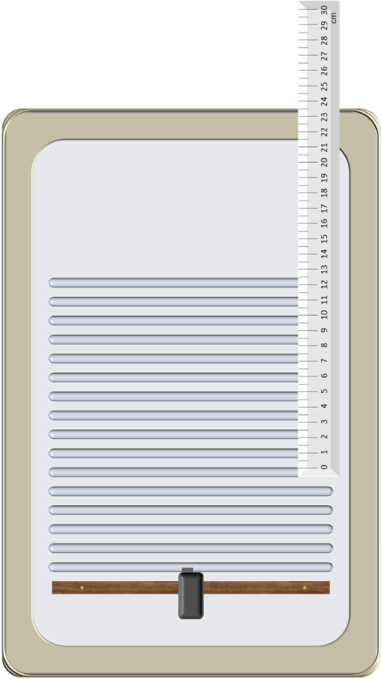
**Method**

***Step 1: measure the speed of a wave***

1. Add water to the ripple tank to a depth of about 2 cm.
2. Set up the vibrating bar so that it makes a clear wave.
3. Stop the wave and line up a ruler along the length of the ripple tank.
4. Make a slow-motion video of a new wave moving along the ruler that includes the timer.
5. Play back and pause the video to take measurements of distance and time.
6. Calculate an average speed from at least three measurements.

***Step 2: measure the wavelength***

1. Pause each slow-motion video made in step 1 and measure the length of about ten wavelengths.
2. Take at least three different measurements.
3. Calculate the average wavelength of the wave.



***Step 3: calculate the frequency of the wave***

Use the wave equation to calculate the speed of the wave.

**V = f x λ**

**To answer:**

1. How can you improve the accuracy of your measurements?
2. What investigation could you carry out to prove your answer to question 2?
3. How do you think the depth of water will affect the frequency of the wave?

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

|  |
| --- |
| **Response activity** |
| **Measuring wave frequency** |

**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: | 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. |
| Activity type: | Application and practice - practical |
| Key words: | Wavelength, frequency, ripple tank |

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

* Diagnostic question: A wave equation
* Diagnostic question: Changing waves
* Diagnostic question: Slow wave

**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.

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 activity**

**It may be necessary to arrange in advance for students to bring smartphones to use this lesson.**

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

* If there is access to a class set of ripple tanks, then students will need to be shown how to use the ones available. This practical may alternatively be carried out as a demonstration.

Key points for the practical / demonstration:

* There is no need to project a light through the ripple tanks. Instead direct measurements are needed.
* The legs of a ripple tank usually have parts that can be adjusted to level the water tray, but using ripple tanks without their legs can help reduce the risk of spillage.
* It may be possible for each group to work next to a sink to allow for easy filling and draining of each ripple tank. For example, the drainage hole could be placed directly over the sink.
* If carried out as a demonstration, a visualiser could be used to project the play-back of any slow-motion footage taken on a phone onto a large screen.

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 report their findings at end of the practical work is a useful check. After a group has fed back, it might be helpful to model an even better answer. You could do this, for example, by asking another group to add to, or clarify, the first observation. Then ask another group to sum up the important part of the observation, and so on.

*Differentiation*

Providing suitable recording sheets can help some students organise their observations so they can more easily focus on the science. If some students are working with a teaching assistant, then a list of prompt questions for the TA could help to make this activity more purposeful. Some students may benefit from being challenged to plan and organise their own record keeping.

**Equipment**

*For a demonstration*

* Ripple tank and accessories
* Timer
* Ruler
* Mobile phone with slow motion video capability
* If available, a visualiser

*For a whole class investigation*

For each student/pair/group:

* Ripple tank and accessories
* Timer
* Ruler
* Mobile phone with slow motion video capability

For the class:

* Cloths or paper towels for clearing up spillages of water.
* Large plastic beakers - if students are not working directly next to sinks.

**Technician notes**

Ripple tank trays are best used without their legs for this investigation. It is worth checking that benches on which they will be used are sufficiently level, and if possible that each ripple tank can be used directly next to a sink. If this is not the case, it may be helpful to suggest a lab. swap for this lesson.

A vibrating beam, controlled by a ripple tank motor, connecting leads and power pack will be needed for each tray, together with the supporting beam and its fixings.

Large plastic beakers may be needed to fill and empty each ripple tank.

Suitable cloths or mops should be provided to mop up any spills that might happen.

**Health and safety**

Some water is likely to be spilled during this investigation and will need to be wiped up immediately to avoid slippery surfaces.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

1. Repeating measurements three or more times allows for any errors to be spotted. An average of acceptable results improves accuracy because it minimised the effect of random errors.

The longer the distance used to measure speed, the smaller the percentage error. Similarly, the greater the number of waves over which the wavelength measurement is taken, the better.

Careful selection of the depth of water and frequency of vibration can produce more clearly defined waves that allow for better accuracy. It may be possible to adjust the lighting to give the waves more contrast.

2. The frequency of the wave is controlled by the vibrating motor and is not dependent on the depth of the water. The depth of water will alter the speed and wavelength of the wave.

3. The same investigation needs to be repeated for different depths of water. The means of measuring the depth could be described, and at least three different depths should be tested.

For each depth, it is important to use the same frequency of vibrations. A good answer should explain how this is ensured.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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