Science Stage 5 Physical world

## Calculating the speed of light using a microwave

Students are guided in completing a short investigation and submitting a brief report and reflection.

Stage 5, PW1 Energy transfer through different mediums can be explained using wave and particle models.

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| Guiding question: | How can we measure the speed of light? |
| What are your students going to learn? (Objectives) | PW1c - describe using the wave model, the features of waves including wavelength, frequency and speed.  WS6 Students conduct investigations by:   1. safely constructing, assembling and manipulating identified equipment   WS9 Students communicate by:   1. using appropriate units for physical quantities and symbols to express relationships, including mathematical ones |
| How are they going to learn it? (Resources and Strategies) | Students will use a microwave to create spot patterns in available soft microwaveable materials to analyse microwave electromagnetic radiation and approximate the speed of light. Students can submit an experimental report that documents their activity and the results obtained. |
| Target date for completion | 2 lessons. |
| How are you going to know that they learned it? (Success criteria) | In the submitted experimental report students can:   * Clearly articulate their investigation * Perform appropriate calculations of the results |
| Collecting evidence of student learning (Verification) | Students will produce a concise experimental report outlining the process undertaken and the results obtained. This report could be submitted via e-mail, Google Classroom or Microsoft Teams to the teacher for feedback. |
| Differentiation including HPGE | Adapting process – students can perform an error analysis of their results and suggest improvements to the experimental method to improve the accuracy of their result. Testing the accuracy of the final calculation by adjusting the materials used, time or power settings of the microwave. |
| Feedback (Evaluation) | Teachers can provide feedback via the submission pathway (e-mail, Google Classroom or Microsoft Teams) to students on their progression towards the learning outcomes. An example [rubric for the Working Scientifically Skills](https://schoolsequella.det.nsw.edu.au/file/bebc596d-7e55-4bf2-83dc-be16daabe9fd/1/science-s45-rubricskills.docx) can be found on the Science Curriculum Support website. |
| Communication | Students and teachers can interact either synchronously (Google Hangouts, Microsoft Teams) or asynchronously (email) to provide ongoing feedback and support to students for their learning. |

### Resources:

* [Science Buddies](https://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p056/physics/measuring-the-speed-of-light-with-a-microwave-oven) has a method for this practical which can easily be followed by students at home.
* [The Wonders of Physics](https://wonders.physics.wisc.edu/measure-the-speed-of-light/) has an alternative method for this practical which can easily be followed by students at home.

[Investigative science](https://education.nsw.gov.au/asset-management/chemicals/section-3-curriculum-support-documents/3-2-science/3-2-3-good-practices-in-chemical-safety-in-science/3-2-3-6-investigative-science) on CSIS contains information required for students undertaking experimental activities away from the classroom environment. CSIS online is being migrated. Select Asset Management in Department A-Z directory and follow the path: Chemical safety in schools > Section 3: Curriculum support documents > 3.2: Science > 3.2.3: Good practices in chemical safety in science > 3.2.3.6: Investigative science

### Lesson sequence

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| Session | Learning Sequence | Evidence of learning |
| 1 | Students can utilise any available microwaveable materials which will safely melt or change appearance when heated by the microwave. Examples include chocolate, egg whites or cheese. On the rear of the microwave will be the manufacturer label which specifies the operating frequency of the device, a typical value is 2.45GHz (2450MHz) but this can vary between some brands. This must be converted to Hertz:   * 1GHz = 1,000,000,000Hz * 1MHz = 1,000,000Hz   The microwaves rotating plate needs to be removed for this activity as we require the uneven heating of the material to observe a suitable result. A microwave safe plate is placed in the microwave to hold the selected material for this activity.  The selected material can be heated in the microwave for 10 seconds. Depending on the material and the power of the microwave this may need to be adjusted to longer or shorter times until small marks from the spot heating can be clearly and separately observed. The spots represent the wave nodes of the microwave energy, the distance between two nodes (or double the distance between two adjacent nodes) is the wavelength. | Photo/video documentation of the activity undertaken included in the experimental report appendix. |
| 2 | Performing the calculations and writing the report (including adjustment for HPGE):  The speed of light can be calculated by doubling the distance (in meters) between adjacent spot heating marks in the material and multiplying by the frequency of the microwave (in hertz). This will give the speed of light in meters per second. An example calculation could be:   * Distance between adjacent spot heating marks   + 6cm = 0.06m * Frequency of the microwave   + 2.45GHz = 2450,000,000Hz * Speed of the wave   + 2(distance) x frequency   + 2(0.06m) x 2.45x109Hz   + 294,000,000ms-1   Comparing this calculated value to the accepted value of 299,792,458ms-1 from [NIST](https://physics.nist.gov/cgi-bin/cuu/Value?c) we can see a slight variation. The accuracy as a percentage can be calculated by:   * (Calculated value ÷ true value) x 100 * (294,000,000ms-1 ÷ 299,792,458ms-1) x 100 * 98.06% accuracy   These results can be reported and submitted to the teacher for feedback.  This activity can be differentiated for HPGE students by the development of an investigation style activity. Students could investigate the accuracy of their calculated speed of light by exchanging different materials in this activity or by altering the settings on the microwave. Due to the accepted and highly accurately known value for the speed of light, this activity is suitable to alter experimental design to assess accuracy of the results obtained based on the percentage shift from the accepted value. | Experimental report submitted to the teacher including the completed calculations using the appropriate units. |