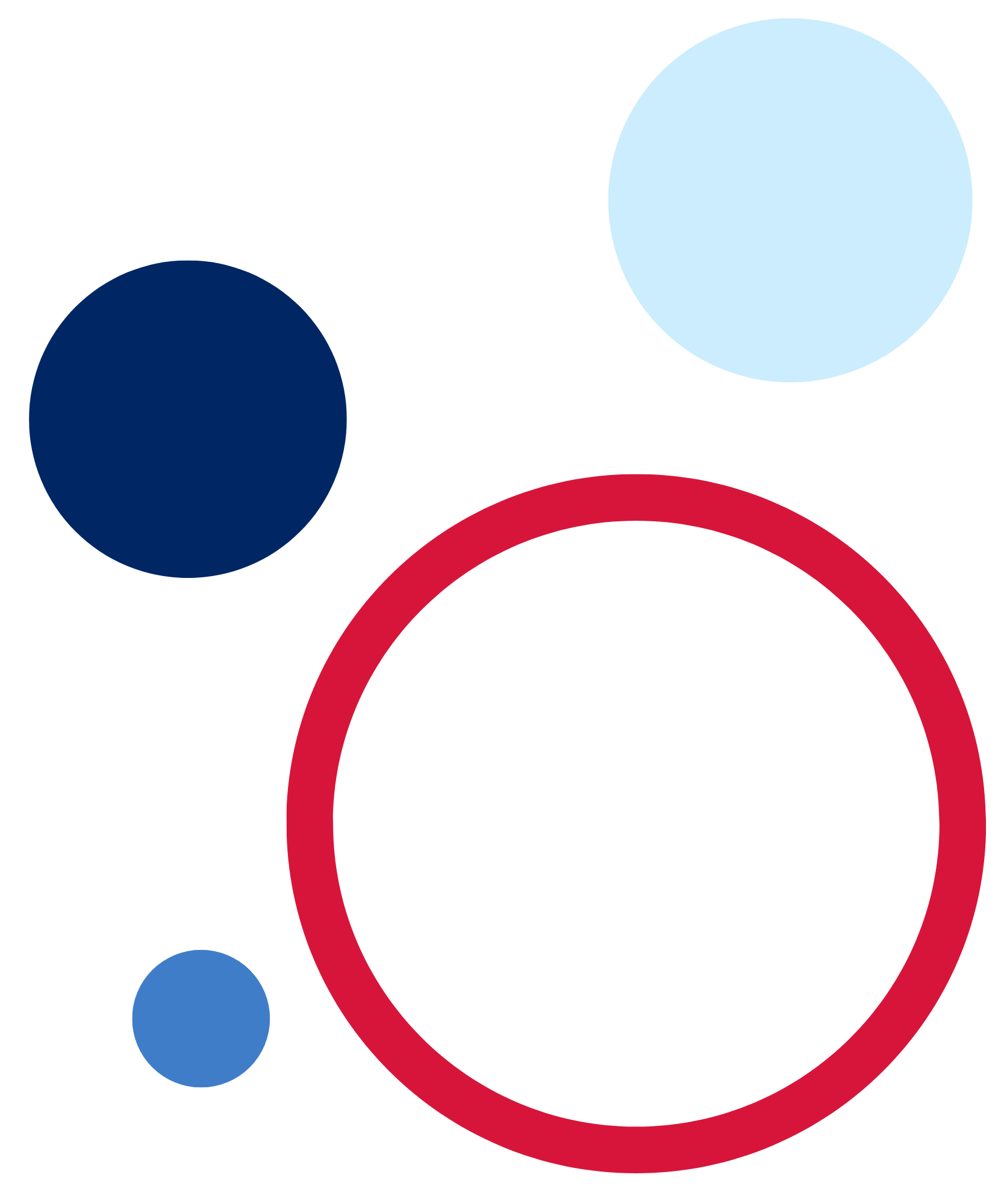
# Physics Stage 6 – learning sequence – a qualitative investigation of the diffraction of light



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## Overview

**Stage and Learning Area**: Physics Stage 6

**Description**: this resource contains 3 activities that can help build students’ skills at recording qualitative observations and explaining diffraction patterns of light. Students will use the Predict-Explain-Observe-Explain (PEOE) framework to challenge their pre-existing ideas of the diffraction of light, while gaining a deeper understanding of the formation of diffraction patterns as predicted by the wave model of light.

**Duration**: while timing will vary based on the mode of delivery, differentiation strategies employed and class or school context, this series of activities should take approximately one period.

## Information for teachers

### Introduction

This short teaching and learning sequence has been designed to help students develop their skills in recording qualitative observations on the diffraction of light from a laser.

The sequence begins with observations students may have experienced personally. They use their Working Scientifically skills and prior understanding to provide an assessment of the method used and the conclusions drawn. This allows students to apply their knowledge of experimental design and they should be encouraged to give reasons for their evaluation.

The second activity uses the computer simulation [Wave Interference](https://phet.colorado.edu/en/simulations/wave-interference), along with the thinking routine Predict-Explain-Observe-Explain (PEOE), as shown in Table 1.

Table 1 – PEOE framework (Ministry of Education, Wellington, New Zealand, 2022)

|  |  |
| --- | --- |
| Step | Predict-Explain-Observe-Explain (PEOE) framework |
| Predict | Record all the things you think you will see. |
| Explain | Record the reasons why you think it will happen this way. |
| Observe | Describe what you did see. |
| Explain | Add to or change your ideas about why it happened. |

Table adapted from ‘[Predict, Observe, Explain (POE)](https://arbs.nzcer.org.nz/predict-observe-explain-poe#:~:text=Predict%2C%20Observe%2C%20Explain%20%28POE%29%201%20It%20can%20be,want%20to%20explore%20the%20concept%3B%205%20generating%20investigations)’ by Chris Joyce, [Ministry of Education, Wellington](https://www.education.govt.nz/), New Zealand and [New Zealand Council for Educational Research](https://www.nzcer.org.nz/).

Students use the simulation to reflect on and challenge their ideas on waves and interference. The follow-on activity encourages students to use the simulation to make preliminary observations and formulate a researchable question. This section of the activity encourages students about how initial observations of the natural world can help direct curiosity and lead to scientific discoveries.

The third activity is centred on conducting a demonstration for students using the PEOE framework. Teachers may use this activity to determine if their students can transfer their prior learning to unfamiliar situations.

The impact of changing variables (for example, wavelength and aperture dimensions) on diffractions’ patterns is also explored. It provides a tangible link to the next syllabus description, where quantitative analysis is used to ‘conduct investigations to analyse quantitatively the interference of light using double slit apparatus and diffraction gratings ’ (NESA 2017).

The nature of the activities should prompt classroom discussions and provide regular opportunities for specific feedback. This feedback should be actionable and allow students to refine and improve their original answers. This feedback can be in the form of probing questions or specific instructions to direct improvement.

### Outcomes

A student:

* develops and evaluates questions and hypotheses for scientific investigation **PH11/12-1**
* conducts investigations to collect valid and reliable primary and secondary data and information **PH11/12-3**
* describes and analyses evidence for the properties of light and evaluates the implications of this evidence for modern theories of physics in the contemporary world **PH12-14**

[Physics Stage 6 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-science/physics-2017) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2017.

### Learning intentions and success criteria

Students:

* develop an understanding of diffraction of light.

Students can:

* develop high quality, researchable scientific questions based on their preliminary observations of diffraction patterns
* recognise the key elements of an effective scientific investigation
* record and explain the qualitative observations from diffraction experiments and simulations accurately.

**Differentiation consideration**: learning intentions should not be differentiated. All students need access to the same core content, big ideas and concepts. Differentiation should be evident in the success criteria, or the activities/support needed to achieve the success criteria (Wiliam and Leahy, 2015). Teachers may co-construct the success criteria with students or adjust them to suit their class context, for example using the strategies and resources for curriculum planning on the [Planning, programming and assessing 7-12](https://education.nsw.gov.au/teaching-and-learning/curriculum/planning-programming-and-assessing-k-12/planning-programming-and-assessing-7-12) webpage.

## Teaching and learning activities

**Light: Wave Model**

**Inquiry question**: What evidence supports the classical wave model of light and what predictions can be made using this model?

Students conduct investigations to analyse qualitatively the diffraction of light

[Physics Stage 6 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-science/physics-2017) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2017.

### Note for teacher

To meet the learning requirements of your students, the activities described below can be completed in a linear sequence or as stand-alone components. The series of activities are designed to help students deepen their understanding of the diffraction of light. The focus is to build the skills needed to recognise the concepts that underlie the diffraction of light and provide explanations to unfamiliar situations involving this phenomenon. The Working Scientifically skills related to making observations and designing experiments have been highlighted in this resource but can be adjusted to suit the focus of your class needs.

### Pre-quiz

**Teacher note:** students can be asked to complete the table below to identify the properties of waves and particles as a pre-test. This can either be completed digitally, orally or on paper as either a class discussion or individual activity.

Complete the table below to identify both the properties of waves and particles. Include an example for each property identified, for example, where could this be observed?

Table 2 – properties of waves and particles

|  |  |
| --- | --- |
| Properties of waves | Properties of particles |
|  |  |
|  |  |
|  |  |

#### Assessment for learning

##### Sample answers

The answers could include:

|  |  |
| --- | --- |
| Properties of waves | Properties of particles |
| **Refraction**: Is the bending of a wave when it passes from one medium to another. This can be observed in optical instruments such as a magnifying glass. | **Mass**: Particles have a given mass. For example, a small grain of sand or even a proton has a known and measurable mass at rest. |
| **Interference**: When 2 or more waves meet, they superpose to form a resultant wave of greater, lower or the same amplitude. This can be seen in the creation of beats when nearby frequencies overlap and create a new resultant wave. | **Kinetic** **energy**: Particles travelling at a given speed will possess kinetic energy. For example, kicking a soccer ball or subatomic particles travelling at high speeds. |
| **Reflection**: Is defined as the change in the direction of a wavefront at the interface between 2 different media, bouncing the wavefront back into the original medium. Reflections in a mirror are an example of light reflecting. | **Momentum**: Particles that are travelling at a certain speed will have momentum. This can be seen in collisions between pool balls. |

### Activity 1

**Teacher note:** this activity can be an introductory activity for students to think deeper about the relationships between observations, experimental design and conclusions. Using their prior understanding and skills, students will assess a flawed investigation. Students should be encouraged to identify and explain flaws they have found in their assessments.

Figure 1 – section of ground floor house plans

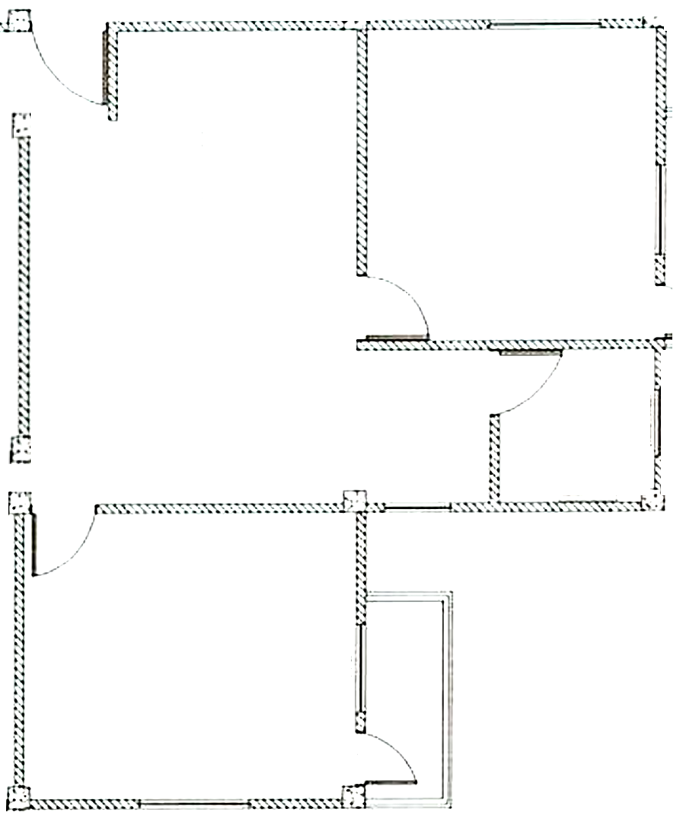


Figure 1 shows a section of the ground floorplans for a house. A student recorded some observations on sound and light within this section of the house (Table 3. They used labels to indicate various positions on the plan and recorded their observations in the table below. Note that the walls of the house are impervious to sound and light.

The student’s notes from the investigation are below.

**Teacher note:** the following is written from a student’s perspective and contains many common errors students make. A discussion centred around the need for clarity and sufficient detail can be discussed with the class.

**Student's notes from the investigation**

**Set-up 1**

The radio was set to a moderate volume setting and a radius was determined from the source to various recording points in the house.

In set-up 1, the radio was placed at the entrance and 3 positions were selected to hear the sound. Each of these positions was set to the same distance from the source. Position 1 was directly in front of the radio (direct line of sight), position 2 was around the corner (no direct line of sight) and position 3 was in room 3 with no direct line of sight.

**Set-up 2**

The student used the same method as in set-up 1. However, the radio was replaced by a standard 60-watt light bulb (filament, not LED). No other light sources were switched on and the observations were made at night.

Table 3 – student's notes and observations

|  |  |
| --- | --- |
| Set-up 1 | Set-up 2 |
|  |  |
| Student’s observations | Student’s observations |
| In positions 1 and 2, the sound was heard clearly. However, in room 3, no sound was heard. | Positions 1 and 2 observed light. The intensity at 1 was greater than 2. No light was observed at position 3. |
| Student’s explanation | Student’s explanation |
| The sound could bounce off the walls as a rubber ball would. This is why it could be heard in positions 1 and 2. However, in the case of position 3, the reflecting path of the walls would be improbable. Each time it reflects off the wall, too much energy is lost. Therefore, the sound will not reach position 3. | The light, in this case, acts as the sound waves in set-up 1. |

**Inference 1:** Sound and light in the set-ups above acted like ‘particles’ and could bounce or reflect off the walls to get around corners. With each reflection, energy was lost and therefore couldn’t travel far from the source around corners.

**Inference 2:** Both sound and light behaved like waves. In the case of the observations made at positions 1 and 2, the waves diffracted around the corner (some reflection would also take place). There are no direct (unobstructed) pathways to position 3 and it is not feasible to measure any sizable intensity (detectable sound or light).

**Questions**

1. Assess the method used by the student and the inferences they made.
2. Explain why it is important to design a well-thought experiment to explain observations of natural phenomena.

**Teacher note:** concerning question 1, it is important to highlight to students that the validity and reliability of their inferences cannot be addressed. The method given is not a proper scientific investigation but some initial observations of natural phenomena. **As stated before, the inferences made by the student are flawed.** This can prompt classroom discussions around the rigour of the scientific method and build specific Working Scientifically outcomes relevant to your class's needs.

#### Assessment for learning

##### Sample answers

The answers could include:

1. **Assess the method used by the student and the inferences they made.**

Points students may raise:

* No values are given, for example, the intensity of sound or light.
* No reference to the environmental conditions has been made or attempted to measure or account for any existing sound or light sources.
* The student has only made statements based on their hearing and sight. No accurate measurement tool was used.
* The observations recorded have no detail about the intensity of sound heard or light observed. Therefore, there could be differences in the relevant strength.
* The detail given would not allow another person to repeat the investigation and gather comparable results.

1. **Explain why it is important to design a well-thought experiment to explain observations of natural phenomena.**

Scientific investigations need to be confident of the conclusion they are making. This

could be judging the effectiveness of a particular vaccine or investigating the relationship between 2 variables. When investigating the relationship between variables, scientists must be certain that the change in one variable impacts the other. Mathematical models are developed from carefully collected data analysed to identify trends, patterns and relationships.

If the experimental design is flawed, the conclusion drawn from the experiment will not hold up to scrutiny can be incorrect or not valid.

### Activity 2

**Teacher note:** the PEOE thinking routine is used in this activity. In the first instance, students will predict the diffraction pattern for each grating (the matching activity). Then, they will use the (PhET 2022) computer simulation to observe and explain. If the equipment is available for a demonstration after this activity, it will help students engage with the topic and gain an insight into skills required for experimenting with light.‬‬

**Task:** a demonstration has been set up for students to observe the diffraction of light. A red laser (650 nm) has been used and a screen with different aperture shapes has been placed in the laser's path.

The diffracted light pattern falls on a screen and the observations are recorded in Table 4. Unfortunately, the scientist mixed up the pictures and the shape outlines. Match the aperture shape to the diffraction pattern you think you observed. Provide an explanation behind your choice (the first one has been done for you).

**Teacher note:** the goal is not to explain the exact science and mathematics behind each shape. Instead, students should predict the expected diffraction patterns caused by the different gratings. In addition, teachers should focus on their students’ reasoning skills. For example, teachers may ask students to articulate their thinking by stating, ‘I think pattern A is caused by grating #1 because ….’. This allows teachers to identify misconceptions and areas of knowledge deficiencies that may be addressed later.

Table 4 – diffraction patterns using 650 nm laser PhET simulation, matching activity

|  |  |  |
| --- | --- | --- |
| Shape | Pattern | Reasoning |
| 1 Diffraction grating 1  Circle diameter: 0.04 mm | A Diffraction pattern 1 | There is a single circular aperture in the grating. Consequently, the diffraction pattern also shows a circular bright spot in the centre, surrounded by alternating bright and dark circular regions. |
| 2 Diffraction grating 2  Height: 0.04 mm, width: 0.04 mm |  |  |
| 3 Diffraction grating 3  Circle diameter: 0.04 mm, square width: 0.04 mm |  |  |
| 4 Diffraction grating 4  Circle diameter: 0.04 mm, lattice spacing: 0.06 mm |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| A Diffraction pattern 1 | B Diffraction pattern 2 | C Diffraction pattern 3 | D Diffraction pattern 4 |

Images from ‘[PhET simulation: Wave Interference](https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html)’ by [University of Colorado Boulder](https://www.colorado.edu/) is licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

**Teacher note:** it may be helpful for teachers to familiarise themselves with the simulation before demonstrating to students how to navigate its various controls. The following activities can also be used to reinforce the distinction between qualitative and quantitative data.

* Use the following simulation to confirm your predictions. Select the **Diffraction** module. Did you get them all correct? (PhET 2022)
* Explore the simulation controls (wavelength and the aperture dimension controls) and how each variable impacts the diffraction pattern. Record some preliminary observations (qualitatively).

**Teacher note:** the next section of this task aims to develop students’ questioning skills. The video [Developing a research question (7:23)](https://www.youtube.com/watch?v=mrWeLJZydUU) from The University of Melbourne could help students gain a deeper understanding of the key elements of scientific inquiry questions. This would be especially useful if the next task is a depth study.

* Record some initial findings based on your preliminary investigation. Are there trends that could be used to form a research question for further investigation?
* Share **one** question with the class and explain why this would be a good foundation for developing a research question?
* What are the limitations of using qualitative data in this investigation compared to quantitative data? What further insights could investigations to obtain quantitative data give into your understanding of the diffraction of light?

#### Assessment for learning

##### Sample answers

The answers could include:

**Task:** match the aperture shape to the diffraction pattern you think you observed. Provide an explanation behind your choice (the first one has been done for you):

1. A
2. B
3. C
4. D

Student answers during their investigation will vary. However, the focus should be on the wavelength and the aperture size.

The amount of diffraction depends on the wavelength of the wave compared with the size of the obstacle that casts a shadow.

Wavelengths much greater the dimensions of the obstacle diffract more – they fill in the shadow regions. On the other hand, there is little bending for waves with wavelengths much smaller than the obstacle and there are definite shadow regions.

**What are the limitations of using qualitative data in this investigation compared to quantitative data? What further insights could investigations to obtain quantitative data give into your understanding of the diffraction of light?**

**Qualitative data indicates a trend or observable pattern, but no concrete relationships can be obtained beyond stating simple descriptions. Quantitative data is numerical and measurements can be taken from an investigation. Highly sensitive measuring tools can produce precise measurements. This raw data can then be analysed, and by using various mathematical tools, relationships and models (such as equations) can be developed. These models should then predict outcomes that can be tested in future investigations. This would give greater insight into the observation and help aid in-depth explanations.**

**Wavelength and aperture dimensions would be a particular area of interest in the diffraction of light. Insights that could be gained include how the intensity of light in the diffraction pattern changes as the wavelength changes or calculates the aperture dimensions from the diffraction pattern. This approach would be similar to X-ray diffraction used to confirm the double-helix model of DNA.**

### Activity 3

**Teacher note:** if the equipment is available, a teacher demonstration showing different diffraction patterns would be a good conclusion to this series of activities and introduce investigations into single and double-slit experiments in the next syllabus description. The video [Demonstrating diffraction using laser light (4:30)](https://www.youtube.com/watch?v=71Rp-jG6Eek) by the IOP (Institute of Physics) gives further guidance in conducting investigations into the diffraction of light.

The diagram below is a basic set-up for a diffraction demonstration. It is an important first set when using (a) laser(s) to conduct a risk assessment and ensure all students understand the reasons for the safety precautions used. Laser pointers used for presentations may be relatively safer than high-powered lasers. However, teachers should still exercise caution and comply with school and departmental policies regarding using lasers in the classroom. Teachers should follow the [safety guidelines [PDF 2.4 MB]](https://education.nsw.gov.au/content/dam/main-education/asset-management/chemical-safety/3._Section_3_Curriculum_Support.pdf) provided by the DoE and the manufacturer's advice. Before use, a risk assessment should be conducted (approved by the head teacher).

Figure 2 – basic set-up for a diffraction demonstration

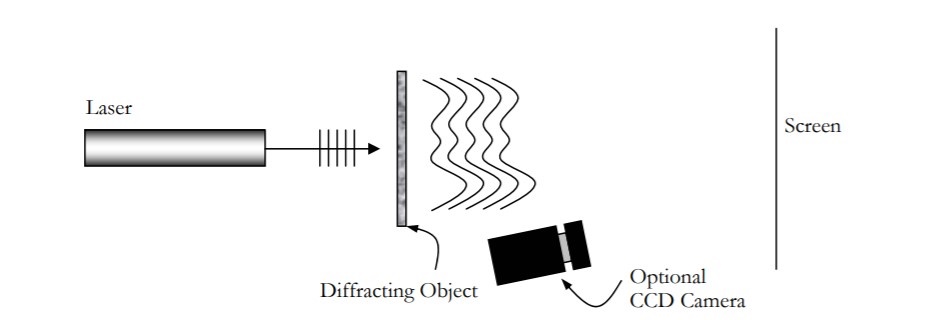


Image from ’[Fraunhofer Diffraction setup](https://eng.libretexts.org/Ancillary_Materials/Laboratory_Experiments/Modern_Optics_Project_Laboratory_(Dunmeyer)/03:_Diffraction/3.02:_New_Page)’ by David Dunmeyer is licensed under [CC BY-NC-SA 4.0](https://creativecommons.org/licenses/by-nc-sa/4.0/).

* The demonstration will work best if at least 3 different diffracting objects and 2 different lasers (different wavelengths) are used.
* The diffracting objects suggested in the table below are:
* diffraction grating
* thin wire (100 microns in diameter)
* single slit
* double slit.
* Complete the following table with your predictions of the diffraction patterns (draw and/or describe) when a laser is shone on them. Explain the reasoning behind your prediction.

Table 5 – student predictions of the diffraction patterns

|  |  |  |  |
| --- | --- | --- | --- |
| Diffraction grating | Thin wire | Single slit | Double slit |
|  |  |  |  |

* Your teacher will now demonstrate the diffraction pattern for each object. Then, compare the predictions you made with the observed results. Can you explain any similarities or differences?
* Predict how a change in wavelength of the laser (increasing and/or decreasing) would impact the diffraction pattern, **or** if the dimensions used in the objects changed (increasing and/or decreasing). Provide the reasoning you used.

**Teacher note:** the conclusion of this activity is an excellent opportunity to link to the next student descriptor ‘conduct investigations to analyse quantitatively the interference of light using double slit apparatus and diffraction gratings ’ (NESA 2017). As students have been using qualitative observations in this sequence, introducing the mathematical models may help students better grasp the understanding behind the equation.

Students who experience explicit teaching practices make greater learning gains than students who do not experience these practices. Explicit teaching recognises that learning is a cumulative and systematic process. Explicit teaching helps students develop sophisticated and well organised ways of thinking, understanding and doing.

[CESE What works best update 2020](https://education.nsw.gov.au/about-us/educational-data/cese/publications/research-reports/what-works-best-2020-update)

#### Assessment for learning

##### Sample answers

**Predict how a change in wavelength of the laser (increasing and/or decreasing) would impact the diffraction pattern OR if the dimensions used in the objects changed (increasing and/or decreasing). Provide the thought process and reasoning you used.**

The answer could include:

Wavelengths much greater than the dimensions of the obstacle diffract more – they fill in the shadow regions. On the other hand, there is little bending for waves with wavelengths much smaller than the obstacle and there are definite shadow regions.

**Teacher note:** student responses should be similar to the answers given in Activity 2. Teachers should evaluate students’ responses to determine if their students can transfer their learning from Activity 2 into Activity 3 (applying their knowledge to unfamiliar situations).

## Support and alignment

**Resource evaluation and support:** all curriculum resources are prepared through a rigorous process. Resources are periodically reviewed as part of our ongoing evaluation plan to ensure currency, relevance and effectiveness. For additional support, advice or feedback, contact the Science Curriculum team by emailing [Science7-12@det.nsw.edu.au](mailto:Science7-12@det.nsw.edu.au).

**Differentiation:** further advice to support Aboriginal and Torres Strait Islander students, EALD students, students with a disability and/or additional needs and High Potential and gifted students can be found on the [Planning programming and assessing 7-12](https://education.nsw.gov.au/teaching-and-learning/curriculum/planning-programming-and-assessing-k-12/planning-programming-and-assessing-7-12) webpage.

**Assessment**: further advice to support formative assessment is available on the [Planning, programming and assessing 7-12](https://education.nsw.gov.au/teaching-and-learning/curriculum/planning-programming-and-assessing-k-12/planning-programming-and-assessing-7-12) webpage.

**Professional learning**: relevant professional learning is available on the [Science statewide staffroom](https://education.nsw.gov.au/teaching-and-learning/curriculum/statewide-staffrooms) and [HSC Professional Learning](https://education.nsw.gov.au/teaching-and-learning/professional-learning/hsc-pl). [Stage 6 Literacy in context](https://education.nsw.gov.au/teaching-and-learning/curriculum/literacy-and-numeracy/teaching-and-learning-resources/literacy/stage-6-literacy-in-context-writing/science) provides further advice to teachers to improve student writing.

**Related resources**: further resources to support Stage 6 Physics can be found on the [HSC hub](https://www.hschub.nsw.edu.au/) and the [Science Curriculum page](https://education.nsw.gov.au/teaching-and-learning/curriculum/science).

**Consulted with**: Curriculum and Reform, Inclusive Education, Multicultural Education, Aboriginal Outcomes and Partnerships and subject matter experts.

**Alignment to system priorities and/or needs**: [School Excellence Policy](https://education.nsw.gov.au/policy-library/policies/pd-2016-0468), [School Success Model](https://education.nsw.gov.au/public-schools/school-success-model/school-success-model-explained).

**Alignment to the School Excellence Framework**: this resource supports the [School Excellence Framework](https://education.nsw.gov.au/about-us/strategies-and-reports/school-excellence-and-accountability/school-excellence/about-sef) elements of curriculum (curriculum provision) and effective classroom practice (lesson planning, explicit teaching).

**Alignment to Australian Professional Teaching Standards**: this resource supports teachers to address [Australian Professional Teaching Standards](https://educationstandards.nsw.edu.au/wps/portal/nesa/teacher-accreditation/meeting-requirements/the-standards/proficient-teacher) 3.2.2, 3.3.2.

**Author**: Science 7-12 Curriculum Team

**Resource**: classroom resource

**Creation date**: updated 10 Jan 2024

## References

[Physics Stage 6 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-science/physics-2017) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2017.

Institute of Physics (the “Institute”) and IOP Publishing (8 February 2019) ‘[Demonstrating diffraction using laser light – for teachers [video]’](https://www.youtube.com/watch?app=desktop&v=71Rp-jG6Eek), Institute of Physics, YouTube, accessed 24 March 2022.

Ministry of Education, Wellington, New Zealand and Joyce C (2006) [*Predict, Observe, Explain (POE)*](https://arbs.nzcer.org.nz/predict-observe-explain-poe#:~:text=Predict%2C%20Observe%2C%20Explain%20%28POE%29%201%20It%20can%20be,want%20to%20explore%20the%20concept%3B%205%20generating%20investigations), New Zealand Council for Educational Research: Assessment Resource Banks website, accessed 24 March 2022.

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State of New South Wales (Department of Education) and CESE (Centre for Education Statistics and Evaluation) (2020b) ‘[What works best in practice](https://education.nsw.gov.au/about-us/educational-data/cese/publications/practical-guides-for-educators-/what-works-best-in-practice)’, CESE, NSW Department of Education, accessed 15 Mar 2022.

Wiliam D and Leahy S (2015) *Embedding formative assessment: practical techniques for K-12 classrooms,* Learning Sciences International, US.

The University of Melbourne (15 February 2018) ‘[Developing a research question [video]](https://www.youtube.com/watch?v=mrWeLJZydUU)’, Academic Skills, The University of Melbourne, YouTube, accessed 24 March 2022.

### Further reading

State of New South Wales (Department of Education) (2022) [*Literacy and numeracy priorities*](https://education.nsw.gov.au/teaching-and-learning/curriculum/literacy-and-numeracy/priorities), NSW Department of Education website, accessed 24 February 2023.

State of New South Wales (Department of Education) (2022) [*Literacy and numeracy*](https://education.nsw.gov.au/teaching-and-learning/curriculum/literacy-and-numeracy), NSW Department of Education website, accessed 9 March 2023.

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