The One That Didn't Get Away

YEAR 5 AND 9
PHYSICAL SCIENCES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

Future Makers

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

QUEENSLAND MUSEUM NETWORK

Queensland Government

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

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EXPLORE – EXPLAIN – ELABORATE – EVALUATE

The One That Didn't Get Away

Teacher Resource

In this activity, students investigate the refraction of light. They explore what happens to a beam of light when it passes through transparent materials, and how refraction can affect the appearance of objects. The ways in which Indigenous cultures, including Aboriginal and Torres Strait Islander people, use scientific knowledge to accurately spear fish in fresh and salt water provides context for the latter inquiry. Explore the spears Queensland Museum has in its collection by searching 'spear' at Queensland Museum Collection Online.

Detailed step-by-step instructions, including variations for Year 5 and Year 9, can be seen below. It is recommended that you use these instructions to guide your students through the activity.

1. Begin with the 'Bent Pencil' experiment. View the pencil from different angles. Ask students to describe their observations, posing questions such as:
   - Where does the pencil appear to be?
   - Where is it actually?

   Ask students to take photos of the pencil from different angles, and to record their observations as a labelled diagram.

2. Using their knowledge of the properties of light, ask students to explain why this might be happening. Provide students with a scientifically accurate explanation of this phenomenon:

   Year 5

   Light is reflecting off the pencil. As light reflects off the lower (submerged) part of the pencil, it is transmitted (or passes) through water and then air.

   Light travels at slightly different speeds through different transparent materials. When light travels from one transparent material to another, the change in speed can cause light to change direction. This is called refraction.

   Let's take another look at the pencil; as the light from the pencil passes from the water to the air, it speeds up a little and changes direction. This change in the direction of light makes the pencil appear as if it is in a different position to where it actually is when placed in water.

   Year 9

   Different materials have different optical densities. The optical density of a material affects the speed at which light is transmitted through the material. Light will travel at slower speeds though more optically dense materials, compared to less dense materials.

   When light passes through two transparent materials of different optical densities, it either slows down or speeds up. This change in speed may cause the light waves to change direction as it crosses the boundary between the two materials. This phenomenon is known as refraction.

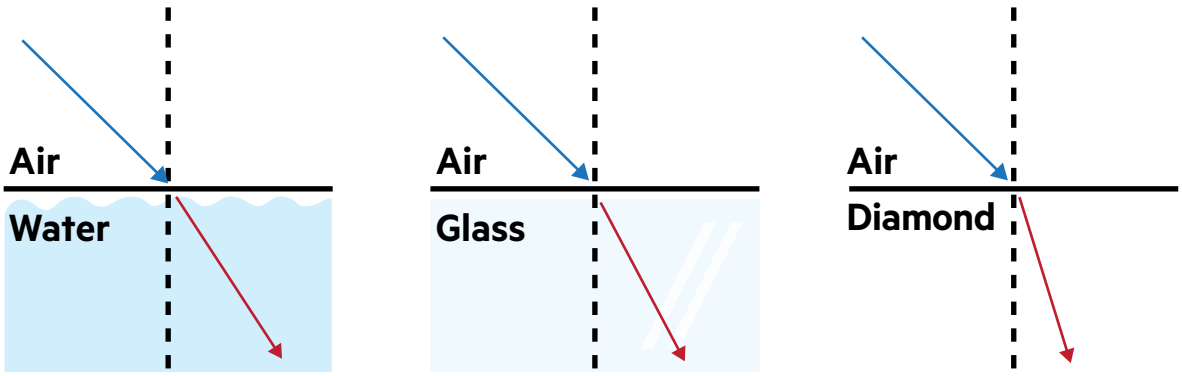
   Let's take another look at the pencil. Light waves reflecting off the submerged part of the pencil

must be transmitted through water and then air before reaching our eyes. Water is denser than air; when light waves pass from water to air they speed up and change direction. This change in the direction of light makes the pencil appear as if it is in a different position to where it actually is when placed in water.

3. Students can further explore refraction by shining a thin beam of light or laser through various transparent materials, including a glass of water, ice, an acrylic or glass rectangular prism and even jelly or gelatine. Students may even change the amount of jelly or gelatine in the mixture, and observe how this affects angle of refraction. Students may also identify additional transparent materials for testing.

   NB: If using a liquid, such as ice, jelly or gelatine, we recommended the use of silicon moulds. A silicon mould will make it much easier for students to remove the liquid from its container. Alternatively, containers lined with cling wrap would also fulfil the same purpose.

   Students observe how light travels through each of the materials and, based on their observations, determine which material appears to refract, and therefore slow light the most (i.e. which material has the greatest optical density). To assist with comparison, students should ensure the light enters each material at the same angle (i.e. 40°). Denser materials will refract light towards the normal (i.e. a line perpendicular to the boundary between the two materials) compared to less dense materials.



Refraction of light waves through water, glass and diamond. Diamond has the greatest optical density of the three materials as the light ray refracts more towards the normal (dotted line) when it crosses through the air-diamond boundary.

NB: Students may find it easier to observe how light travels through each material when the classroom lights are dimmed or turned off. Ensure appropriate safety precautions are taken if lights are dimmed or turned off during this time.

Year 5

In order to assist comparisons, students could draw ray diagrams of each tested material or take a series of bird's eye photographs of how each material refracts light. Students could then view these diagrams or images side-by-side to determine which material refracts light the most, and which material refracts light the least.

Year 9

In order to assist comparisons, students can draw a ray diagram for each tested material, and then calculate the angle of refraction. As discussed previously, optically dense materials will bend light towards the normal; this will result in a smaller angle of refraction. Less dense materials will bend light away from the normal; this will result in a larger angle of refraction.

4. Ask students: **Could refraction affect how we see objects that are underwater?**
   Record students' predictions. Ensure students provide reasons for their responses.

5. Set the context of future learning by sharing the following information from the Australian Institute of Aboriginal and Torres Strait Islander Studies[1] (AIATSIS):
   "[Fishing] forms part of the deep cultural and spiritual connection many communities have with their waters and marine resources, whether saltwater or freshwater. Fishing is a matter of practice, and is informed by traditional knowledge."
   "Many Aboriginal and Torres Strait Islander peoples have a strong relationship with the oceans or inland waterways that form part of their country."
   "For thousands of years, Aboriginal and Torres Strait Islander people have used fishing to build a livelihood for themselves, their families and their communities. A catch of fresh fish provides a community with immediate subsistence and future trade and sale options, as well as employment."
   While sharing this information, students could view the Living Off Our Waters photo gallery from AIATSIS. Students could identify how fishing practices have changed over time and discuss the impact of marine technology developments.
   Inform students that many different peoples from around the world, including Aboriginal and Torres Strait Islander peoples, have used their knowledge of refraction to spear fish for tens of thousands of years. Students will explore how in this investigation.

6. Students work in small groups to complete *The One That Didn't Get Away: Refraction Investigation*.
   After completing the investigation, facilitate a whole-class discussion to explore students' findings. Students then complete *The One That Didn't Get Away: Design Challenge*.
   Alternatively, Year 9 teachers could ask their students to modify the experiment in order to investigate a related hypothesis or question. For example, students may investigate how increasing quantities of salt affect refraction or how other solutes (i.e. sugar) affect refraction.

7. Students apply their understanding of refraction to complete the activity, *Fishy Physics*.

1 Australian Institute of Aboriginal and Torres Strait Islander Studies. (2007). A brief history of Indigenous fishing. Retrieved from https://aiatsis.gov.au/exhibitions/brief-history-indigenous-fishing

Curriculum Links

Science

YEAR 5

Science Understanding

Light from a source forms shadows and can be absorbed, reflected and refracted (ACSSU080)

Science as a Human Endeavour

Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)

Science Inquiry Skills

With guidance, pose clarifying questions and make predictions about scientific investigations (ACSIS231)

Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks (ACSIS086)

Decide variables to be changed and measured in fair tests, and observe measure and record data with accuracy using digital technologies as appropriate (ACSIS087)

Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate (ACSIS090)

Compare data with predictions and use as evidence in developing explanations (ACSIS218)

Reflect on and suggest improvements to scientific investigations (ACSIS091)

Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

YEAR 9

Science Understanding

Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)

Science Inquiry Skills

Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)

Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS166)

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS169)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

Mathematics

YEAR 9

Measurement and Geometry

Apply trigonometry to solve right-angled triangle problems (ACMMG224)

Design and Technology

YEAR 5 & 6

Design and Technologies: Knowledge and Understanding

Investigate characteristics and properties of a range of materials, systems, components, tools and equipment and evaluate the impact of their use (ACTDEK023)

Design and Technologies: Processes and Production Skills

Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024)

Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)

Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions (ACTDEP026)

YEAR 7 & 8

Design and Technologies: Knowledge and Understanding

Analyse ways to produce designed solutions through selecting and combining characteristics and properties of materials, systems, components, tools and equipment (ACTDEK034)

Design and Technologies: Processes and Production Skills

Critique needs or opportunities for designing and investigate, analyse and select from a range of materials, components, tools, equipment and processes to develop design ideas (ACTDEP035)

Generate, develop, test and communicate design ideas, plans and processes for various audiences using appropriate technical terms and technologies including graphical representation techniques (ACTDEP036)

Select and justify choices of materials, components, tools, equipment and techniques to effectively and safely make designed solutions (ACTDEP037)

Curriculum Links

YEAR 9 & 10

Design and Technologies: Knowledge and Understanding

Investigate and make judgements on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (ACTDEK046)

Design and Technologies: Processes and Production Skills

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range of materials, systems, components, tools and equipment to develop design ideas (ACTDEP048)

Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication (ACTDEP049)

Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions (ACTDEP050)

General Capabilities

Literacy

Comprehending texts through listening, reading and viewing

Composing texts through speaking, writing and creating

Information and Communication Technology

Investigating with ICT

Critical and Creative Thinking

Inquiring: Identifying, exploring and organising information and ideas

Reflecting on thinking and processes

Personal and Social Capability

Social management

Cross-Curriculum Priorities

Aboriginal and Torres Strait Islander Histories and Cultures

Aboriginal and Torres Strait Islander Peoples have holistic belief systems and are spiritually and intellectually connected to the land, sea, sky and waterways. (OI.3)

Aboriginal and Torres Strait Islander Peoples' ways of life are uniquely expressed through ways of being, knowing, thinking and doing. (OI.5)

The One That Didn't Get Away

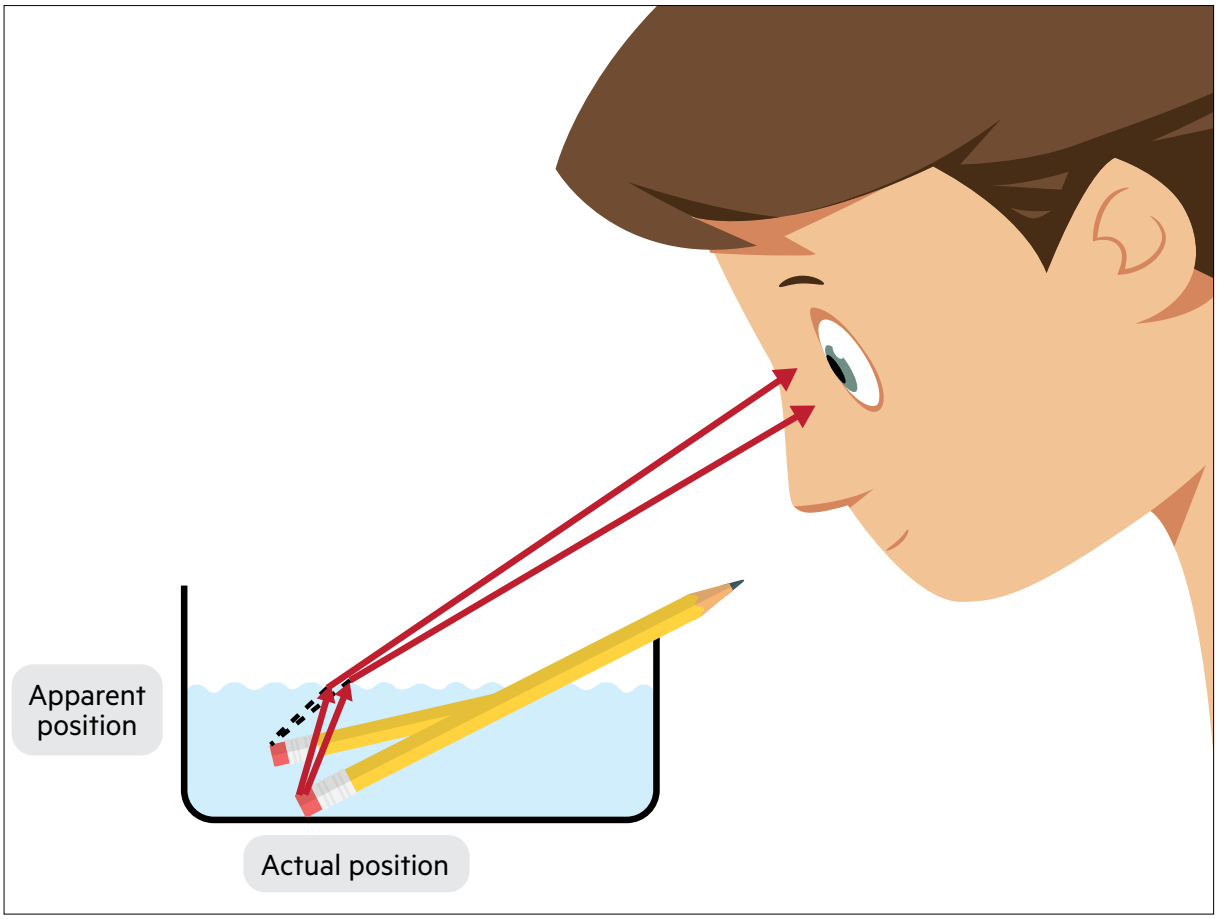
Student Activity

Refraction: Year 5

Light is reflecting off the pencil. As light reflects off the lower (submerged) part of the pencil, it is transmitted (or passes) through water and then air.

Light travels at slightly different speeds through different transparent materials. When light travels from one transparent material to another, the change in speed can cause light to change direction. This is called refraction.

Let's take another look at the pencil; as the light from the pencil passes from the water to the air, it speeds up a little and changes direction. This change in the direction of light makes the pencil appear as if it is in a different position to where it actually is when placed in water.



Refraction of light waves from water to air.

The One That Didn't Get Away

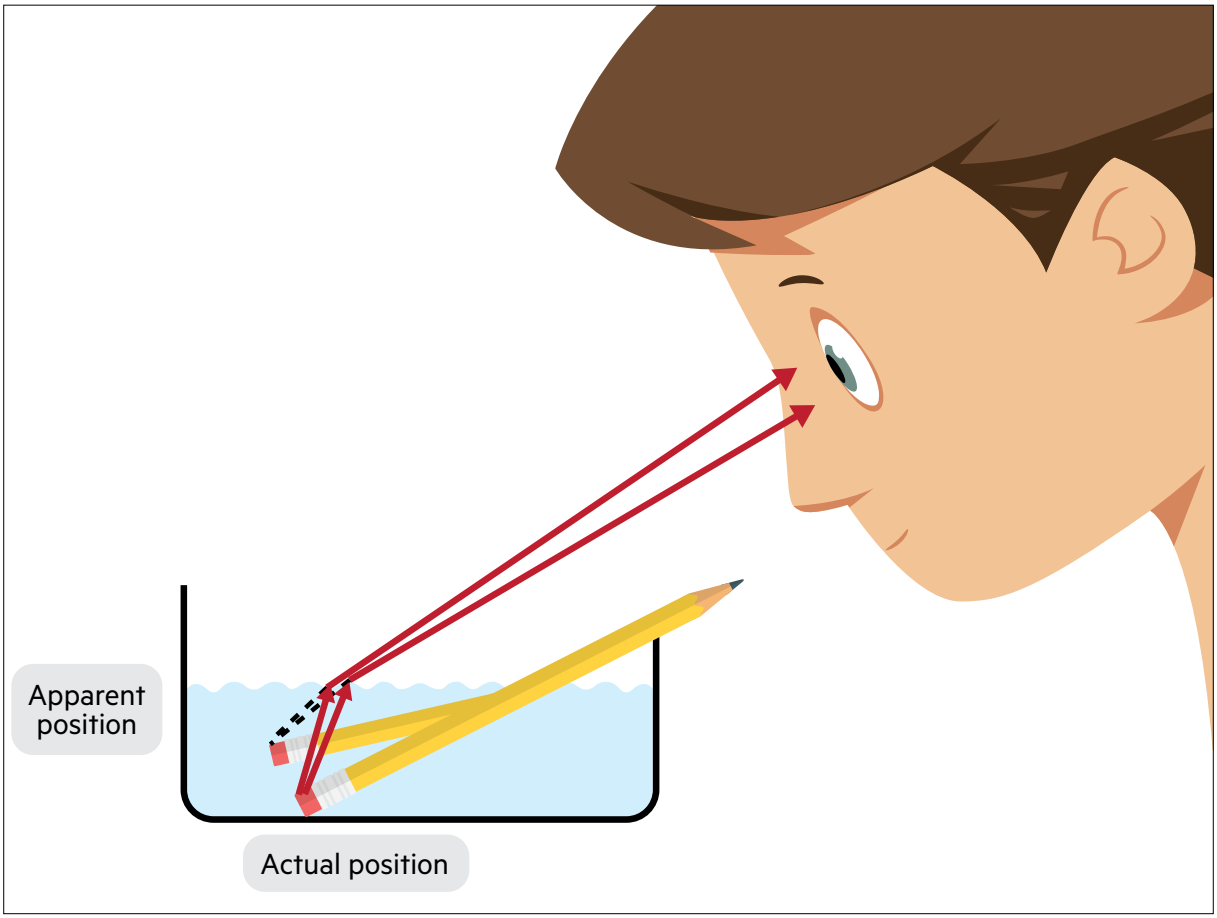
Student Activity

Refraction: Year 9

Different materials have different optical densities. The optical density of a material affects the speed at which light is transmitted through the material. Light will travel at slower speeds though more optically dense materials, compared to less dense materials.

When light passes through two transparent materials of different optical densities, it either slows down or speeds up. This change in speed may cause the light waves to change direction as they cross the boundary between the two materials. This phenomenon is known as refraction.

Let's take another look at the pencil. Light waves reflecting off the submerged part of the pencil must be transmitted through water and then air before reaching our eyes. Water is denser than air; when light waves pass from water to air they speed up and change direction. This change in the direction of light makes the pencil appear as if it is in a different position to where it actually is when placed in water.



Refraction of light waves from water to air.

The One That Didn't Get Away

Student Activity

Refraction Investigation

People from around the world, including Aboriginal and Torres Strait Islander people, have used their knowledge of refraction to spear fish for tens of thousands of years. In this investigation, you will explore how refraction affects the way we view objects that are underwater.

Materials

- 3 x transparent rectangular 2.5L containers
- 600 g coloured modelling clay
- 15 g black modelling clay
- Toothpick, cut into thirds
- 4 L water
- 70 g table salt
- Rolling pin
- Teaspoon
- Scale
- Bamboo skewer
- Extension activity materials:
    - Laser pointer, <1 mW
    - Ruler
    - Fine tip marker

Method

1. Divide the coloured modelling clay into thirds. Use the rolling pin to roll out each portion of clay until it is a similar size to the base of the containers. Place one piece of clay into each container.

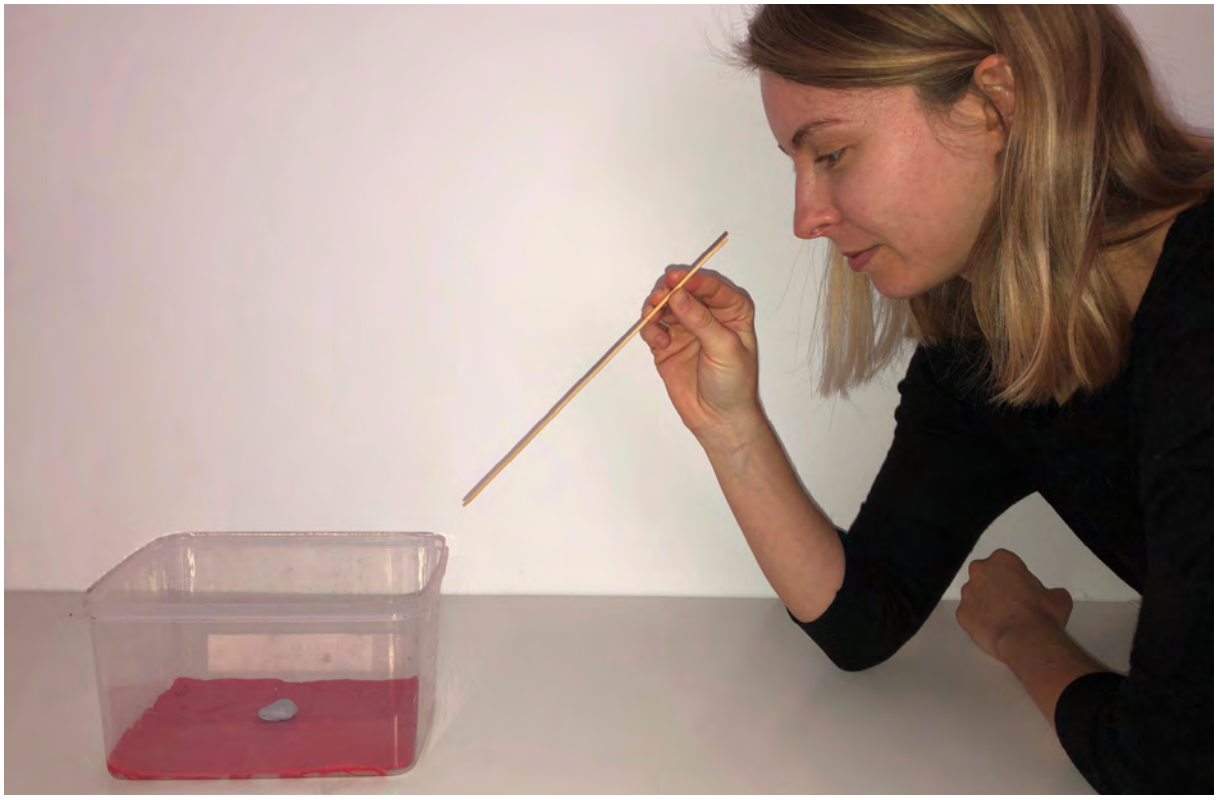
2. Divide the black modelling clay into thirds. Roll each portion of clay into the shape of a fish. Use one third of a toothpick to attach one model fish to the bottom of each container.

3. Fill one container with 2 L of water.

4. Fill another container with 2 L of water. Add 70 g salt to the water. Stir to dissolve the salt.

5. Place the containers in a row, with the empty container on the left, the container filled with water in the middle, and the container filled with salt water on the right. Leave the containers overnight.

6. Start with the empty container. Carefully aim the skewer at the middle of the fish from the edge of the container. Make sure you hold the skewer at an angle, at least 5 cm above the container. Look directly above the skewer before you spear the fish.



An example of how to aim the skewer at the fish.

7. Try to spear the fish in the middle. Repeat five times. Record your observations and results.

8. Repeat Steps 6 and 7 with the remaining two containers. Record your observations and results.

9. Return to the fresh and salt water containers. Adjust your aim so that you successfully spear the fish in each container. Take note of where you need to aim the skewer in order to successfully spear the fish, and then move on to discussing your results.

Variables

Record the variables in the table below.

Independent variable	Dependent variable	Control variable

Results

1. Record your observations. Describe where your spear landed in relation to the fish.

No Water	Fresh Water	Salt Water

2. Remove the modelling clay from the containers. Record the strike distance from the fish for each test, and then represent this data on a Cartesian plane.

Strike Distance from Fish: No Water

Attempt	Hit	Miss	Distance (cm)	
			X axis	Y axis

Strike Distance from Fish: Fresh Water

Attempt	Hit	Miss	Distance (cm)	
			X axis	Y axis

Strike Distance from Fish: Salt Water

Attempt	Hit	Miss	Distance (cm)	
			X axis	Y axis

3. Use the above data to calculate the percent accuracy for each test.

Percent Accuracy

No Water	
Fresh Water	
Salt Water	

Discussion

1. Draw a ray diagram to show how light travels from the fish to our eyes. Use your understanding of light to explain what is happening in each test.

No Water

Ray Diagram	Explanation

Fresh Water

Ray Diagram	Explanation

Salt Water

Ray Diagram	Explanation

2. Which test yielded the most accurate results? Explain why this is the case, and how these results may differ in a real world context.

The refraction of light can change where an object appears visually. You can investigate how different materials affect the refraction of light in the online simulations: Bending Light by PhET Interactive Simulations or Refraction Interaction by The Physics Classroom.

Evaluation

1. Describe any challenges you experienced during the investigation.

2. Explain how you could improve the investigation.

Extension

Calculate the angle of refraction for fresh and salt water using a laser pointer and the appropriate trigonometric ratio (i.e. sine, cosine or tangent). Draw a diagram, and then record your working out and results below. *Hint: Your teacher may turn the lights off in the classroom to make it easier to see the laser beam.*

The One That Didn't Get Away

Student Activity

Design Challenge

Task:

Design a device that helps people account for refraction when fishing in salt water. People using the device should not need to adjust their aim in order to spear the fish.

You must:

- **Investigate** how light travels through water and where a person should aim if they are to spear a fish in salt water.
- **Design** a device that will help a person account for refraction when fishing in salt water. The person using the device should not need to adjust their aim in order to hit the fish.
- **Create** a model of your device.
- **Test** the model by simulating spear fishing in salt water. How could you test the effectiveness of your device?
- **Refine** your device to improve on the original design.
- **Collaborate** in teams of two.
- **Evaluate** your design. You may also be required to evaluate social interactions and your ability to work effectively in a team.

Investigate and Design

Draw a labelled diagram of your device, including reasons for your design and selection of materials.

Create and Test

Test the device and record the results in the PMI Chart below.

Plus	Minus	Interesting

Refine

Recommend future changes that could improve the effectiveness of the device.

The One That Didn't Get Away

Student Activity

Fishy Physics

Archerfish are a family of freshwater and estuarine fishes. Four species of archerfish are found in Australia; two of these species, the Banded Archerfish (*Toxotes jaculatrix*) and Seven-spot Archerfish (*Toxotes chatareus*) are found in the mangrove swamps, freshwater rivers and streams of North and Far North Queensland.

Banded Archerfish, *Toxotes jaculatrix*. © Queensland Museum, Bruce Cowell

Archerfish feed mainly on terrestrial and aquatic insects, but also on other small fish, crustaceans and floating plant matter. Archerfish have developed a unique ability to feed on terrestrial insects. When an archerfish spots an insect, it carefully aims and spits a jet of water. This jet of water has enough force to knock the insect into the water, where it is quickly consumed by the archerfish. You can check out a video of the archerfish in action here or by searching for 'archerfish spitting' videos on the internet. While most archerfish are able to spit distances of up to 150 cm, some larger specimens can spit water that spans a distance of 2 – 3 metres!

In order to successfully catch prey, archerfish must accommodate for the refraction of light at the surface of the water. Use your scientific understanding of refraction and light to answer the following questions.

1. Hypothesise how archerfish experience refraction. You may like to draw a ray diagram to help communicate your ideas.

2. Explain the adaptations that have enabled this animal to accommodate for refraction. These adaptations may be structural, functional or behavioural. You may also like to conduct further research to answer this question.

3. Describe any other challenges the archerfish may experience when catching its prey. Explain how the animal might overcome these challenges.

4. These animals also experience refraction:

    - Giant Trevally, *Caranx ignobilis*
    - Caspian Tern, *Hydroprogne caspia*
    - Eastern Osprey, *Pandion cristatus*

    Select an animal to research further. Describe how this animal experiences refraction, and explain how they have accommodated for this phenomenon. You can view these animals and learn more about their habitats in *Wild State* at Queensland Museum.