Applicable standards
The national curriculum in England

KS3 Science

Element of the curriculum	Lessons 1	2	3	4	5	6
Physics						
• Energy: energy changes and transfers, changes in systems	✓		✓			
• Forces: as pushes or pulls	✓	✓	✓			
• Forces: using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces	✓	✓	✓	✓		
• Forces: gravity	✓	✓	✓	✓		
• Forces: resistance to motion of water	✓					
• Forces: measured in newtons		✓	✓			
• Forces: moment as the turning effect of a force			✓			
• Forces: associated with deforming objects				✓		
• Forces and motion: cause objects to stop or start moving, or to change their speed or direction of motion	✓	✓	✓			
• Pressure in fluids: pressure in liquids, increasing with depth; upthrust effects, floating and sinking	✓	✓		✓		
• Pressure in fluids: pressure measured by ratio of force over area				✓		
Chemistry						
• Chemical reactions: oxidation reactions, displacement reactions, catalysts					✓	✓
• Materials					✓	
Biology						
• Structure and function of living organisms						✓
• Material cycles and energy: cellular respiration						✓
• Interactions and interdependencies: relationships in an ecosystem						✓
Working Scientifically						
• Scientific attitudes	✓	✓	✓	✓	✓	✓
• Experimental skills and investigations	✓	✓	✓	✓	✓	✓
• Analysis and evaluation	✓	✓	✓	✓	✓	✓
• Measurement	✓	✓	✓	✓	✓	

Applicable standards
Next Generation Science Standards (NGSS)

Grade 5 Science and Engineering

Element of the curriculum	Lessons 1	2	3	4	5	6
Matter and Its Interactions						
5-PS1-3. Make observations and measurements to identify materials based on their properties.				✓	✓	
Motion and Stability: Forces and Interactions						
5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.	✓	✓	✓	✓		
Engineering Design						
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	✓	✓	✓	✓	✓	✓
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	✓	✓	✓	✓	✓	✓
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	✓	✓	✓	✓	✓	

Grade 6-8 Middle School Science and Engineering

Element of the curriculum	Lessons 1	2	3	4	5	6
Matter and Its Interactions						
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.					✓	✓
Motion and Stability: Forces and Interactions						
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	✓	✓	✓			
From Molecules to Organisms: Structures and Processes						
MS-LS1-3. Use arguments supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.						✓
MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and /or release energy as this matter moves through an organism.						✓

Applicable standards
Next Generation Science Standards (NGSS)

Grade 6-8 Middle School Science and Engineering (continued)

Element of the curriculum	Lessons 1	2	3	4	5	6
Engineering Design						
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	✓	✓	✓	✓	✓	✓
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	✓	✓	✓	✓	✓	✓
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	✓	✓	✓	✓	✓	

Science and Engineering Practices

Element of the curriculum	Lessons 1	2	3	4	5	6
• Asking questions	✓	✓	✓	✓	✓	✓
• Developing and using models	✓	✓	✓	✓	✓	
• Planning and carrying out investigations	✓	✓	✓	✓	✓	✓
• Analyzing and interpreting data	✓	✓	✓	✓	✓	✓
• Using mathematics		✓	✓	✓		
• Constructing explanations	✓	✓	✓	✓	✓	✓
• Engaging in argument from evidence	✓	✓	✓	✓	✓	✓
• Obtaining, evaluating and communicating information	✓	✓	✓	✓	✓	✓

SCHEME OF WORK

Lesson 1: Submarine shape investigation

Overview

This lesson starts off by establishing the story of the whole unit. The students will be using the information learned in the unit to design a submarine for exploring the ocean depths.

The context of the lesson is a practical investigation to discover a suitable shape that can dive and rise at a speed safe enough for the scientists inside the submarine. Students develop their understanding of forces, surface area, and fair testing.

Learning outcomes

- Test different shapes to compare how they fall through the water
- Explain how the shape affects the speed of descent
- Design and carry out a fair test
- Explain how differences in gravitational and resistive forces affect descent of an object
- Explain why surface area affects the speed of descent

Resources

Slideshow 1: Submarine shape investigation

360VR Expedition Guide: Diving in a submarine

Activity Overview 1: Submarine shape investigation

Student Sheet 1a: Submarine shape investigation

Student Sheet 1b: Submarine shape investigation (differentiated)

Mark Scheme 1: Submarine shape investigation

360VR Story: Diving in a submarine

Lesson 2: Submarine buoyancy investigation

Overview

This lesson encourages students to investigate hands-on the property of neutral buoyancy, and to discuss its importance in terms of submarines.

There is a practical investigation to achieve neutral buoyancy for a floating object by adding weight. This session also explores the mathematics of density and buoyancy.

Learning outcomes

- Describe how to make floating objects sink
- Make an object neutrally buoyant through experimentation
- Explain how neutral buoyancy is achieved in terms of forces
- Calculate the volume of a spherical object
- Calculate the weight required to make a floating object neutrally buoyant

Resources

Slideshow 2: Submarine buoyancy investigation

360VR Expedition Guide: Diving in a submarine

Activity Overview 2: Submarine buoyancy investigation

Student Sheet 2a: Submarine buoyancy investigation

Student Sheet 2b: Ballast tank diagram

Mark Scheme 2: Submarine buoyancy investigation

360VR Story: Diving in a submarine

Lesson 3: Submarine launch investigation

Overview

The submarines used for the XL Catlin Deep Ocean Survey were in the strictest sense submersibles. A distinction is made between true submarines that operate independently and submersibles which require the support of a surface vessel.

In this lesson, students develop an understanding of structural strength and stability. They will then design and build a model crane suitable for lifting and moving a weight. This activity replicates the science involved in launching and recovering a submersible using a surface vessel.

Learning outcomes

- Describe the features of a strong and stable structure
- Describe the purpose of each part of a crane's structure
- Construct a working model of a crane
- Calculate the moments of some given examples
- Explain the importance of launching and raising the submarine from the back of a ship, rather than the side

Resources

Slideshow 3: Submarine launch investigation

Activity Overview 3: Designing a crane

Student Sheet 3a: Designing a crane

Student Sheet 3b: Moments calculations

Student Sheet 3c: Gears and pulleys

Mark Scheme 3: Submarine launch investigation

360 Video:
- Submarine launch
- Submersible recovery

Lesson 4: Submarine pressure investigation

Overview

The operating depth limit for the submersibles used on the XL Catlin Deep Ocean Survey was 1,000 feet. To put this in context, recreational scuba diving has a limit of 130 feet, but the deepest point in the ocean is an astounding 36,070 feet down.

In this lesson, students investigate the effects of pressure increasing with depth, and the implications that this has for submarine design. Get the design wrong and the submarine will implode.

Learning outcomes

- Describe the dangers of exploring at depth
- Explain why pressure increases with depth
- Design and carry out a fair test to investigate the effects of increasing depth
- Calculate the amount of pressure caused at different depths
- Explain, in terms of forces, why submarines have a safe limit to which they can dive

Resources

Slideshow 4: Submarine pressure investigation

Activity Overview 4a: Under pressure

Activity Overview 4b: Submarine pressure investigation

Student Sheet 4a: Submarine pressure investigation

Student Sheet 4b: Pressure calculations

Student Sheet 4c: Cartesian diver

Mark Scheme 4: Submarine pressure investigation

Video:
- Under Pressure
- Submarine Engineer

Lesson 5: Submarine materials investigation

Overview

Submarines have to operate in difficult environments. First, they need to operate under pressure. Second, they have to cope with the corrosive nature of seawater. Different parts of the submarine will need different materials. There is no point building a submarine for scientific operation out of solid metal.

In this lesson, students will start by reflecting on historical submarine designs and some were not very successful. They will then debate materials choices for building a submarine. A practical investigation looks at how to protect the submarine from rusting.

Learning outcomes

- Describe why several different materials are needed to build a submarine
- Carry out a fair investigation into the effects of salt and water on rusting
- Explain why different conditions cause different amounts of rusting
- Make justified choices for the materials used to build a submarine
- Explain oxidation reactions with balanced equations

Resources

Slideshow 5: Submarine materials investigation

Activity Overview 5: Submarine 'rusting' investigation

Student Sheet 5a: Submarine 'rusting' investigation

Student Sheet 5b: Materials cards

Student Sheet 5c: Submarine materials choices

Student Sheet 5d: Submarine 'rusting' predictions

Mark Scheme 5: Submarine launch investigation

Lesson 6: Submarine life support investigation

Overview

Researching using submarines means that the scientists are working in an enclosed space deep underwater for hours at a time. This lesson investigates the life support systems needed to keep scientists and explorers alive.

Students will conduct an investigation into how limewater can reduce the amount of carbon dioxide in an atmosphere. Students will then design the life support systems needed for a submarine. The lesson concludes with students compiling all their research from the unit to create a submarine design presentation.

Learning outcomes

- Describe the dangers to explorers in the deep ocean
- Conduct an investigation into respiration
- Describe how respiration occurs and its importance
- Balance the respiration equation
- Explain how submarines are built and engineered to sustain life

Resources

Slideshow 6: Submarine life support investigation

Activity Overview 6: Respiration investigation

Student Sheet 6a: Respiration investigation

Student Sheet 6b: Life support design

Student Sheet 6c: Submarine presentation

Mark Scheme 6: Submarine life support investigation

360 Video: Exploring the deep ocean

Gallery:
- Deep sea creatures
- Life around the vent

Diagram: Deep ocean poster

LESSON 1: SUBMARINE SHAPE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

Lesson overview

This lesson starts off by establishing the story of the whole unit. The students will be using the information learned in the unit to design a submarine for exploring the ocean depths.

The context of the lesson is a practical investigation to discover a suitable shape that can dive and rise at a speed safe enough for the scientists inside the submarine. Students develop their understanding of forces, surface area, and fair testing.

Keywords

- **Concepts:** forces, water resistance, surface area, fair testing.

Details

Time
60 minutes

Curriculum links
KS3 Physics:
- Forces: force arrows, resistance to motion of water, gravity

KS3 Working scientifically:
- Experimental skills and investigations
- Analysis and evaluation
- Measurement

Lesson steps	Learning outcomes
1 (15 mins) **Brief** Students view 360VR panoramas of a submarine dive and answer questions, before being introduced to the purpose of the overall module (designing a submarine) and aim for this lesson (choosing a suitable shape). Students set themselves targets based on the intended learning outcomes for the lesson.	Understand the wider context and learning outcomes
2 (25 mins) **Investigation** Students follow the investigation brief to try to find a 'submarine' shape that falls through a cylinder of water in a given time. Students are encouraged to adapt their results, and make changes as they go, while considering how they keep their testing fair.	**Foundation** Test different shapes to compare how they fall through the water **Developing** Explain how the shape affects the speed of descent **Competent** Design and carry out a fair test
3 (10 mins) **Forces and surface area** Using the slides, students are introduced to the role of forces in descent and the effects of surface area on descent. Students demonstrate their learning by follow-up questions on their investigation worksheets.	**Expert** Explain how differences in gravitational and resistive forces affect descent of an object **Advanced** Explain why surface area affects the speed of descent
4 (5 mins) **Summary conversation** Students demonstrate their learning by drafting a short conversation between themselves and a new team member, to explain the purpose of the lesson.	Demonstrate learning
5 (5 mins) **Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance in the context of the Scheme of Work to design a submarine.	Reflect on learning

Resources

Activities Overview

360VR Expedition Guide: Diving in a submarine

Activity Overview 1: Submarine shape investigation

Student Sheets

Student Sheet 1a: Submarine shape investigation

Student Sheet 1b: Submarine shape investigation (differentiated)

Mark Scheme

Mark Scheme 1: Submarine shape investigation

Slideshow

Slideshow 1

Multimedia

360VR Story: Diving in a submarine

Subject Update

About: XL Catlin Deep Ocean Survey

Learn more: Investigation skills for younger students

How to: Quick start to 360VR in the classroom

How to: 4 ways to use 360VR in the classroom

How to: Use Google Expeditions

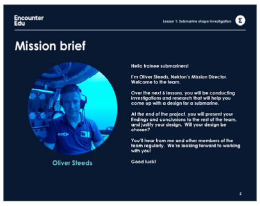
TEACHER GUIDANCE 1: SUBMARINE SHAPE INVESTIGATION

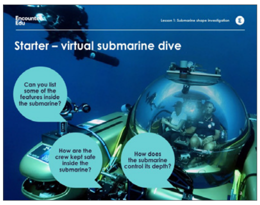
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

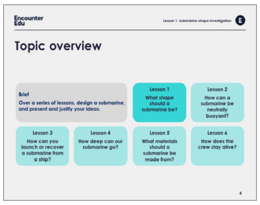
Step

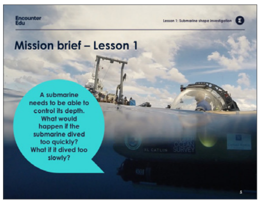
1

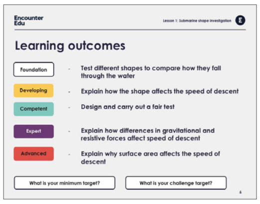
15 mins











The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Using **slide 2**, read through the mission brief as a whole class, selecting students to read out loud.

The next section involves using 360° virtual reality technology in the classroom. You can do this in one of two ways.
First, you can use the Google Expeditions platform. This requires individual students having access to compatible mobile or tablet devices and virtual reality viewers.
The second method is viewing the 360 gallery on the Encounter Edu website. The 360°media can be viewed on all connected devices including using an interactive white board.
Further guidance can be found in the **Subject Updates How to: Quick start to 360VR in the classroom**, **How to: 4 ways to use 360VR in the classroom**, and **How to: Use Google Expeditions.**

Guidance on the 360° panorama imagery can be found in the **360VR Expedition Guide - Diving in a submarine.**

Students explore the **Diving in a submarine** panoramas on the in the Encounter Edu 360VR gallery or on the Google Expeditions platform.

Guide a whole class discussion on the panoramas using the information on the respective platforms and in the **360VR Expedition Guide - Diving in a submarine.**

Following the 360VR exploration, set the scene of the whole topic unit using **slides 4-5**. The aim is for the students to use information from each of the following lessons to design a submarine, and justify their choices.

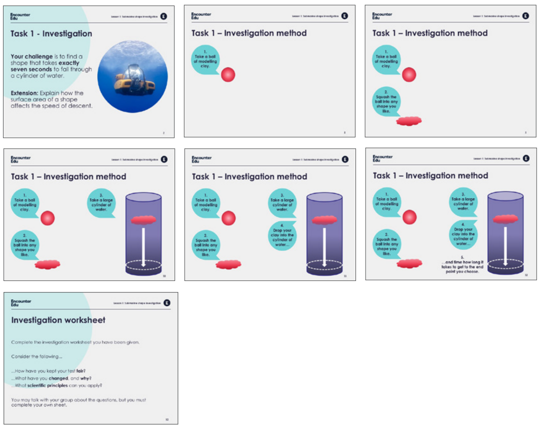
Show students learning outcomes on **slide 6**. Ask students to set themselves a minimum target and challenge target in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

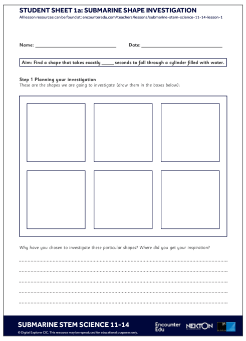
TEACHER GUIDANCE 1: SUBMARINE SHAPE INVESTIGATION

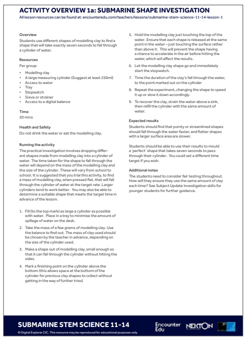
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

Step

2
25 mins







The purpose of Step 2 is for students to become more familiar with the idea of surface area, forces and investigation design through experimentation.

The practical investigation involves dropping different shapes made from modelling clay into a cylinder of water. The time taken for the shape to fall through the water will depend on the mass of the modelling clay and the size of the cylinder. These will vary from school to school. It is suggested that you trial this activity, to find a mass of modelling clay, when pressed flat, that will fall through the cylinder of water at the target rate. See **Activity Overview 1** for more details.

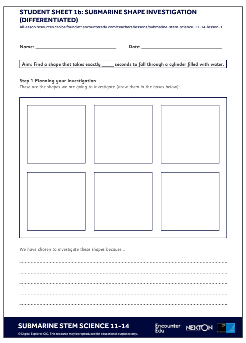
Using **slides 7-12**, explain the aim of the practical investigation, while also modelling the method of the investigation.

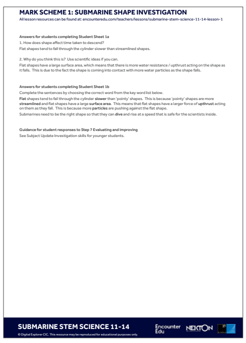
Hand student groups **Student Sheet 1a** or **Student Sheet 1b** (differentiated) and go through these with students using **slide 13**.

Students conduct their investigation and complete Steps 1 to 5 on their investigation worksheets **(Student Sheet 1a** or **1b)**. As an extension, students can try out more shapes, or be introduced to the idea of surface area and forces before the class discussion.

Ask students to draw the shapes that came closest to the time target on a mini whiteboard, and show it to the class. Question students to explain how they arrived at this shape through their investigation.

3
10 mins





The purpose of Step 3 is for students to understand the importance of forces and surface area.

Using **slides 14-20**, describe the forces that act on the shape, and how surface area affects the descent through the cylinder.
Then use **slide 21** to explain Task 2.

Students answer the 'Considering evidence' and 'Evaluating and improving' questions in Step 6 and 7 on their **Student Sheet 1a** or **1b**.

Take feedback from the class. Focus on students justifying their ideas.

Display or hand out **Mark Scheme 1** for **Student Sheet 1a** or **1b**. Students mark their own work and make corrections where necessary.

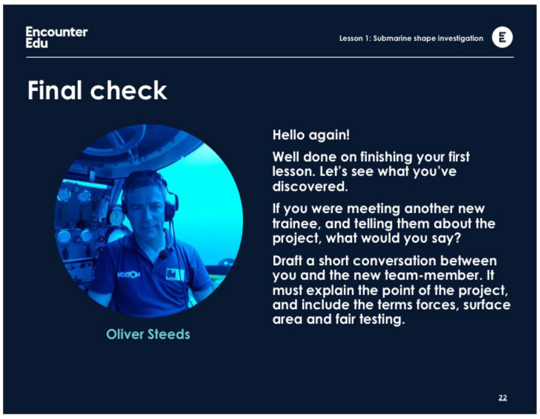
TEACHER GUIDANCE 1: SUBMARINE SHAPE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

Step

4

5 mins



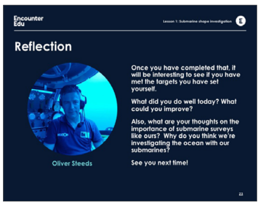
The purpose of Step 4 is for students to demonstrate their learning.

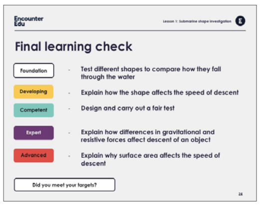
Reintroduce the team member on **slide 19.** Linking back to the lesson, and the overall context of the unit, students role play a short conversation between themselves and the new team-member. It must explain the point of the project, and include the words forces, surface area and fair testing.

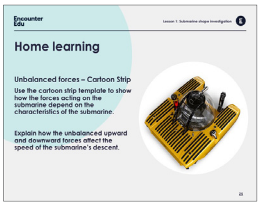
Have a conversation performed. Ask other students if the given criteria have been met. Ask students to read out the comments they have made on their partner's work. This will highlight if they have understood the success criteria.

5

5 mins







The purpose of Step 4 is for students to reflect on their learning.

Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson. They then write a short sentence explaining their achievement.

Ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Use **slide 22** to set the home learning task if using.

ACTIVITY OVERVIEW 1a: SUBMARINE SHAPE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

Overview

Students use different shapes of modelling clay to find a shape that will take exactly seven seconds to fall through a cylinder of water.

Resources

Per group:

- Modelling clay
- A large measuring cylinder (Suggest at least 250ml)
- Access to water
- Tray
- Stopwatch
- Sieve or strainer
- Access to a digital balance

Time

20 mins

Health and Safety

Do not drink the water or eat the modelling clay.

Running the activity

The practical investigation involves dropping different shapes made from modelling clay into a cylinder of water. The time taken for the shape to fall through the water will depend on the mass of the modelling clay and the size of the cylinder. These will vary from school to school. It is suggested that you trial this activity, to find a mass of modelling clay, when pressed flat, that will fall through the cylinder of water at the target rate. Larger cylinders tend to work better. You may also be able to determine a suitable shape that meets the target time in advance of the lesson.

1. Fill (to the top mark) as large a cylinder as possible with water. Place in a tray to minimise the amount of spillage of water on the desk.
2. Take the mass of a few grams of modelling clay. Use the balance to find out. The mass of clay used should be chosen by the teacher in advance, depending on the size of the cylinder used.
3. Make a shape out of modelling clay, small enough so that it can fall through the cylinder without hitting the sides.
4. Mark a finishing point on the cylinder above the bottom (this allows space at the bottom of the cylinder for previous clay shapes to collect without getting in the way of further tries)
5. Hold the modelling clay just touching the top of the water. Ensure that each shape is released at the same point in the water – just touching the surface rather than above it. This will prevent the shape having a chance to accelerate in the air before hitting the water, which will affect the results.
6. Let the modelling clay shape go and immediately start the stopwatch.
7. Time the duration of the clay's fall through the water, to the point marked out on the cylinder
8. Repeat the experiment, changing the shape to speed it up or slow it down accordingly.
9. To recover the clay, strain the water above a sink, then refill the cylinder with the same amount of water.

Expected results

Students should find that pointy or streamlined shapes should fall through the water faster, and flatter shapes with a larger surface area are slower.

Students should be able to use their results to mould a 'perfect' shape that takes seven seconds to pass through their cylinder. You could set a different time target if you wish.

Additional notes

The students need to consider fair testing throughout. How will they ensure they use the same amount of clay each time? See Subject Update Investigation skills for younger students for further guidance.

STUDENT SHEET 1a: SUBMARINE SHAPE INVESTIGATION

Name: ______________________________ **Date:** ______________________________

Aim: Find a shape that takes exactly _____ seconds to fall through a cylinder filled with water.

Step 1 Planning your investigation

These are the shapes we are going to investigate (draw them in the boxes below):

Why have you chosen to investigate these particular shapes? Where did you get your inspiration?

....

....

....

....

....

STUDENT SHEET 1a: SUBMARINE SHAPE INVESTIGATION

Step 2 Making a fair test
I will need to keep these variables the same for each test.

Step 3 Making predictions
Prediction (what **I think** will happen):

This shape will be the fastest	This shape will be the slowest	This shape will be the closest to the target time

STUDENT SHEET 1a: SUBMARINE SHAPE INVESTIGATION

Explain your reasoning for your predictions. Use scientific ideas.

....

....

....

....

....

Step 4 Results

Draw a table in your book to record your results.

Step 5 Obtaining more evidence

Based on your results, are there any more shapes you want to investigate? Draw them below.

Explain your reasons for choosing these extra shapes:

....

....

....

....

STUDENT SHEET 1a: SUBMARINE SHAPE INVESTIGATION

Step 6 Considering evidence
Answer the following questions in your book.

1. How does shape affect time taken to descend?

2. Why do you think this is? Use scientific ideas if you can.

Step 7 Evaluating and improving
Answer the following questions in your book.

1. Was your test fair? Explain why.

2. What could you do next time to make your test fairer?

3. Why is it important to test each shape more than once?

4. Were there any unusual results in your experiment? If so, which ones?

5. Why did you think you obtained these unusual results?

6. How would you stop these happening next time?

7. How could you extend this investigation?

8. What will your extended investigation let you find out?

9. Based on this experiment, what kind of shape would you like your submarine to have and why?

STUDENT SHEET 1b: SUBMARINE SHAPE INVESTIGATION (DIFFERENTIATED)

Name: ________________________________ **Date:** ________________________________

Aim: Find a shape that takes exactly _____ seconds to fall through a cylinder filled with water.

Step 1 Planning your investigation

These are the shapes we are going to investigate (draw them in the boxes below):

We have chosen to investigate these shapes because...

....

....

....

....

....

STUDENT SHEET 1b: SUBMARINE SHAPE INVESTIGATION (DIFFERENTIATED)

Step 2 Making a fair test
I will need to keep these variables the same for each test.

Step 3 Making predictions
Prediction (what **I think** *will happen):*

This shape will be the fastest

This shape will be the slowest

STUDENT SHEET 1b: SUBMARINE SHAPE INVESTIGATION (DIFFERENTIATED)

I think this because...

....

....

....

....

....

Step 4 Results

Complete the table to record your results.

Shape of modelling clay (Draw and/or describe below)	Time taken to fall through cylinder of water (s)			
	1	2	3	Mean Av.

STUDENT SHEET 1b: SUBMARINE SHAPE INVESTIGATION (DIFFERENTIATED)

Step 5 Obtaining more evidence

Did your shapes get close to the target time? If not, suggest some extra shapes that you want to investigate, and draw them below.

We have chosen to investigate these extra shapes because...

....

....

....

....

....

Shape of modelling clay (Draw and/or describe below)	Time taken to fall through cylinder of water (s)			
	1	2	3	Mean Av.

STUDENT SHEET 1b: SUBMARINE SHAPE INVESTIGATION (DIFFERENTIATED)

Step 6 Considering evidence
Which shape was the closest to the target time? Draw it in the box.

Complete the sentences using the key words below:

____________ shapes tend to fall through the cylinder ____________ than 'pointy' shapes. This is because 'pointy' shapes are more ____________ , and flat shapes have a large ____________ ____________. This means that flat shapes have a larger ____________ force acting on them as they fall. This is because more ____________ are pushing against the flat shape.

Submarines need to be the right shape so that they can ____________ and rise at a speed that is safe for the scientists inside.

Dive **Particles** **Slower** **Flat** **Resistive** **Surface area** **Streamlined**

MARK SCHEME 1: SUBMARINE SHAPE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-1

Answers for students completing Student Sheet 1a

1. How does shape affect time taken to descend?

Flat shapes tend to fall through the cylinder slower than streamlined shapes.

2. Why do you think this is? Use scientific ideas if you can.

Flat shapes have a large surface area, which means that there is more water resistance acting on the shape as it falls. This is due to the fact the shape is coming into contact with more water particles as the shape falls.

Answers for students completing Student Sheet 1b

Complete the sentences by choosing the correct word from the key word list below.

Flat shapes tend to fall through the cylinder **slower** than 'pointy' shapes. This is because 'pointy' shapes are more **streamlined** and flat shapes have a large **surface area.** This means that flat shapes have a larger **resistive** force acting on them as they fall. This is because more **particles** are pushing against the flat shape.

Submarines need to be the right shape so that they can **dive** and rise at a speed that is safe for the scientists inside.

Guidance for student responses to Step 7 Evaluating and improving

See Subject Update Investigation skills for younger students.

LESSON 2: SUBMARINE BUOYANCY INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

Lesson overview

This lesson encourages students to investigate hands-on the property of neutral buoyancy, and to discuss its importance in terms of submarines.

There is a practical investigation to achieve neutral buoyancy for a floating object by adding weight. This session also explores the mathematics of density and buoyancy.

Keywords

- **Names:** Newton, kilograms, ballast, equilibrium
- **Concepts:** density, weight, force, volume

Details

Time
60 minutes

Curriculum links
Physics:
- Balanced forces
- Pressure in fluids

Working Scientifically:
- Experimental skills and investigations, analysis and evaluation, measurement

Lesson steps		Learning outcomes
1 15 mins	**Brief** Students view 360VR panoramas of a submarine dive and answer questions, before being introduced to the aim for this lesson, creating a submarine that is neutrally buoyant. Students set themselves targets based on the intended learning outcomes for the lesson.	Understand the wider context and learning outcomes
2 20 mins	**Investigation** Students follow the investigation brief to try to make their ping pong ball neutrally buoyant. Students are encouraged to adapt to their results, and make changes as they go.	**Foundation** Describe how to make floating objects sink **Developing** Make an object neutrally buoyant through experimentation
3 15 mins	**Calculate neutral buoyancy** Using the slides, students learn how an object becomes neutrally buoyant in terms of forces and displacement. **Demonstrate learning** Students calculate the amount of mass needed to make their ping pong ball neutrally buoyant, and conduct the experiment to see if their calculations matched the result obtained. Advanced students may wish to calculate this before their experiment.	**Competent** Explain how neutral buoyancy is achieved in terms of forces **Expert** Calculate the density of a spherical object **Advanced** Calculate the weight required to make a floating object neutrally buoyant
4 5 mins	**Summary conversation** Students demonstrate their learning by tweeting a summary of the lesson, or making an Instagram post.	Demonstrate learning
5 5 mins	**Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance to the context of the overall unit of work.	Reflect on learning

Resources

Activities Overview

360VR Expedition Guide: Diving in a submarine

Activity Overview 2: Submarine buoyancy investigation

Student Sheets

Student Sheet 2a: Submarine buoyancy investigation

Student Sheet 2b: Ballast tank diagram

Mark Scheme

Mark Scheme 2: Submarine buoyancy investigation

Slideshow

Slideshow 2

Multimedia

360VR Story: Diving in a submarine

Subject Update

About: XL Catlin Deep Ocean Survey

Learn more: Investigation skills for younger students

How to: Quick start to 360VR in the classroom

How to: 4 ways to use 360VR in the classroom

How to: Use Google Expeditions

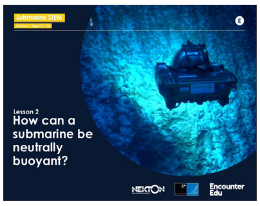
TEACHER GUIDANCE 2: SUBMARINE BUOYANCY INVESTIGATION

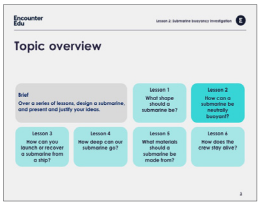
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

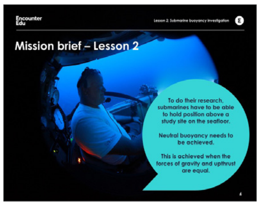
Step

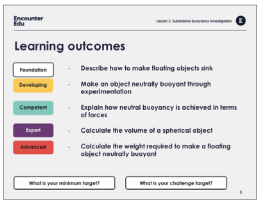
1

15 mins









The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

The next section involves using 360° virtual reality technology in the classroom. You can do this in one of two ways.
First, you can use the Google Expeditions platform. This requires individual students having access to compatible mobile or tablet devices and virtual reality viewers.
The second method is viewing the 360 gallery on the Encounter Edu website. The 360°media can be viewed on all connected devices including using an interactive white board.
Further guidance can be found in the **Subject Updates How to: Quick start to 360VR in the classroom** and **How to: 4 ways to use 360VR in the classroom.**

Guidance on the 360° panorama imagery can be found in **360VR Expedition Guide - Diving in a submarine.**
If students have viewed the 360° panoramas in the previous lesson, focus on the content that was glossed over and is pertinent to this lesson.

Students explore the **Diving in a submarine** panoramas in the Encounter Edu 360VR gallery or on the Google Expeditions platform, focusing on the panoramas of the submersible underwater.

Guide a whole class discussion on the panoramas using the information on the respective platforms and in the **360VR Expedition Guide - Diving in a submarine.**

Following the 360VR exploration, set the scene of the whole topic unit using **slides 3-4**. The aim is for the students to use information from each of the following lessons to design a submarine, and justify their choices.

Show students learning outcomes on **slide 5**. Ask students to set themselves a minimum target and challenge targets in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

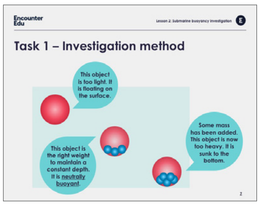
TEACHER GUIDANCE 2: SUBMARINE BUOYANCY INVESTIGATION

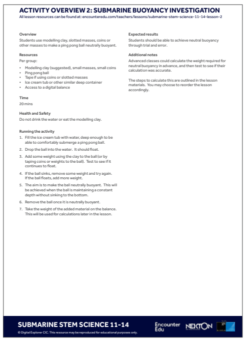
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

Step

2

20 mins





The purpose of Step 2 is for students to become more familiar with neutral buoyancy, and the aim of the practical task to make a ping pong ball neutrally buoyant.

Using **slides 6-8**, teacher explains the aim of the practical investigation, whilst also modelling the general method of the investigation.

Students conduct their investigation and try to make their ping pong ball neutrally buoyant through trial and error. As an extension, students can calculate the amount of weight needed to add to the ping pong ball in advance of the practical task using later slides and worksheets for guidance.

Once buoyancy has been achieved, students measure the amount of mass that needed to be added.

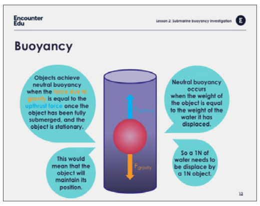
Use targeted questions to determine how the students are approaching the task.

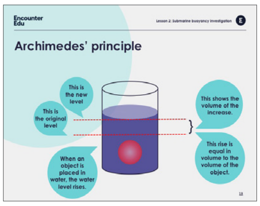
Ask students to check each other's calculations, should the extension task be used.

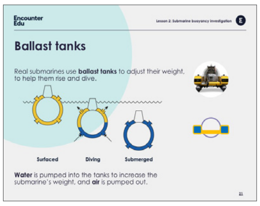
For more detailed guidance on the practical investigation, see **Activity Overview 2.**

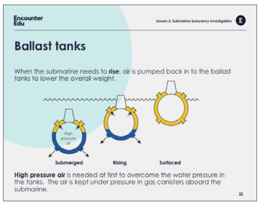
3

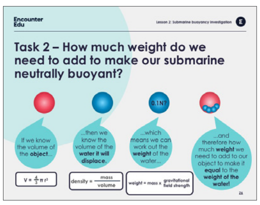
15 mins

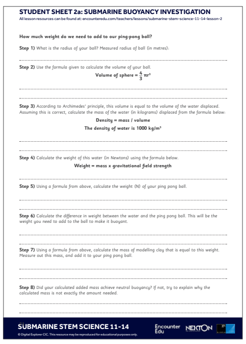












The purpose of Step 3 is for students to understand how scientists can calculate the amount of weight to achieve buoyancy in advance, rather than relying on trial and error.

Using **slides 9-22**, explain the science and mathematics behind buoyancy, and how scientists would use this approach in real-life contexts. Introduce Archimedes' principle, and how ballast tanks work in submarines. Students can then attempt to calculate the amount of weight that will be needed to make their ping pong ball neutrally buoyant.

Explain task 2 using **slides 23-26** and hand out **Student Sheet 2a** if required. Students complete calculations, and compare this to the amount they measured in the practical task.

Take feedback from the class. Focus on students justifying their ideas.

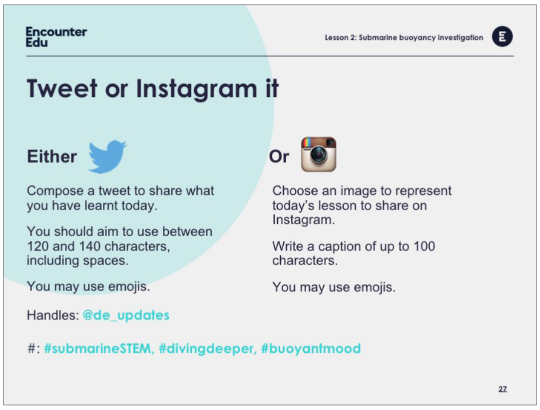
Ask targeted students why their calculated values differ from their obtained values.

TEACHER GUIDANCE 2: SUBMARINE BUOYANCY INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

Step

4
5 mins



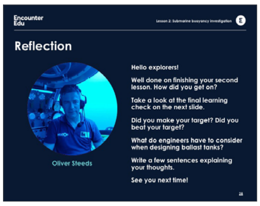
The purpose of Step 4 is for students to demonstrate their learning.

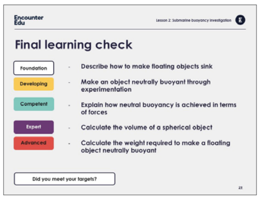
Using **slide 27**, ask students to compose a tweet or Instagram post to share their learning.
Ask students to peer assess each others' tweets or posts.

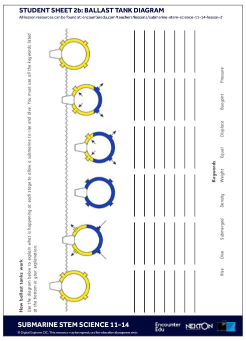
Having learnt about some tricky concepts, this challenges students to write much more concisely and consider the value of images when communicating.

Ask students to read out and comment on their partner's tweet or post. This will highlight if they have understood the success criteria. Poor comments like 'good try' should be replaced using the success criteria and you may have to model this.

5
5 mins







The purpose of Step 5 is for students to reflect on their learning.

Reintroduce the team member on **slide 28** to close the lesson. Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson. They then write a short sentence explaining their achievement.

Using **slide 29**, ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Use **slide 30** to set the home learning task on **Student Sheet 2b.**

ACTIVITY OVERVIEW 2: SUBMARINE BUOYANCY INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

Overview

Students use modelling clay, slotted masses, coins or other masses to make a ping pong ball neutrally buoyant.

Resources

Per group:

- Modelling clay (suggested), small masses, small coins
- Ping pong ball
- Tape if using coins or slotted masses
- Ice cream tub or other similar deep container
- Access to a digital balance

Time

20 mins

Health and Safety

Do not drink the water or eat the modelling clay.

Running the activity

1. Fill the ice cream tub with water, deep enough to be able to comfortably submerge a ping pong ball.
2. Drop the ball into the water. It should float.
3. Add some weight using the clay to the ball (or by taping coins or weights to the ball). Test to see if it continues to float.
4. If the ball sinks, remove some weight and try again. If the ball floats, add more weight.
5. The aim is to make the ball neutrally buoyant. This will be achieved when the ball is maintaining a constant depth without sinking to the bottom.
6. Remove the ball once it is neutrally buoyant.
7. Take the weight of the added material on the balance. This will be used for calculations later in the lesson.

Expected results

Students should be able to achieve neutral buoyancy through trial and error.

Additional notes

Advanced classes could calculate the weight required for neutral buoyancy in advance, and then test to see if their calculation was accurate.

The steps to calculate this are outlined in the lesson materials. You may choose to reorder the lesson accordingly.

STUDENT SHEET 2a: SUBMARINE BUOYANCY INVESTIGATION

How much weight do we need to add to our ping-pong ball?

Step 1) What is the radius of your ball? Measured radius of ball (in metres):

....

Step 2) Use the formula given to calculate the volume of your ball.

$$\textbf{Volume of sphere} = \frac{4}{3}\pi r^3$$

....

....

Step 3) According to Archimedes' principle, this volume is equal to the volume of the water displaced. Assuming this is correct, calculate the mass of the water (in kilograms) displaced from the formula below:

Density = mass / volume

The density of water is 1000 kg/m^3

....

....

Step 4) Calculate the weight of this water (in Newtons) using the formula below.

Weight = mass x gravitational field strength

....

Step 5) Using a formula from above, calculate the weight (N) of your ping pong ball. Measure the mass of your ping pong ball using a scale.

....

....

Step 6) Calculate the difference in weight between the water and the ping pong ball. This will be the weight you need to add to the ball to make it neutrally buoyant.

....

....

Step 7) Using a formula from above, calculate the mass of modelling clay that is equal to this weight. Measure out this mass, and add it to your ping pong ball.

....

....

Step 8) Did your calculated added mass achieve neutral buoyancy? If not, try to explain why the calculated mass is not exactly the amount needed.

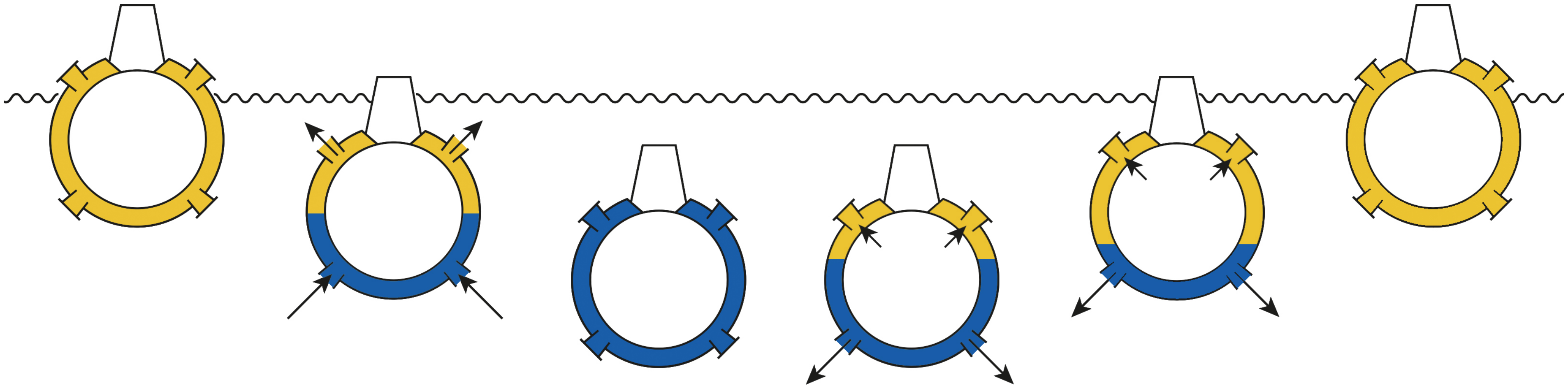
....

....

STUDENT SHEET 2b: BALLAST TANK DIAGRAM

How ballast tanks work

Use the diagram below to explain what is happening at each stage to allow a submarine to rise and dive. You must use all the keywords listed at the bottom in your explanation.



Keywords

Rise Dive Submerged Density Weight Equal Displace Buoyant Pressure

MARK SCHEME 2: SUBMARINE BUOYANCY INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-2

Answers for Student Sheet 2a

1. What is the radius of your ball? Measured radius of ball (in metres):

   The radius should be 0.02m. Regulation ping pong balls have radii of 0.02m.

   The easiest way to measure the ball is using a set of calipers to measure the diameter, which should be 40 cm = 0.04 m. Then the radius can be easily calculated by remembering radius = diameter/2.

2. Use the formula given to calculate the volume of your ball.

   Volume = $(4/3)\pi r^3 = (4/3)\pi(0.02\text{m})^3 = 0.0000335\text{m}^3$

3. According to Archimedes' principle, this volume is equal to the volume of water displaced. Assuming this is correct, calculate the mass of the water (in kilograms) displaced from the formula.

   Mass = Density x Volume = $1000\ \text{kg/m}^3 \times 0.0000335\text{m}^3 = 0.0335\ \text{kg}$

4. Calculate the weight of this water (in Newtons) using the formula.

   Weight = $0.0335\ \text{kg} \times 10\ \text{m/s}^2 = 0.335\ (\text{kg}\cdot\text{m})/\text{s}^2 = 0.335\ \text{N}$

5. Using a formula from above, calculate the weight (N) of your ping pong ball. Measure the mass of your ping pong ball using a scale.

   First measure the mass of the ball, which for a regulation ping pong ball should be 2.7 g = 0.0027 kg

   Weight $= 0.0027\ \text{kg} \times 10\ \text{m/s}^2 = 0.027\ (\text{kg}\cdot\text{m})/\text{s}^2 = 0.027\ \text{N}$

6. Calculate the difference in weight between the water and the ping pong ball. This will be the weight you need to add to the ball to make it neutrally buoyant.

   Difference in weight = 0.335 N – 0.027 N = 0.308 N

7. Using a formula from above, calculate the mass of modelling clay that is equal to this weight. Measure out this mass, and add it to your ping pong ball.

   Mass = Weight/(Gravitational field strength) = $(0.308\ \text{N})/(10\ \text{m/s}^2) = (0.308\ \text{kg}\cdot\text{m/s}^2)/(10\text{m/s}^2) = 0.0308\ \text{kg} = 30.8\ \text{g}$

8. Did your calculated added mass achieve neutral buoyancy? If not, try to explain why the calculated mass is not exactly the amount needed.

   The calculated mass should be very close. However, measurement errors, i.e. measurement of the radius, or rounding errors, i.e. rounding π or gravitational field strength, contribute to inaccuracy. Additionally, depending on how the additional mass is added to the ball the effective volume of the ball will have changed, and calculations have not accounted for such change in ball volume and the volume of water displaced.

Answers for Student Sheet 2b

Student answers will vary but should incorporate all of the keywords and explain concepts shared in slides 9-12 and 21-22.

LESSON 3: SUBMARINE LAUNCH INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Lesson overview

The submarines used for the XL Catlin Deep Ocean Survey were in the strictest sense submersibles. A distinction is made between true submarines that operate independently and submersibles which require the support of a surface vessel.
In this lesson, students develop an understanding of structural strength and stability. They will then design and build a model crane suitable for lifting and moving a weight. This activity replicates the science involved in launching and recovering a submersible using a surface vessel.

Keywords

- **Names:** weight, Newton, Newton-metres
- **Concepts:** forces, moments, structures

Details

Time
60 minutes

Curriculum links
KS3 Physics:
- Forces: forces as pushes and pulls, moment as the turning effect of a force, forces measured in Newtons
- Forces and motion: cause objects to stop or start moving

KS3 Working scientifically:
- Experimental skills and investigations
- Analysis and evaluation

Lesson steps		Learning outcomes
1 (5 mins)	**Brief** Students are introduced to the concept of structures, and how structures are designed and built for strength by looking at the similarities between various structures. The context of designing and building a crane to launch and recover a submersible vehicle at sea is introduced. Students set themselves targets based on the learning criteria of the lesson.	Understand the wider context and learning outcomes
2 (40 mins)	**Cranes** Students follow the investigation brief to try to design and build a crane suitable for lifting and placing a mass. Students are encouraged to adapt their designs, and make changes as they go.	**Foundation** Describe how to produce a strong and stable structure **Developing** Describe the purpose of each part of a crane's structure **Competent** Construct a working model of a crane
3 (10 mins)	**Calculate moments** Using the slides, students learn how to calculate moments, and the safety considerations when launching and recovering a submersible vehicle. **Demonstrate learning** Students calculate various moments due to lifting a submersible vehicle at sea, and determine if they will result in a surface vessel tipping. Teacher may well wish to dedicate more time to the design and build task.	**Expert** Calculate the moments of some given examples **Advanced** Explain the importance of launching and raising the submarine from the back of a ship, rather than the side
4 (5 mins)	**Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance in the context of the Scheme of Work to design a submarine.	Reflect on learning

Resources

Activities Overview

Activity Overview 3: Designing a crane

Student Sheets

Student Sheet 3a: Designing a crane

Student Sheet 3b: Moments calculations

Student Sheet 3c: Gears and pulleys

Mark Scheme

Mark Scheme 3: Submarine launch investigation

Slideshow

Slideshow 3

Multimedia

360VR Video:
- Submarine launch
- Submarine recovery

Subject Update

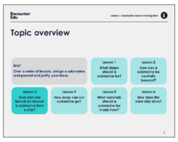
Learn more: Exploring the deep

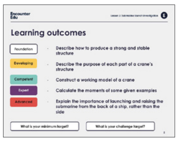
LESSON 3: SUBMARINE LAUNCH INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Step

1
5 mins





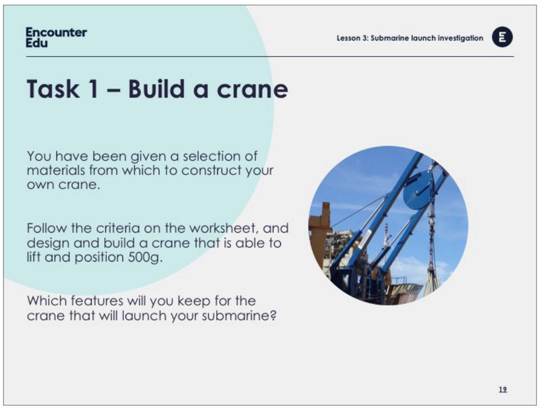
The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

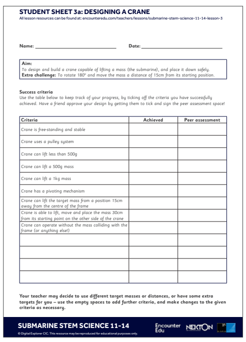
Display the structures shown on **slides 2-5**. The idea is for students to spot the features of a structure that they will apply throughout the lesson.

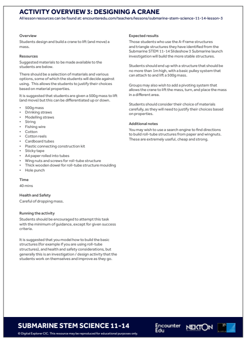
Following the exploration, teacher sets the scene of the lesson using **slides 6-7**. The students are to design and build a working crane to lift a mass.

Show students lesson outcomes on **slide 8**. Ask them to set themselves a minimum target and challenge target in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

2
40 mins







The purpose of Step 2 is for students to become more familiar with the features of a crane and how they are built, before trying it out themselves.

Further guidance for this activity is available on **Activity Overview 3**.

To make this task more 'real', consider having students view the two **360VR Videos: Submarine launch** and **Submarine recovery**

Using **slides 9-19**, teacher explains the features of a crane and the functions of the different parts, before setting the criteria for the design and build task.

Using **Student Sheet 3a**, student groups should plan a design for their crane, considering the criteria set. Student groups should sketch out their idea for a crane before commencing the build phase.
Once student groups have completed their planning, they can then start on the build phase using the materials provided.
Prompt and evaluation questions are included on **Student Sheet 3a** for groups to review their task.

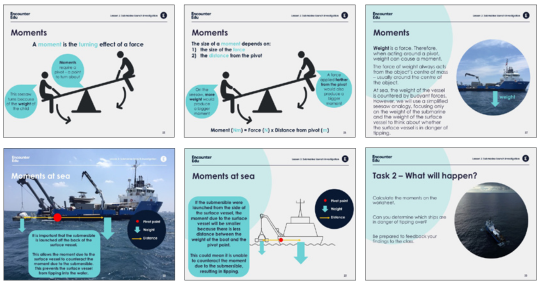
Student groups evaluate each other's designs using the peer assessment section on **Student Sheet 3a**.

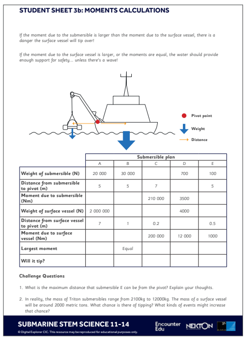
LESSON 3: SUBMARINE LAUNCH INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Step

3
10 mins





The purpose of Step 3 is for students to demonstrate their learning.

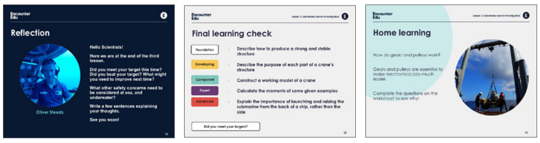
Using **slides 20-30**, explain how to calculate moments, and the considerations for safety when launching and raising the submersible.

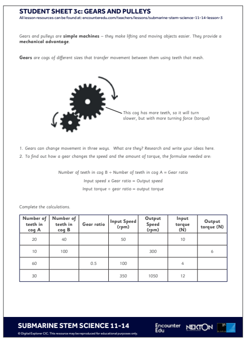
Depending on time, you may wish to add this step to home learning in addition to the home learning task on **Student Sheet 3c**.

Students work through the calculations for moments on **Student Sheet 3b**, and predict if the ship launching the submersible will tilt or not.

Display or read out the answers to the calculations. Students can tally how many they got right on mini whiteboards or raise their hands to show their score.

4
5 mins





The purpose of Step 4 is for students to reflect on their learning.

Reintroduce the team member on **slide 31**. Linking back to the lesson, and the overall context of the unit, students answer reflection questions and make a judgement as to the extent to which they met their targets.

Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson, showing **slide 32**. They then write a short sentence explaining their achievements.

Ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Set the home learning task **Student Sheet 3c** (and/or **Student Sheet 3b**), showing **slide 33**.

ACTIVITY OVERVIEW 3: DESIGNING A CRANE

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Overview

Students design and build a crane to lift (and move) a mass.

Resources

Suggested materials to be made available to the students are below.

There should be a selection of materials and various options, some of which the students will decide against using. This allows the students to justify their choices based on material properties.

It is suggested that students are given a 500g mass to lift (and move) but this can be differentiated up or down.

- 500g mass
- Drinking straws
- Modelling straws
- String or twine
- Fishing wire
- Spools or bobbins
- Cardboard tubes
- Plastic connecting construction kit
- Sticky tape
- Pencils or wooden dowels
- A4 paper rolled into tubes
- Wing nuts and screws for roll-tube structure
- Thick wooden dowel for roll-tube structure moulding
- Hole punch

Time

40 mins

Health and Safety

Careful of dropping mass.

Running the activity

Students should be encouraged to attempt this task with the minimum of guidance, except for given success criteria.

It is suggested that you model how to build the basic structures (for example if you are using roll-tube structures), and health and safety considerations, but generally this is an investigation / design activity that the students work on themselves and improve as they go.

Expected results

Those students who use the A-Frame structures and triangle structures they have identified from the Submarine STEM 11-14 Slideshow 3 Submarine launch investigation will build the more stable structures.

Students should end up with a structure that should be no more than 1m high, with a basic pulley system that can attach to and lift a 500g mass.

Groups may also wish to add a pivoting system that allows the crane to lift the mass, turn, and place the mass in a different area.

Students should consider their choice of materials carefully, as they will need to justify their choices based on properties.

Additional notes

You may wish to use a search engine to find directions to build roll-tube structures from paper and wing nuts. These are extremely useful, cheap and strong.

STUDENT SHEET 3a: DESIGNING A CRANE

Name: ______________________________ **Date:** ______________________________

Aim:
To design and build a crane capable of lifting a mass (the submarine), and place it down safely.
Extra challenge: To rotate 180° and move the mass a distance of 15cm from its starting position.

Success criteria
Use the table below to keep track of your progress, by ticking off the criteria you have successfully achieved. Have a friend approve your design by getting them to tick and sign the peer assessment space!

Criteria	Achieved	Peer assessment
Crane is free-standing and stable		
Crane uses a pulley system		
Crane can lift less than 500g		
Crane can lift a 500g mass		
Crane can lift a 1kg mass		
Crane has a pivoting mechanism		
Crane can lift the target mass from a position 15cm away from the centre of the frame		
Crane is able to lift, move and place the mass 180° from its starting point on the other side of the crane		
Crane can operate without the mass colliding with the frame (or anything else!)		

Your teacher may decide to use different target masses or distances, or have some extra targets for you – use the empty spaces to add further criteria, and make changes to the given criteria as necessary.

STUDENT SHEET 3a: DESIGNING A CRANE

Planning

Look at the materials available to you. Decide what features your crane will have, and what you will use to make them. Then, draw or write your ideas in the boxes below.

Feature	What I will make it from	Why I have chosen this material
Structure / Framework		
Lifting cable		
Pulley		
Pivot		

What is your crane going to look like? Sketch your ideas and label the parts. Don't forget to give some idea of how tall and wide your crane might be!

STUDENT SHEET 3a: DESIGNING A CRANE

Changing ideas
Now you have started building your crane, have you made any changes to your original design? Explain your reasons.

Evaluating and improving

1. Was your design successful? Explain why.

....

....

....

2. What could you do next time to make your crane even better?

....

....

....

3. Why is it important for scientists to understand how materials behave when designing structures?

....

....

....

4. Were there any problems during your build? If so, what happened?

....

....

....

5. How would you stop these happening next time?

....

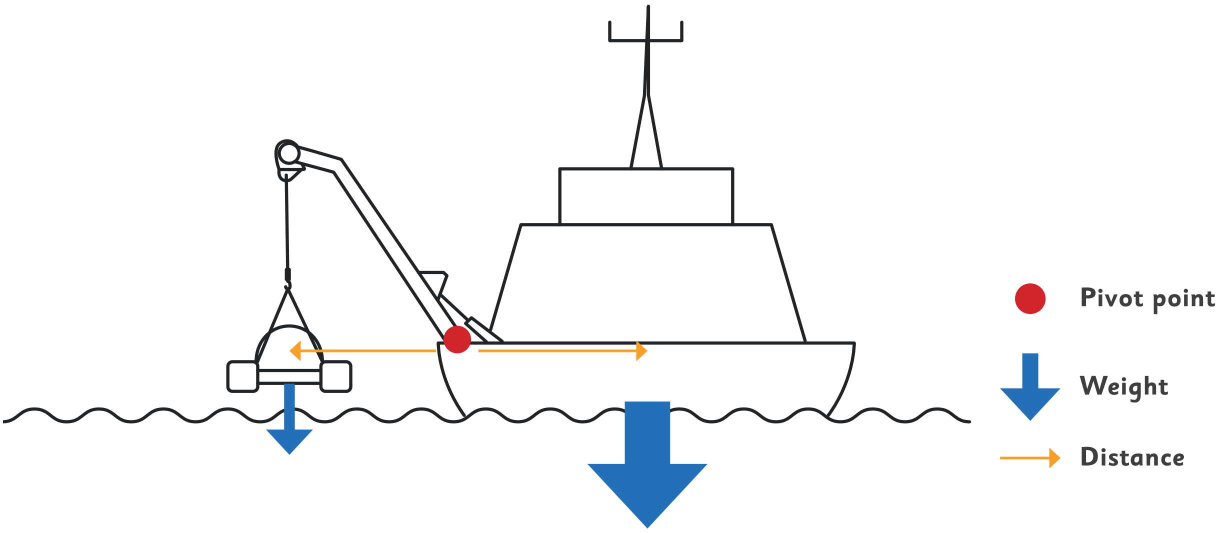
....

....

STUDENT SHEET 3b: MOMENTS CALCULATIONS

If the moment due to the submersible is larger than the moment due to the surface vessel, there is a danger the surface vessel will tip over!

If the moment due to the surface vessel is larger, or the moments are equal, the water should provide enough support for safety... unless there's a wave!



	Submersible plan				
	A	B	C	D	E
Weight of submersible (N)	20 000	30 000		700	100
Distance from submersible to pivot (m)	5	5	7		5
Moment due to submersible (Nm)			210 000	3500	
Weight of surface vessel (N)	2 000 000			4000	
Distance from surface vessel to pivot (m)	7	1	0.2		0.5
Moment due to surface vessel (Nm)			200 000	12 000	1000
Largest moment		*Equal*			
Will it tip?					

Challenge Questions

1. *What is the maximum distance that submersible E can be from the pivot? Explain your thoughts.*

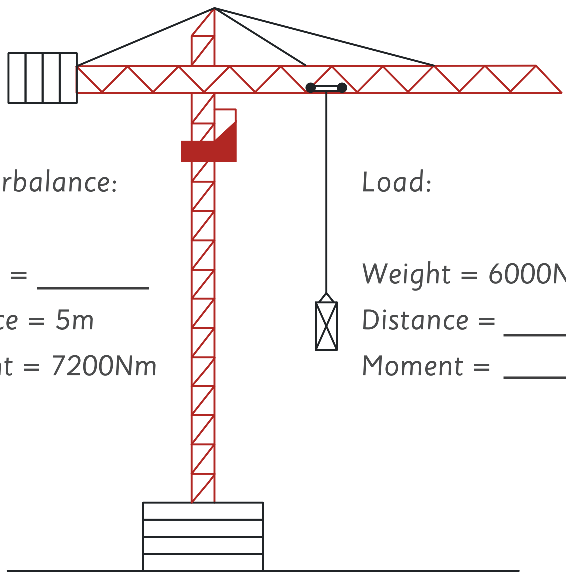
2. *In reality, the mass of Triton submersibles range from 2100kg to 12000kg. The mass of a surface vessel will be around 2000 metric tons. What chance is there of tipping? What kinds of events might increase that chance?*

STUDENT SHEET 3b: MOMENTS CALCULATIONS

Cranes and moments

The moments for each crane below are balanced. Calculate the missing values used in the following pictures. (Gravitational field strength is taken as 10N/kg).

Crane A



Counterbalance:

Weight = ________

Distance = 5m

Moment = 7200Nm

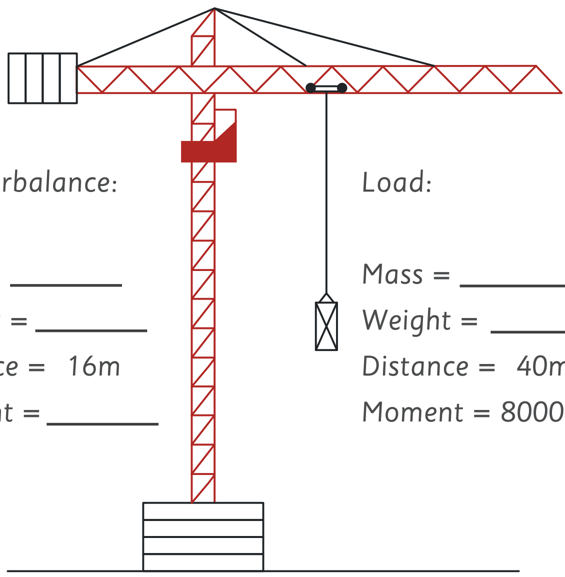
Load:

Weight = 6000N

Distance = ________

Moment = ________

Crane B



Counterbalance:

Mass = ________

Weight = ________

Distance = 16m

Moment = ________

Load:

Mass = ________

Weight = ________

Distance = 40m

Moment = 8000Nm

Challenge Question

What would happen if the cranes were to increase the distance of the load from the pivot?

....

....

....

....

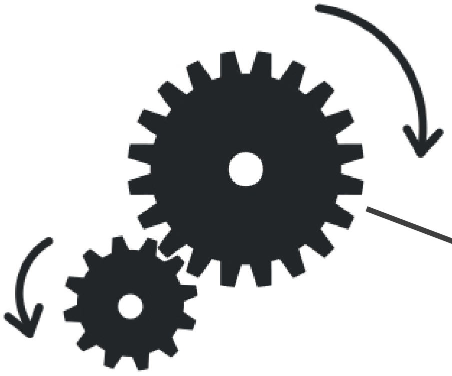
....

....

STUDENT SHEET 3c: GEARS AND PULLEYS

Gears and pulleys are **simple machines** – they make lifting and moving objects easier. They provide a **mechanical advantage**.

Gears are cogs of different sizes that transfer movement between them using teeth that mesh.



1. Gears can change movement in three ways. What are they? Research and write your ideas here.

2. To find out how a gear changes the speed and the amount of torque, the formulae needed are:

Number of teeth in output gear ÷ Number of teeth in input gear = Gear ratio

Input speed x Gear ratio = Output speed

Input torque ÷ Gear ratio = Output torque

Complete the calculations.

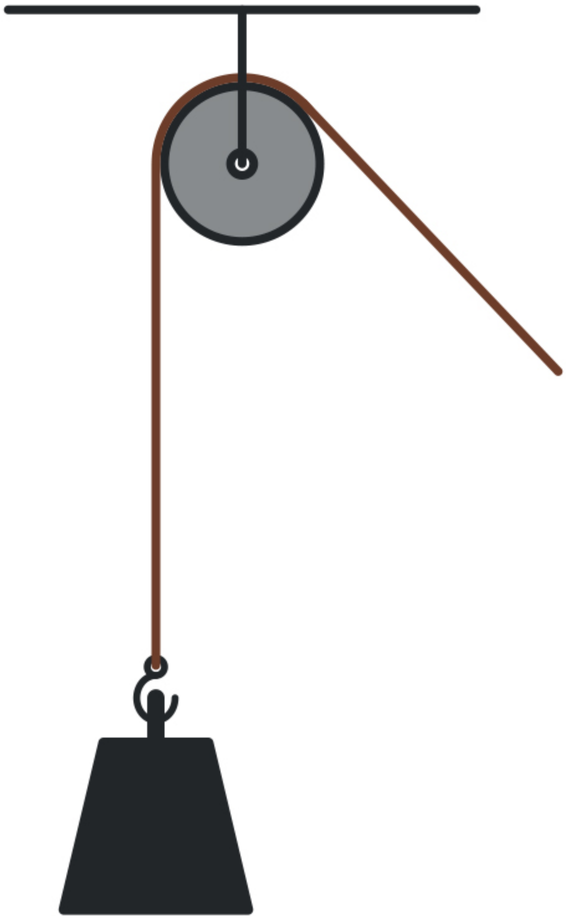
Number of teeth in input gear	Number of teeth in output gear	Gear ratio	Input Speed (rpm)	Output Speed (rpm)	Input torque (N)	Output torque (N)
20	40		50		10	
10	100			300		6
60		0.5	100		4	
30			350	1050	12	

Complete the sentences below:

Mechanical advantage is a measure of force amplification. This is given by the **gear ratio.** Note that **torque** is only amplified if the gear ratio is greater than 1. This means the output gear has ______________ (more/less) teeth than the input gear. If the gear ratio is greater than 1, the output gear has ______________ (more/less) teeth than the input gear, and torque is actually reduced and instead speed is amplified.

STUDENT SHEET 3c: GEARS AND PULLEYS

Pulley systems *can be designed to change the direction of a force, and to allow a smaller force to have a greater effect.*



A fixed pulley system like this one can be used to lift objects, such as your submersible. On the diagram, label the following:

Weight of object (load) **Direction of lifting force (effort)**

Pivot **Direction of movement** **Pulley** **Fixed support**

Complete the sentences below:

In a system like this, the pulley stays ______________ *in place. This system changes the* ______________ *of the force needed to move something, but not the amount of force. Without a pulley, to lift an object directly upwards a person would have to rely on the power from their* ______________. *However, with the pulley, a human can use their* ______________ *as well! This means their muscles can use less* ______________ . *The moving wheel also reduces* ______________ .

Friction **Fixed** **Muscles** **Direction** **Body-weight** **Effort**

MARK SCHEME 3: SUBMARINE LAUNCH INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Answers for Student Sheet 3a

Planning

Below are some suggested features and justifications.

Feature	What will I make it from	Why have I chosen this material
A triangle or A-frame design Structure / framework	A sensible choice of material, e.g. roll-tube structures or cardboard tubes	A justification on strength, stability, etc.
Lifting cable	A reasonable material such as twine	A justification based on strength, able to 'roll' around pulley and something that won't stretch
Pulley	A reasonable choice such as a spool	A justification based on shape, ability to sit on an axle
Pivot	A reasonable choice such as a pencil, wooden dowel	A justification based on shape / ability to be rotated around

Evaluating and improving

Why is it important for scientists to understand how materials behave when designing structures?

Scientists need to be able to predict if a structure is going to be able to perform and cope with its function without breaking before it is built. This will save money and time, and the best materials can be selected in advance.

Answers for Student Sheet 3b

	Submersible				
	A	B	C	D	E
Weight of submersible (N)	20 000	30 000	30 000	700	100
Distance from submersible to pivot (m)	5	5	7	5	5
Moment due to submersible (Nm)	100 000	150 000	210 000	3500	500
Weight of surface vessel (N)	2 000 000	150 000	1 000 000	4000	2000
Distance from surface vessel to pivot (m)	7	1	0.2	3	0.5
Moment due to surface vessel (Nm)	14 000 000	150 000	200 000	12 000	1000
Largest moment	Surface Vessel	Equal	Submersible	Surface Vessel	Surface Vessel
Will it tip?	No	No	Yes	No	No

MARK SCHEME 3: SUBMARINE LAUNCH INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-3

Challenge questions

1. What is the maximum distance that submersible E can be from the pivot? Explain your thoughts.

Submersible E can be a maximum of 10m from the pivot, because at this point the moments would be equal. Any more, and there is a danger of tipping.

2. In reality, the mass of Triton submersibles range from 2100kg to 12000kg. The mass of a surface vessel will be around 2 000 metric tons. What chance is there of tipping? What kinds of events might increase that chance?

There is a small chance of the surface vessel tipping as the moment due to the surface vessel will be much larger, meaning that the submersible will have to be extended far out to sea until the moments approach equality. A large swell or wave (causing the centre of gravity of the surface vessel to shift very close to the pivot point) could increase the chances of tipping.

Crane Questions

Crane A		Crane B	
Counterbalance	Load	Counterbalance	Load
Weight = 1440 N Distance = 5m Moment = 7200Nm	Weight = 6000N Distance = 1.2m Moment = 7200Nm	Mass = 50kg Weight = 500N Distance = 16m Moment = 8000Nm	Mass = 20kg Weight = 200N Distance = 40m Moment = 8000Nm

Challenge question

What would happen if the cranes were to increase the distance of the load from the pivot?

The cranes would potentially tip forward lowering the load because the moment due to the load will be larger than the moment due to the counterweight.

Answers for Student Sheet 3c

1. Gears can change movement in three ways. What are they? Research and write your ideas here.

Change the direction of movement; change the speed of movement; and act as force multipliers (mechanical advantage).

2. Gear calculations

Number of teeth in input gear	Number of teeth in output gear	Gear ratio	Input Speed (rpm)	Output Speed (rpm)	Input torque (N)	Output torque (N)
20	40	2	50	100	10	5
10	100	10	30	300	60	6
60	30	0.5	100	50	4	8
30	90	3	350	1050	12	4

Gear systems sentence completion

Mechanical advantage is a measure of force amplification. This is given by the gear ratio. Note that torque is only amplified if the gear ratio is greater than 1. This means the output gear has **more** teeth than the input gear. If the gear ratio is greater than 1, the output gear has **less** teeth than the input gear, and torque is actually reduced and instead speed is amplified.

Pulley systems sentence completion

In a system like this, the pulley stays **fixed** in place. This system changes the **direction** of the force needed to move something, but not the amount of force. Without a pulley, to lift an object directly upwards a person would have to rely on the power from their **muscles**. However, with the pulley, a human can use their **body-weight** as well! This means their muscles can use less **effort**. The moving wheel also reduces **friction**.

LESSON 4: SUBMARINE PRESSURE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

Lesson overview

The operating depth limit for the submersibles used on the XL Catlin Deep Ocean Survey was 1,000 feet. To put this in context, recreational scuba diving has a limit of 130 feet, but the deepest point in the ocean is an astounding 36,070 feet down.

In this lesson, students investigate the effects of pressure increasing with depth, and the implications that this has for submarine design. Get the design wrong and the submarine will implode.

Keywords

- **Names:** Pascal (Pa), metres
- **Concepts:** pressure, depth, balanced forces

Details

Time
60+ minutes

Curriculum links
KS3 Physics:
- Pressure in fluids: pressure in liquids increasing with depth, pressure measured by ratio of force over area

KS3 Working scientifically:
- Experimental skills and investigations
- Analysis and evaluation
- Measurement

Lesson steps / Learning outcomes

Lesson steps	Learning outcomes
1 (15 mins) **Brief** Students are introduced to the concept of pressure at depth through a demonstration. The context of designing an investigation into the effects of pressure on submersibles is introduced. Students set themselves targets based on the learning criteria of the lesson.	Understand the wider context and learning outcomes. **Foundation** Describe the dangers of exploring at depth **Developing** Explain why pressure increases with depth
2 (30 mins) **Investigation** Students follow the investigation brief to try to design and carry out an investigation into the effects of pressure at depth on a submarine's hull. Students are encouraged to adapt and design their plan through practical trials.	**Competent** Design and carry out a fair test to investigate the effects of increasing depth
3 (15 mins) **Pressure calculations** Using the slides, students learn how to calculate pressure at depth, and the importance of the submersible's structure supporting the forces of the water. **Demonstrate learning** Students calculate pressure at depth for various contexts, and predict if a submersible will be able to safely dive to a given depth.	**Expert** Calculate the amount of pressure caused at different depths **Advanced** Explain, in terms of forces, why submarines have a safe limit to which they can dive
4 (5 mins) **Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance to the context of the Scheme of Work.	Reflect on learning

Resources

Activities Overview

Activity Overview 4a: Under pressure

Activity Overview 4b: Submarine pressure investigation

Student Sheets

Student Sheet 4a: Submarine pressure investigation

Student Sheet 4b: Pressure calculations

Student Sheet 4c: Cartesian diver

Mark Scheme

Mark Scheme 4: Submarine pressure investigation

Slideshow

Slideshow 4

Multimedia

Video / Activity: Under pressure

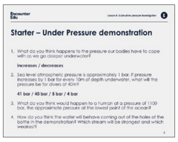
Video / Activity: Submarine Engineer

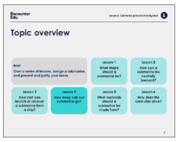
TEACHER GUIDANCE 4: SUBMARINE PRESSURE INVESTIGATION

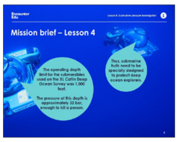
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

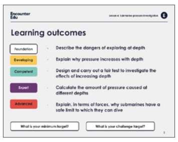
Step

1
15 mins









The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Either use the demonstration of how water behaves under pressure using **Activity Overview 4a** or show the video from **Activity Under Pressure**.

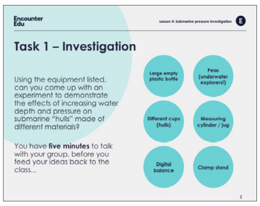
If you are using the demonstration, ask questions 1-4 on **slide 2**, before you start the demonstration.
If you are using the video, ask the questions while watching the video, pausing at the following times to ask each question:
00:10 Question 1
00:23 Question 2
00:40 Question 3
01:58 Question 4

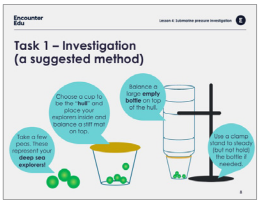
Answers to the questions on **slide 2** are:
1. increases
2. 5 bar
3. humans would be crushed
4. bottom stream will be strongest and top weakest

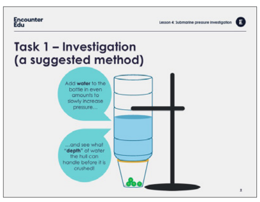
Following the exploration, set the scene of the lesson using **slides 3-4**.

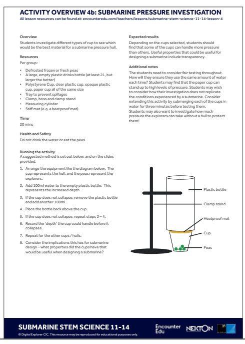
Show students lesson outcomes on **slide 5**. Ask them to set themselves a minimum target and challenge target in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

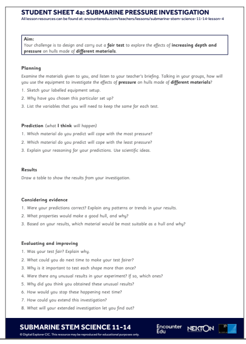
2
30 mins











The purpose of Step 2 is for students to become more familiar with the idea of pressure.

Further guidance for this activity is available on **Activity Overview 4b**.

Using **slides 6-9**, explain the context and the criteria for the investigation of water pressure task. While students are encouraged to design their own experiment, a suggested method is outlined on the slides as support.

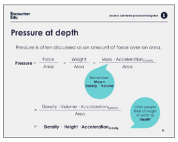
Using **Student Sheet 4a**, students design and carry out an experiment to investigate the effects of increased depth and pressure on various cups, representing hulls.

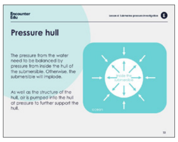
TEACHER GUIDANCE 4: SUBMARINE PRESSURE INVESTIGATION

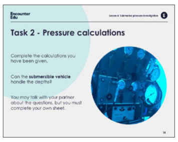
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

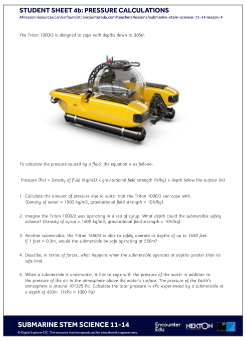
Step

3
15 mins









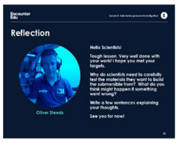
The purpose of Step 3 is for students to demonstrate their learning.

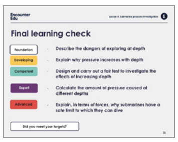
Explain how to calculate water pressure using **slides 10-14**, reaffirming the fact the pressure is a force applied to an area.

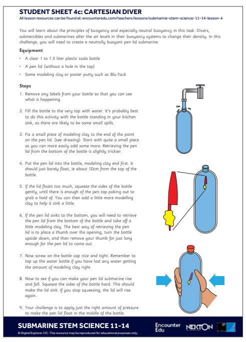
Students work through the calculations and questions on **Student Sheet 4b**, related to pressure and dangers at depth.

Display answers on the board, and ask students to feedback their score. Answers are in **Mark Scheme 4.**

4
5 mins







The purpose of Step 4 is for students to reflect on their learning.

Reintroduce the team member on **slide 15**. Linking back to the lesson, and the overall context of the unit, students answer reflection questions and make a judgement as to the extent to which they met their targets.
Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson, showing **slide 16**. They then write a short sentence explaining their achievements.

Ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Set the home learning task **Student Sheet 4c** with students predicting what will happen in the rusting investigation using **slide 17**. A video demonstration of the **Activity Submarine Engineer** is available in lesson resources.

ACTIVITY OVERVIEW 4a: UNDER PRESSURE

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

Overview

At sea level the atmosphere exerts a pressure of 1 bar. This is the normal pressure that we feel. If you have ever been in an airplane, been up a mountain or dived in the ocean, you might have felt your ears pop. This is because of the air pressure changing.

Pressure underwater increases at 1 bar for every 10 metres (or 33 feet). This means that at 40 metres below the surface, where the deep reef team are working, the pressure is 5 bar, or five times greater than at sea level.

The deepest point in the ocean is the Challenger Deep, which is 10,994 metres (36,070 feet) deep. The pressure here is about 1,100 bar. This is the equivalent of taking the Eiffel Tower, turning it upside down and putting it on your big toe. Only three people have been to the bottom of the ocean in specially designed submarines.

This activity shows the relationship between water depth and pressure.

Resources

Each student group will need:

- 1.5 – 2 litre plastic bottle
- Masking or duct tape
- Scissors or similar tool to create holes

Time

30 mins

Health and Safety

Scissors should be child friendly and used under adult supervision.

Running the activity

1. Divide students into groups of 5-6.
2. Tell the class that they are going to investigate the relationship between pressure and depth.
3. Students should make three holes, evenly spaced, in a vertical line, in the bottle.
4. Cover the holes with tape and fill the bottle with water, and put the lid on.
5. Stand the bottle in a sink or take it outside and ask students to guess how the water will behave coming out of the holes. Where will the pressure be greatest? How will you know?
6. Untape the holes and unscrew the lid. What do students observe?

ACTIVITY OVERVIEW 4b: SUBMARINE PRESSURE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

Overview

Students investigate different types of cup to see which would be the best material for a submarine pressure hull.

Resources

Per group:

- Defrosted frozen or fresh peas
- A large, empty plastic drink bottle with lid (at least 2L, but larger the better)
- Polystyrene cup, clear plastic cup, opaque plastic cup, paper cup all of similar shape and size
- Tray to prevent spillages
- Clamp, boss and clamp stand
- Measuring cylinder
- Stiff mat (e.g. a heatproof mat or stiff cardboard)

Time

20 mins

Health and Safety

Do not drink the water or eat the peas.

Running the activity

A suggested method is set out below, and on the slides provided.

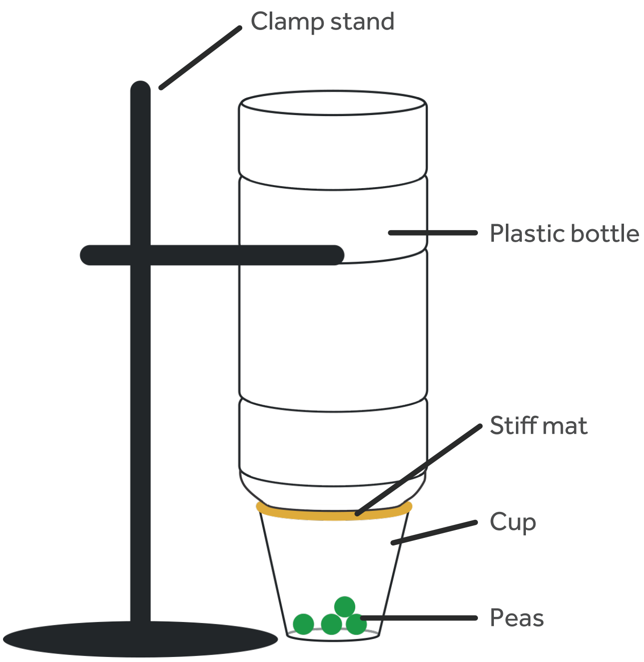
1. Arrange the equipment like the diagram below. The cup represents the hull, and the peas represent the explorers.
2. Remove the plastic bottle and add 100ml of water then replace the lid and place the bottle back on the cup/hull. This represents the increased depth.
3. If the cup does not collapse, remove the plastic bottle and add another 100ml of water. Place the bottle back on the cup.
4. If the cup does not collapse, repeat step 3.
5. Record the 'depth' of water the cup could handle before it collapsed.
6. Repeat for the other cups / hulls.
7. Consider the implications this has for submarine design. What properties did the cups have that would be useful when designing a submarine? Also, consider properties beyond withstanding pressure.

Expected results

Depending on the cups selected, students should find that some of the cups can handle more pressure than others. Another property that could be useful for designing a submarine include transparency.

Additional notes

The students need to consider fair testing throughout. How will they ensure they use the same amount of water each time? Students may find that the paper cup can stand up to high levels of pressure, especially compared to plastic cups that have reduced which make them more susceptible to collapse. Students may wish to consider how their investigation does not replicate the conditions experienced by a submarine. Consider extending this activity by submerging each of the cups in water for three minutes before testing them.
Students may also want to investigate how much pressure the explorers can take without a hull to protect them!



STUDENT SHEET 4a: SUBMARINE PRESSURE INVESTIGATION

Aim:
Your challenge is to design and carry out a **fair test** to explore the effects of **increasing depth and pressure** on hulls made of **different materials**.

Planning

Examine the materials given to you, and listen to your teacher's briefing. Talking in your groups, how will you use the equipment to investigate the effects of **pressure** on hulls made of **different materials**?

1. Sketch your labelled equipment setup.
2. Why have you chosen this particular set up?
3. List the variables that you will need to keep the same for each test.

Prediction (what **I think** will happen)

1. Which material do you predict will cope with the most pressure?
2. Which material do you predict will cope with the least pressure?
3. Explain your reasoning for your predictions. Use scientific ideas.

Results

Draw a table to show the results from your investigation.

Considering evidence

1. Were your predictions correct? Explain any patterns or trends in your results.
2. What properties would make a good hull, and why?
3. Based on your results, which material would be most suitable as a hull and why?

Evaluating and improving

1. Was your test fair? Explain why.
2. What could you do next time to make your test fairer?
3. Why is it important to test each shape more than once?
4. Were there any unusual results in your experiment? If so, which ones?
5. Why did you think you obtained these unusual results?
6. How would you stop these happening next time?
7. How could you extend this investigation?
8. What will your extended investigation let you find out?

STUDENT SHEET 4b: PRESSURE CALCULATIONS

The Triton 1000/2 is designed to cope with depths down to 305m.

To calculate the pressure caused by a fluid, the equation is as follows:

Pressure = Density of fluid (kg/m^3) x depth of fluid (m) x acceleration due to gravity (m/s^2)

1. Calculate the maximum amount of pressure due to water that the Triton 1000/2 can cope with. (Density of water = 1000 kg/m^3, acceleration due to gravity = 10 m/s^2).

2. Imagine the Triton 1000/2 was operating in a sea of syrup. What depth could the submersible safely achieve? (Density of syrup = 1400 kg/m^3, acceleration due to gravity = 10 m/s^2).

3. Another submersible, the Triton 1650/3 is able to safely operate at depths of up to 1650 feet. If 1 foot = 0.3m, would the submersible be safe operating at 550m? Show your calculations.

4. Describe, in terms of forces, what happens when the submersible operates at depths greater than its safe limit.

5. When a submersible is underwater, it has to cope with the pressure of the water in addition to the pressure of the air in the atmosphere above the water's surface. The pressure of the Earth's atmosphere is around 101325 Pa. Calculate the total pressure in kPa experienced by a submersible at a depth of 450m. (1kPa = 1000 Pa)

STUDENT SHEET 4c: CARTESIAN DIVER

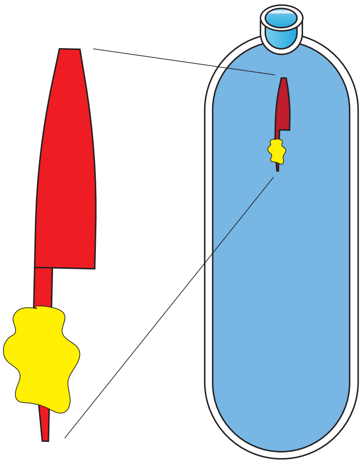
You will learn about the principles of buoyancy and especially neutral buoyancy in this task. Divers, submersibles and submarines alter the air levels in their buoyancy systems to change their density. In this challenge, you will need to create a neutrally buoyant pen lid submarine.

Equipment

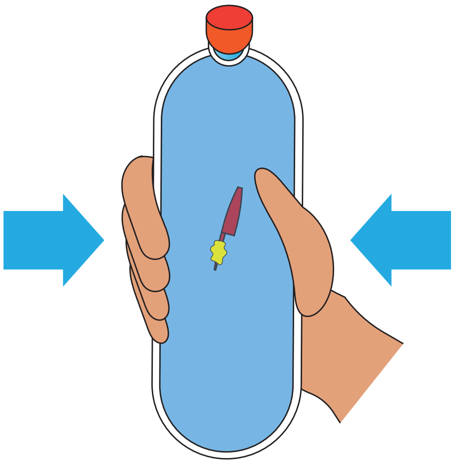
- A clear 1 to 1.5 liter plastic soda bottle
- A pen lid (without a hole in the top)
- Some modeling clay or poster putty such as Blu-Tack

Steps

1. Remove any labels from your bottle so that you can see what is happening.
2. Fill the bottle to the very top with water. It's probably best to do this activity with the bottle standing near your kitchen sink, as there are likely to be some small spills.
3. Fix a small piece of modeling clay to the end of the point on the pen lid (see drawing). Start with quite a small piece as you can more easily add some more. Retrieving the pen lid from the bottom of the bottle is slightly trickier.



4. Put the pen lid into the bottle, modeling clay end first. It should just barely float, ie about 10cm from the top of the bottle.
5. If the lid floats too much, squeeze the sides of the bottle gently, until there is enough of the pen top poking out to grab a hold of. You can then add a little more modelling clay to help it sink a little.
6. If the pen lid sinks to the bottom, you will need to retrieve the pen lid from the bottom of the bottle and take off a little modeling clay. The best way of retrieving the pen lid is to place a thumb over the opening, turn the bottle upside down, and then remove your thumb for just long enough for the pen lid to come out. Do this over the sink.



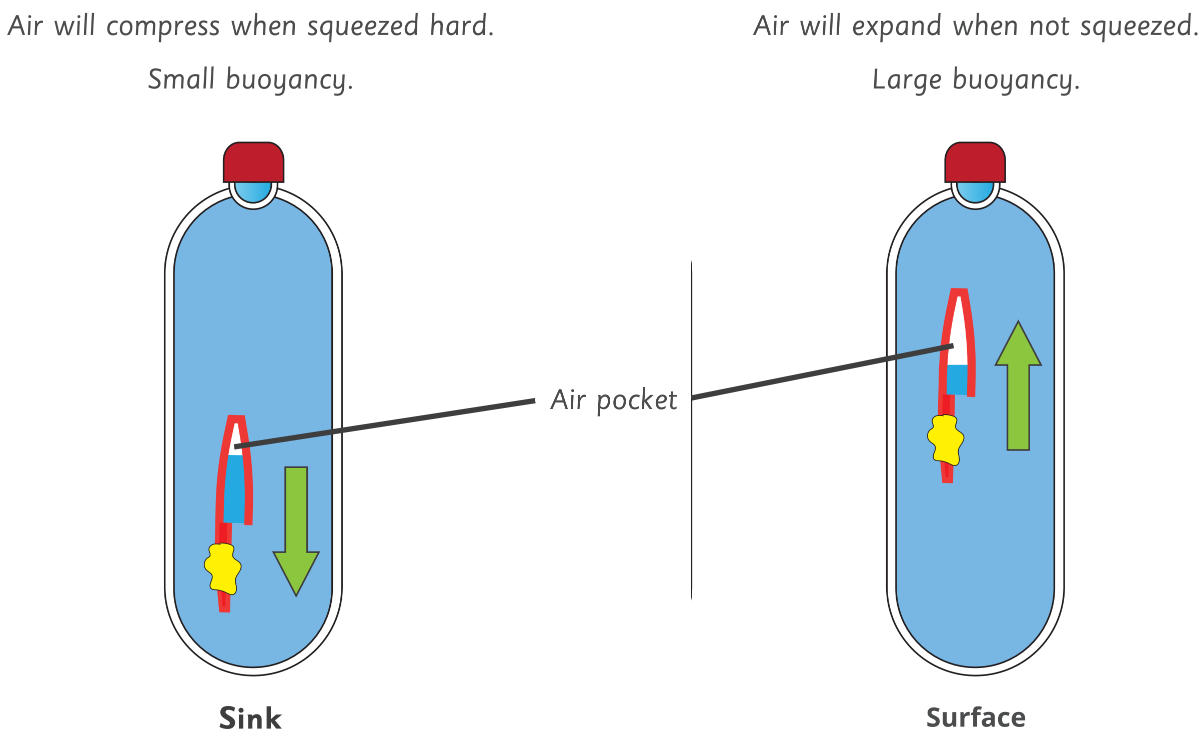
7. Now screw on the bottle cap nice and tight. Remember to top up the water bottle if you have lost any water getting the amount of modeling clay right.
8. Now to see if you can make your pen lid submarine rise and fall. Squeeze the sides of the bottle hard. This should make the lid sink. If you stop squeezing, the lid will rise again.
9. Your challenge is to apply just the right amount of pressure to make the pen lid float in the middle of the bottle.

STUDENT SHEET 4c: CARTESIAN DIVER

STEM learning

This activity is all about density. When you squeeze the sides of the bottle, the air trapped inside the pen lid is compressed. This makes the pen lid more dense than the water, as the air bubble is smaller. As it is now less dense than the water, the pen lid sinks.

When you release the sides of the bottle, the air bubble is no longer compressed and the volume of the air increases. This makes the pen lid less dense than the water, so it rises.



MARK SCHEME 4: SUBMARINE PRESSURE INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-4

Answers for Student Sheet 4a

Below are some example answers the students may come up with. Many responses will depend on their individual investigations.

Considering evidence

1. What properties would make a good hull, and why?

Strong to cope with the pressure, watertight, transparent so that the crew can see.

2. Based on your results, which material would be most suitable as a hull and why?

Justification that relates to their investigation, and the material that best meets the properties discussed in the question above.

Evaluating and improving

1. Was your test fair? Explain why.

Justification based on how their controlled variables such as the amount of water added each time, and repeat results that were undertaken

2. Were there any unusual results in your experiment? If so, which ones?

Identification of any anomalies / results and repeats that did not fit the pattern of the other results.

3. How could you extend this investigation?

Use materials more like those that would be used to make submarines. Scale the investigation up to the size of a real submersible. Use a more effective method of simulating water pressure.

4. What will your extended investigation let you find out?

If there are any materials that are more suitable than the materials investigated in the lab. If the materials will behave as expected at the sizes needed to build a submersible.

Answers for Student Sheet 4b

1. Calculate the maximum amount of pressure due to water that the Triton 1000/2 can cope with the maximum pressure that it could withstand would be at a depth of 305m.

Pressure = 1000 kg/m^3 x 305 m x 10 m/s^2 = 3,050,000 $kg/(m{\cdot}s^2)$ = 3,050,000 Pa

2. Imagine the Triton 1000/2 was operating in a sea of syrup. What depth could the submersible safely achieve? We calculated the maximum pressure that the submersible can withstand in question 1.

Depth = Pressure / (Density x acceleration due to gravity) = 3,050,000 Pa / (1400 kg/m^3 x 10 m/s^2) = 218 m

3. Another submersible, the Triton 1650/3 is able to safely operate at depths of up to 1650 feet. If 1 foot = 0.3m, would the submersible be safe operating at 550m?

Maximum operating depth in m = 1650 ft x $0.3\,\frac{m}{ft}$ = 495 m.

No, the submersible will not be able to operate at 550m.

4. Describe, in terms of forces, what happens when the submersible operates at depths greater than its safe limit.

The force due to the weight of the water is larger than the force that the submarine's pressurised hull can provide. This will cause the hull to implode.

5. When a submersible is underwater, it has to cope with the pressure of the water in addition to the pressure of the air in the atmosphere above the water's surface. The pressure of the Earth's atmosphere is around 101325 Pa. Calculate the total pressure experienced by a submersible at a depth of 450m.

Pressure due to water = 1000 kg/m^3 x 450 m x 10 m/s^2 = 4,500,000 $kg/(m{\cdot}s^2)$ = 4,500,000 Pa
Total pressure = Pressure due to water + Pressure due to the atmosphere
= 4,500,000 Pa + 101325 Pa = 4,601,325 Pa = 4,601 kPa

LESSON 5: SUBMARINE MATERIALS INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Lesson overview

Submarines have to operate in difficult environments. First, they need to operate under pressure. Second, they have to cope with the corrosive nature of seawater. Different parts of the submarine will need different materials. There is no point building a submarine for scientific operation out of solid metal. In this lesson, students will start by reflecting on historical submarine designs and some were not very successful. They will then debate materials choices for building a submarine. A practical investigation looks at how to protect the submarine from rusting.

Keywords

- **Names:** rusting, catalysts, density, hardness, strength, flexibility, ductility, malleability, toughness
- **Concepts:** properties of materials, oxidation, chemical reactions

Details

Time
60 minutes

Curriculum links
KS3 Chemistry:
- Chemical properties
- Material properties

KS3 Working scientifically:
- Experimental skills and investigations
- Analysis and evaluation
- Measurement

Lesson steps		Learning outcomes
1 10 mins	**Brief** Students are introduced to the concept of submarine design and choice of materials through a look at an early, unsuccessful submarine design. Students set themselves targets based on the learning criteria of the lesson.	Understand the wider context and learning outcomes. **Foundation** Describe why several different materials are needed to build a submarine
2 20 mins	**Investigation** Students follow the investigation brief to design and carry out an investigation into rusting and the effects of different environments on an iron nail.	**Developing** Carry out a fair investigation into the effects of salt and water on rusting **Competent** Explain why different conditions cause different amounts of rusting
3 25 mins	**Choice of materials** Using the materials cards, students make justified choices for the materials to build their submarine. **Demonstrate learning** By answering questions, students explain their choice of materials, and attempt to explain the science of rusting.	**Expert** Make justified choices for the materials used to build a submarine **Advanced** Explain oxidation reactions with balanced equations
4 5 mins	**Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance in the context of the Scheme of Work to design a submarine.	Reflect on learning

Resources

Activities Overview

Activity Overview 5: Submarine 'rusting' investigation

Student Sheets

Student Sheet 5a: Submarine 'rusting' investigation

Student Sheet 5b: Materials cards

Student Sheet 5c: Submarine materials choices

Student Sheet 5d: Submarine 'rusting' predictions

Mark Scheme

Mark Scheme 5: Submarine materials investigation

Slideshow

Slideshow 5

Subject Update

Glossary: Materials properties

Learn more: Investigation skills for younger students

Differentiation

By task
You may decide to not include the balanced equation question or explanation of rusting in terms of oxidation.

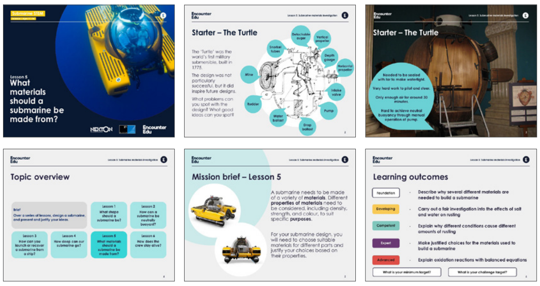
By support
Supply a glossary containing new and unfamiliar key words to students.

TEACHER GUIDANCE 5: SUBMARINE MATERIALS INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

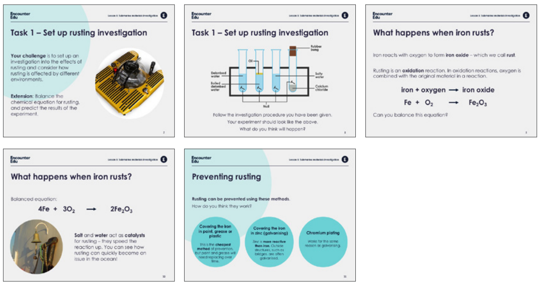
Step

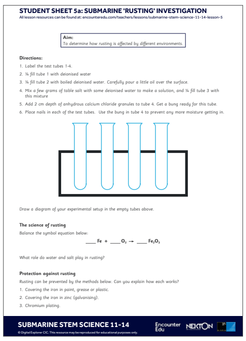
1
10 mins

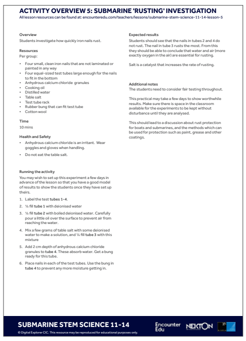


- The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.
- Show students the diagram of the 'Turtle' on **slide 2.** Using think-pair-share, students consider the questions on the slide. Review the activity using the photo and information on **slide 3.**
- Think-pair-share involves students considering answers to the two questions individually for one minute, then agreeing a response in a pair for one minute, before sharing with the whole class.
- Following the exploration, teacher sets the scene of the lesson using **slides 4-5.** The students are to investigate the materials needed to make a submarine.
- Show students lesson outcomes on **slide 6.** Ask them to set themselves a minimum target and challenge target in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

2
20 mins







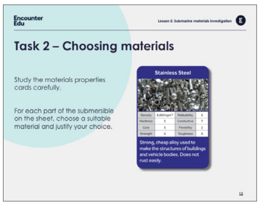
- The purpose of Step 2 is for students to become more familiar with rusting and the properties of materials.
- Further guidance for this activity is available on **Activity Overview 5.**
- Using **slides 7-8** explain how to set up the rusting experiment.
- Using **Student Sheet 5a**, student groups set up the rusting experiment, and place it at the back of the classroom ready to investigate at a later date. Students answer the questions about their choices and the science behind rusting.
- Review students answers to the questions using **slides 9-11.**

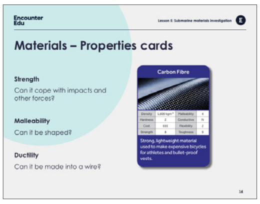
TEACHER GUIDANCE 5: SUBMARINE MATERIALS INVESTIGATION

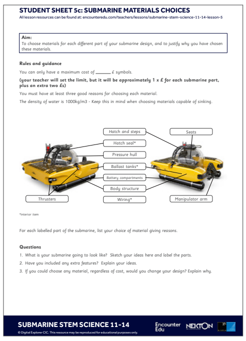
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Step

3
25 mins







The purpose of Step 3 is for students to demonstrate their learning, through choosing materials to build a submarine.

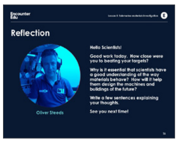
Using **slide 12** explain the task to select materials for various parts of the submarine. Use **slides 13-15** to go through the different information on the materials cards in **Student Sheet 5b**.

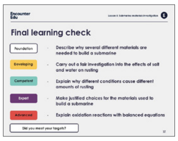
Students may need additional support and the **Subject Update Glossary: Materials properties** provides definitions of key terms.

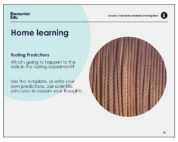
Students working individually or in pairs examine the materials cards on **Student Sheet 5b**, and select a material for selected parts of their submersible based on their properties and costs.
Students complete a table using **Student Sheet 5c** justifying their choices.
Depending on time, students can evaluate their choices of materials, or complete this task as part of their home learning.

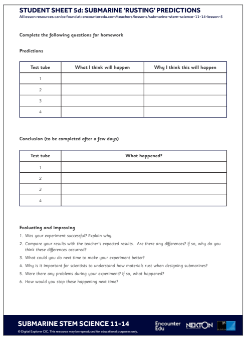
Ask selected students to read out the materials they have chosen, and the rest of the class can agree or argue their choice of material.

4
5 mins









The purpose of Step 4 is for students to reflect on their learning.

Reintroduce the team member on **slide 16**. Linking back to the lesson, and the overall context of the unit, students answer reflection questions and make a judgement as to the extent to which they met their targets.
Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson, showing **slide 17**. They then write a short sentence explaining their achievements.

Ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Set the home learning task **Student Sheet 5d** with students predicting what will happen in the rusting investigation using **slide 18**.

ACTIVITY OVERVIEW 5: SUBMARINE 'RUSTING' INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Overview

Students investigate how quickly iron nails rust.

Resources

Per group:

- Four small, clean iron nails that are not laminated or painted in any way
- Four equal-sized test tubes large enough for the nails to fit in the bottom
- Anhydrous calcium chloride granules
- Cooking oil
- Distilled water
- Table salt
- Test tube rack
- Rubber bung/stopper that can fit test tube

Time

10 mins

Health and Safety

- Anhydrous calcium chloride is an irritant. Wear goggles and gloves when handling.
- Do not eat the table salt.

Running the activity

You may wish to set up this experiment a few days in advance of the lesson so that you have a good model of results to show the students once they have set up theirs.

1. Label the test **tubes 1-4**.
2. ¼ fill **tube 1** with deionised water
3. ¼ fill **tube 2** with boiled deionised water. Carefully pour a little oil over the surface to prevent air from reaching the water.
4. Mix a few grams of table salt with some deionised water to make a solution, and ¼ fill **tube 3** with this mixture
5. Add 2 cm depth of anhydrous calcium chloride granules to **tube 4**. These absorb water. Get a bung ready for this tube.
6. Place nails in each of the test tubes. Use the bung in **tube 4** to prevent any more moisture getting in.

Expected results

Students should see that the nails in tubes 2 and 4 do not rust. The nail in tube 3 rusts the most. From this they should be able to conclude that water and air (more exactly oxygen in the air) are essential for rusting.

Salt is a catalyst that increases the rate of rusting.

Additional notes

The students need to consider fair testing throughout.

This practical may take a few days to show worthwhile results. Make sure there is space in the classroom available for the experiments to be kept without disturbance until they are analysed.

This should lead to a discussion about rust protection for boats and submarines, and the methods which can be used for protection such as paint, grease and other coatings.

STUDENT SHEET 5a: SUBMARINE 'RUSTING' INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Aim:
To determine how rusting is affected by different environments.

Directions:

1. Label the test tubes 1-4.
2. ¼ fill tube 1 with deionised water
3. ¼ fill tube 2 with boiled deionised water. Carefully pour a little oil over the surface.
4. Mix a few grams of table salt with some deionised water to make a solution, and ¼ fill tube 3 with this mixture
5. Add 2 cm depth of anhydrous calcium chloride granules to tube 4. Get a bung ready for this tube.
6. Place nails in each of the test tubes. Use the bung in tube 4 to prevent any more moisture getting in.

Draw a diagram of your experimental setup in the empty tubes above.

The science of rusting

Balance the symbol equation below:

$$\_\_\_\_\ Fe + \_\_\_\_\ O_2 \rightarrow \_\_\_\_\ Fe_2O_3$$

What role do water and salt play in rusting?

Protection against rusting

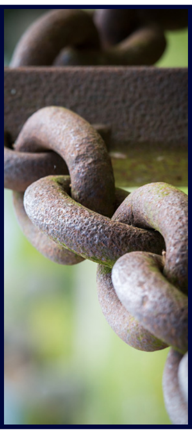
Rusting can be prevented by the methods below. Can you explain how each works?

1. Covering the iron in paint, grease or plastic.
2. Covering the iron in zinc (galvanising).
3. Chromium plating.

STUDENT SHEET 5b: MATERIALS CARDS

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

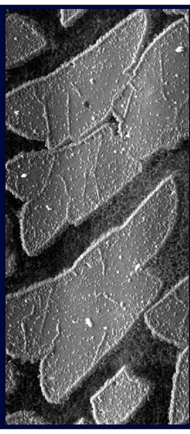
Iron



Density	7,900 kgm^{-3}	Malleability	6
Hardness	4	Conductive	Y
Cost	£	Flexibility	3
Strength	5	Toughness	7

Relatively soft but heavy metal that rusts easily. Used to make steel.

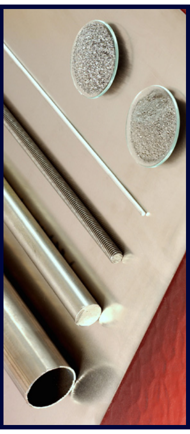
Graphene



Density	400 kgm^{-3}	Malleability	9
Hardness	10	Conductive	Y
Cost	££££	Flexibility	7
Strength	10	Toughness	10

Expensive "nano-material" difficult to obtain in large quantities. Used to make electronics.

Titanium



Density	4,500 kgm^{-3}	Malleability	3
Hardness	6	Conductive	Y
Cost	£££	Flexibility	2
Strength	10	Toughness	9

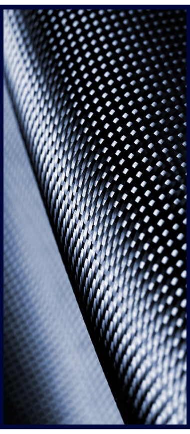
Very strong, light metal. Does not rust. Used to make replacement hip joints.

Diamond

Density	3,500 kgm^{-3}	Malleability	0
Hardness	10	Conductive	N
Cost	£££££	Flexibility	0
Strength	8	Toughness	10

Very hard material found in mines, used for jewellery and the tips of industrial drills.

Carbon Fibre



Density	1,600 kgm^{-3}	Malleability	4
Hardness	2	Conductive	N
Cost	£££	Flexibility	2
Strength	8	Toughness	9

Strong, lightweight material used to make expensive bicycles for athletes and bullet-proof vests.

Graphite

Density	2,100 kgm^{-3}	Malleability	0
Hardness	1	Conductive	Y
Cost	£	Flexibility	2
Strength	2	Toughness	2

Cheap, soft material used to make pencils. Conducts heat and electricity.

Stainless Steel

Density	8,000 kgm^{-3}	Malleability	6
Hardness	5	Conductive	Y
Cost	£	Flexibility	2
Strength	6	Toughness	8

Strong, cheap alloy used to make the structures of buildings and vehicle bodies. Does not rust easily.

Rubber

Density	1,100 kgm^{-3}	Malleability	10
Hardness	2	Conductive	N
Cost	£	Flexibility	7
Strength	3	Toughness	7

Flexible and soft insulator that is cheap and easy to obtain.

STUDENT SHEET 5b: MATERIALS CARDS

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Copper

Density	9,000 kgm^{-3}	Malleability	7
Hardness	3	Conductive	Y
Cost	£	Flexibility	3
Strength	4	Toughness	6

Used to make coins and plumbing.

Aluminium

Density	2,700 kgm^{-3}	Malleability	6
Hardness	3	Ductility	3
Cost	£	Flexibility	7
Strength	2	Toughness	7

Commonly used for building the bodies of aeroplanes. Does not rust.

Brass

Density	8,500 kgm^{-3}	Malleability	6
Hardness	3	Conductive	Y
Cost	££	Flexibility	2
Strength	6	Toughness	8

An alloy, used to make musical instruments.

Clear Acrylic

Density	1,100 kgm^{-3}	Malleability	7
Hardness	7	Ductility	7
Cost	££	Flexibility	4
Strength	6	Toughness	6

Transparent. Often used instead of glass for items such as kitchenware.

Glass

Density	2,800 kgm^{-3}	Malleability	1
Hardness	2	Conductive	N
Cost	£	Flexibility	2
Strength	2	Toughness	8

Transparent material that can be made into sheets for windows and moulded into shapes for bottles and containers.

Fibreglass

Density	1,500 kgm^{-3}	Malleability	2
Hardness	7	Ductility	9
Cost	££	Flexibility	7
Strength	5	Toughness	6

Tough material used to make the hulls of lightweight yachts.

Wood

Density	800 kgm^{-3}	Malleability	2
Hardness	2	Conductive	N
Cost	£	Flexibility	4
Strength	2	Toughness	5

Readily available material used to build furniture and the frames of houses.

Polystyrene

Density	1,000 kgm^{-3}	Malleability	2
Hardness	0	Ductility	0
Cost	£	Flexibility	5
Strength	2	Toughness	1

Cheap, light. Often used as insulation and packing material.

STUDENT SHEET 5c: SUBMARINE MATERIALS CHOICES

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Aim:
To choose materials for each different part of your submarine design, and to justify why you have chosen these materials.

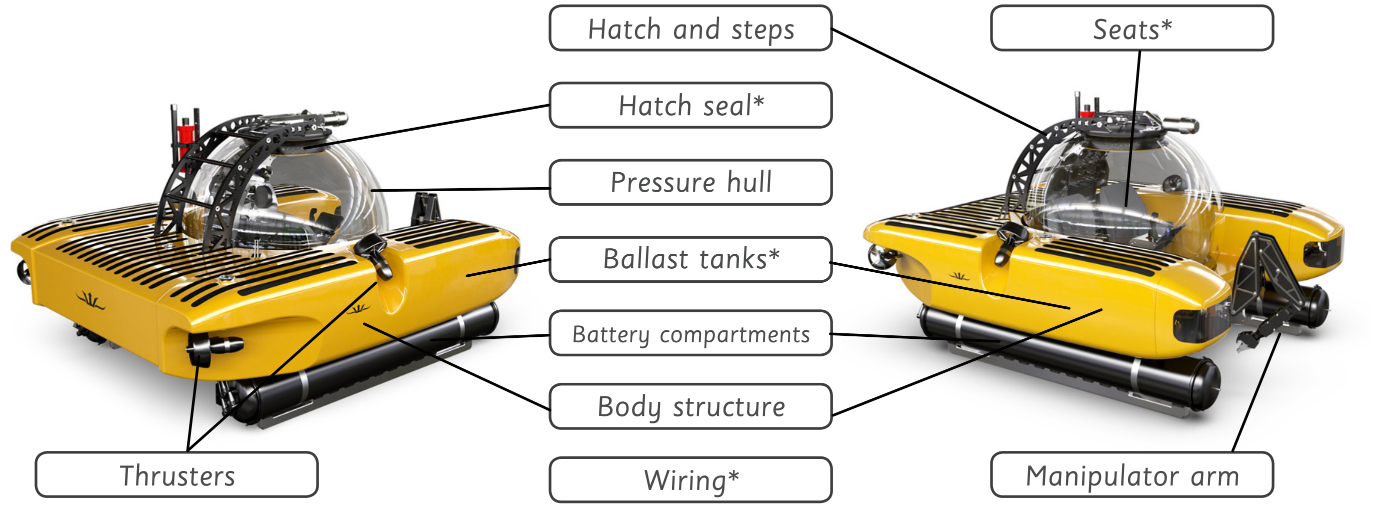
Rules and guidance

You can only have a maximum cost of ______ £ symbols.

(Your teacher will set the limit, but it will be approximately 1 x £ for each submarine part, plus an extra two £s.)

You must have at least three good reasons for choosing each material.

The density of water is 1000kg/m^3 - Keep this in mind when choosing materials capable of sinking.



*interior item

For each labelled part of the submarine, list your choice of material giving reasons.

Questions

1. What is your submarine going to look like? Sketch your ideas here and label the parts.
2. Have you included any extra features? Explain your ideas.
3. If you could choose any material, regardless of cost, would you change your design? Explain why.

STUDENT SHEET 5d: SUBMARINE 'RUSTING' PREDICTIONS

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Complete the following questions for homework

Predictions

Test tube	What I think will happen	Why I think this will happen
1		
2		
3		
4		

Conclusion (to be completed after a few days)

Test tube	What happened?
1	
2	
3	
4	

Evaluating and improving

1. Was your experiment successful? Explain why.
2. Compare your results with the teacher's expected results. Are there any differences? If so, why do you think these differences occurred?
3. What could you do next time to make your experiment better?
4. Why is it important for scientists to understand how materials rust when designing submarines?
5. Were there any problems during your experiment? If so, what happened?
6. How would you stop these happening next time?

MARK SCHEME 5: SUBMARINE MATERIALS INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-5

Answers for Student Sheet 5a

The science of rusting

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

What role do water and salt play in rusting?

Salt and water are catalysts. They speed up the rusting reaction, without being changed by the reaction.

Protecting against rusting

1. Covering the iron in paint, grease or plastic.
   This prevents oxygen getting to the iron, stopping the reaction from happening.

2. Covering the iron in zinc (galvanising).
   The oxygen in the air reacts with the zinc rather than the iron, preventing the rusting reaction occurring. The layer of zinc oxide that is produced forms a protective layer around the iron.

3. Chromium plating.
   Similar to above, oxygen in the air reacts with the chromium rather than the iron, preventing the rusting reaction occurring. This is known as sacrificial protection.

Answers for Student Sheet 5d

Predictions

Test tube	What I think will happen	Why I think this will happen
1	Student should predict there will be some rusting	Student should justify that all reactants present
2	Student should predict there will be no rusting	Student should justify that the oil will prevent oxygen from getting to the nail
3	Student should predict there will be a lot of rusting	Student should justify that the salt and water will speed up the reaction
4	Student should predict there will be no rusting	Student should justify that the anhydrous copper sulphate will absorb the water and the bung will stop more oxygen getting in

Conclusion (expected results)

Test tube	What happened?
1	Some rusting
2	Should not rust
3	Rusts the most
4	Should not rust

LESSON 6: SUBMARINE LIFE SUPPORT INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

Lesson overview

Researching using submarines means that the scientists are working in an enclosed space deep underwater for hours at a time. This lesson investigates the life support systems needed to keep scientists and explorers alive.

Students will conduct an investigation into how limewater can reduce the amount of carbon dioxide in an atmosphere. Students will then design the life support systems needed for a submarine. The lesson concludes with students compiling all their research from the unit to create a submarine design presentation.

Keywords

- **Names:** glucose, cells, energy
- **Concepts:** respiration, feasibility

Details

Time
60 minutes (option to extend)

Curriculum links
KS3 Biology:
- Structure and function of living organisms
- Relationships in an ecosystem

KS3 Working scientifically:
- Experimental skills and investigations
- Analysis and evaluation

Lesson steps / Learning outcomes

Step	Lesson steps	Learning outcomes
1 (15 mins)	**Brief** Students recall the seven requirements for life, and the teacher introduces the context of the lesson – How life is supported in underwater vehicles. Students set themselves targets based on the learning criteria of the lesson.	Understand the wider context and learning outcomes.
2 (15 mins)	**Investigation** Students follow the investigation brief to carry out an investigation into the effects of respiration. **Demonstrate learning** Students answer questions pertaining to the investigation and consider the implications for life support for the submersible's crew.	**Foundation** Describe the dangers to explorers in the deep ocean **Developing** Conduct an investigation into respiration **Competent** Describe how respiration occurs and its importance **Expert** Balance the respiration equation
3 (25 mins)	**Demonstrate learning** By filling out a template, students explain how they intend to support life in their submersible design.	**Advanced** Explain how submarines are built and engineered to sustain life
4 (5 mins)	**Self-reflection** Students decide if they have met their targets set at the beginning of the lesson, and reflect on the lesson's importance to the context of the Scheme of Work.	Reflect on learning

Resources

Activities Overview

Activity Overview 6:
Respiration investigation

Student Sheets

Student Sheet 6a:
Respiration investigation

Student Sheet 6b:
Life support design

Student Sheet 6c:
Submarine presentation

Mark Scheme

Mark Scheme 6:
Submarine life support investigation

Slideshow

Slideshow 6

Multimedia

360VR Video: Exploring the deep ocean

Gallery:
- Deep sea creatures
- Life around the vent

Diagram:
Deep ocean poster

Subject Update

How to: Quick start to 360VR in the classroom

How to: 4 ways to use 360VR in the classroom

Differentiation

By task
You may wish to remove the symbol equation for respiration and focus solely on the word equation.

By support
Provide sentence starters to help students explain their life-support system design.

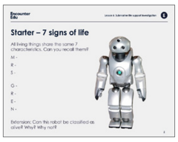
TEACHER GUIDANCE 6: SUBMARINE LIFE SUPPORT INVESTIGATION

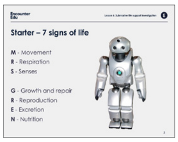
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

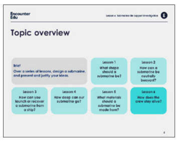
Step

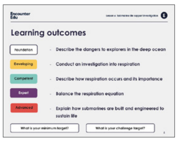
1

15 mins









The purpose of Step 1 is to share the learning outcomes, set the context and engage students with the learning.

Using **slide 2**, students recall MRS GREN and the 7 characteristics of life.

Use **slide 3** to review this as a whole class discussion.

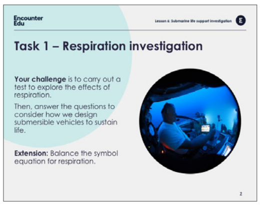
Teacher sets the scene of the lesson using **slides 4-5**. Students are to investigate the effects of respiration, and consider how to design their submarine to sustain life underwater.

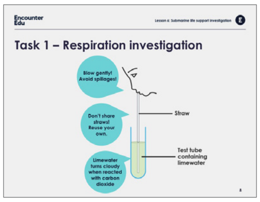
Watch the **360VR Video Exploring the deep ocean** either as a whole class or with students watching on individual devices. See **Subject Updates How to: Quick start to 360VR in the classroom** and **How to: 4 ways to use 360VR in the classroom** for more information.

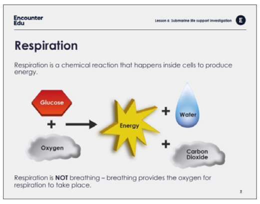
Show students lesson outcomes on **slide 6**. Ask them to set themselves a minimum target and challenge target in their books, highlighting their expected progress if appropriate. Take feedback, ensuring targets set are suitable.

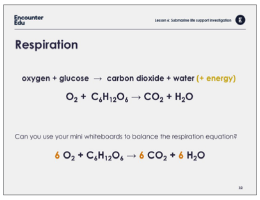
2

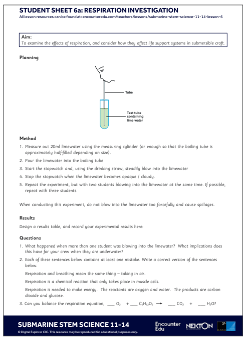
15 mins

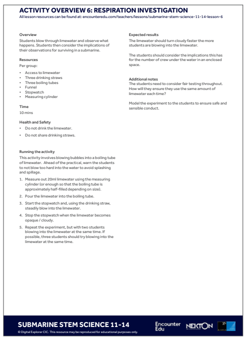












The purpose of Step 2 is for students to conduct an investigation into respiration and consider implications for submarine life support.

Further guidance for this activity is available on **Activity Overview 6**.

Using **slides 7-8**, explain the idea of the investigation. Emphasise the safety precautions.

Using **Student Sheet 6a**, student groups follow the investigation brief to carry out an investigation into the effects of respiration, and answer questions pertaining to the investigation and consider the implications for life support for submarine crews.

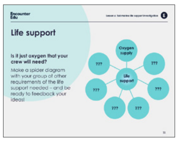
If students need further support on respiration, use **slides 9-10**.

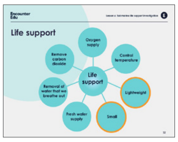
TEACHER GUIDANCE 6: SUBMARINE LIFE SUPPORT INVESTIGATION

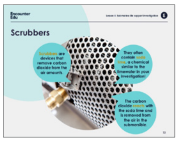
All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

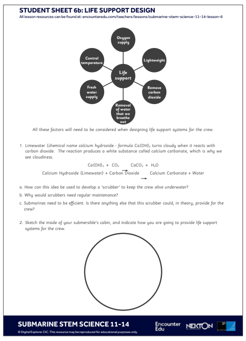
Step

3
25 mins









The purpose of Step 3 is for students to demonstrate their learning, through designing life support for a submarine.

Using **slide 11**, ask students to consider what factors they need to consider in designing a life support system for a submarine. Review this using **slide 12**.

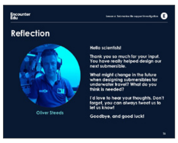
Using **slides 13-14**, explain to students how scrubbers work in a submarine referring back to the respiration investigation, as well as the purpose of desiccants. Use **slide 15**, explain the second lesson task, designing the life support for a submarine and hand out **Student Sheet 6b**.

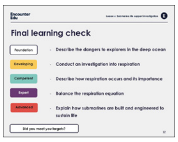
Students design the life support for a submarine using **Student Sheet 6b**, considering feasibility, properties of materials and cost.

Select students to present and explain their designs to the rest of the class.

If you wish students to create a synthesis presentation of the entire unit, use **Student Sheet 6c** to introduce this. Submarine presentations can be created as home learning and / or in an additional lesson.

4
5 mins





The purpose of Step 4 is for students to reflect on their learning.

Reintroduce the team member on **slide 16.** Linking back to the lesson, and the overall context of the unit, students answer reflection questions and make a judgement as to the extent to which they met their targets.

Students could swap books or look at their own answers, and decide if they met the targets set at the beginning of the lesson, showing **slide 17**. They then write a short sentence explaining their achievements.

Ask, by show of hands, which students think they met their minimum and challenge targets from the start of the lesson.

Set the home learning task with students investigating deep sea life using **slide 18.** Point students to the **Deep sea creatures** and **Life around the vent** galleries in the Discovery Zone.

ACTIVITY OVERVIEW 6: RESPIRATION INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

Overview

Students blow through limewater and observe what happens. Students then consider the implications of their observations for surviving in a submarine.

Resources

Per group:

- Access to limewater
- Three drinking straws
- Three boiling tubes
- Funnel
- Stopwatch
- Measuring cylinder

Time

10 mins

Health and Safety

- Do not drink the limewater.
- Do not share drinking straws.

Running the activity

This activity involves blowing bubbles into a boiling tube of limewater. Ahead of the practical, warn the students to not blow too hard into the water to avoid splashing and spillage.

1. Measure out 20ml limewater using the measuring cylinder (or enough so that the boiling tube is approximately half-filled depending on size).
2. Pour the limewater into the boiling tube.
3. Start the stopwatch and, using the drinking straw, steadily blow into the limewater.
4. Stop the stopwatch when the limewater becomes opaque / cloudy.
5. Repeat the experiment, but with two students blowing into the limewater at the same time. If possible, three students should try blowing into the limewater at the same time.

Expected results

The limewater should turn cloudy faster the more students are blowing into the limewater.

The students should consider the implications this has for the number of crew under the water in an enclosed space.

Additional notes

The students need to consider fair testing throughout. How will they ensure they use the same amount of limewater each time?

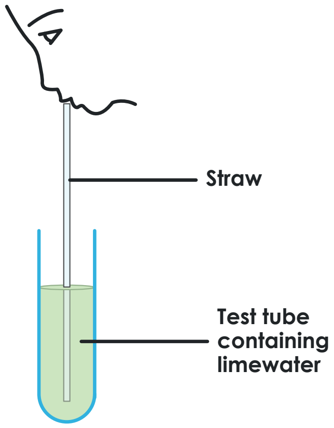
Model the experiment to the students to ensure safe and sensible conduct.

STUDENT SHEET 6a: RESPIRATION INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

Aim:
To examine the effects of respiration, and consider how they affect life support systems in submersible craft.

Planning



Method

1. *Measure out 20ml limewater using the measuring cylinder (or enough so that the boiling tube is approximately half-filled depending on size).*
2. *Pour the limewater into the boiling tube.*
3. *Start the stopwatch and, using the drinking straw, steadily blow into the limewater.*
4. *Stop the stopwatch when the limewater becomes opaque / cloudy.*
5. *Repeat the experiment, but with two students blowing into the limewater at the same time. If possible, repeat with three students.*

When conducting this experiment, do not blow into the limewater too forcefully, which will cause spillages.

Results

Design a results table, and record your experimental results.

Questions

1. *What happened when more than one student was blowing into the limewater? What implications does this have for your crew when they are underwater?*
2. *Each of these sentences below contains at least one mistake. Write a correct version of the sentences below.*

   Respiration and breathing mean the same thing – taking in air.

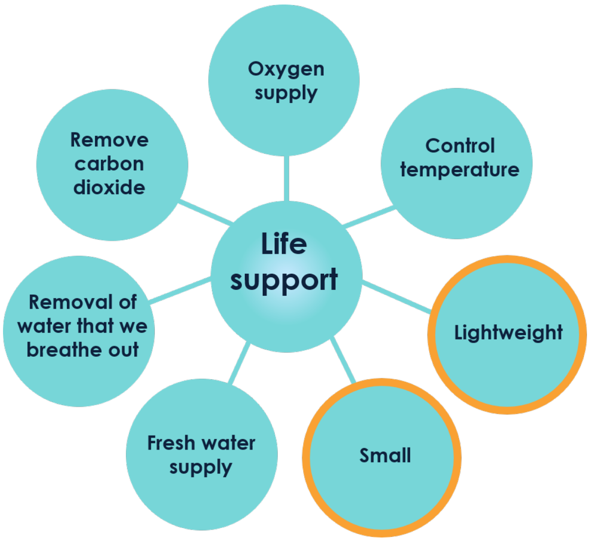
   Respiration is a chemical reaction that only takes place in muscle cells.

   Respiration is needed to make energy. The reactants are oxygen and water. The products are carbon dioxide and glucose.

3. *Can you balance the respiration equation,* $\_\_\_\ O_2 + \_\_\_\ C_6H_{12}O_6 \rightarrow \_\_\_\ CO_2 + \_\_\_\ H_2O$?

STUDENT SHEET 6b: LIFE SUPPORT DESIGN

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6



All these factors will need to be considered when designing life support systems for the crew.

1. Limewater (chemical name calcium hydroxide - formula $Ca(OH)_2$) turns cloudy when it reacts with carbon dioxide. The reaction produces a white substance called calcium carbonate, which is why we see cloudiness.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

Calcium Hydroxide (Limewater) + Carbon Dioxide ⟶ Calcium Carbonate + Water

a. How can this idea be used to develop a 'scrubber' to keep the crew alive underwater?

b. Why would scrubbers need regular maintenance?

c. Submarines need to be efficient. Is there anything else that this scrubber could, in theory, provide for the crew?

2. Sketch the inside of your submersible's cabin, and indicate how you are going to provide life support systems for the crew.

STUDENT SHEET 6c: SUBMARINE PRESENTATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

My submarine design Presentation planner

Need a hand getting started with your presentation? Summarise your ideas here, and use them to help your planning.

(Sketch a picture of your submarine here)

I have chosen this shape for my submersible because…

To launch and recover the sub, the crane has been designed to…

We use a pulley because…

Some of the problems of launching the submarine from the side of a surface vessel are…

Rusting happens when…

This is prevented on the sub by…

The crew are kept alive by….

Some of the dangers explorers face at depth are…

The submarine is made neutrally buoyant by…

It raises and lowers by…

Most of the structure of the sub is made from…

Because…

I will make the pressure hull out of…

Because…

The ballast tanks are made from…

Because…

MARK SCHEME 6: SUBMARINE LIFE SUPPORT INVESTIGATION

All lesson resources can be found at: encounteredu.com/teachers/lessons/submarine-stem-science-11-14-lesson-6

Answers for Student Sheet 6a

1. The limewater turned cloudier quicker the more people were blowing into the limewater. This means that with more crew aboard, more carbon dioxide is going to be produced, and the oxygen is going to be used for respiration faster. The life support systems will need to be designed with the number of crew in mind.
2. Each of these sentences below contains at least one mistake. Write a correct version of the sentences below.

   Respiration and breathing are not the same thing. Breathing takes air into the lungs. Respiration is a chemical reaction that produces energy.

   Respiration is a chemical reaction that takes place in all living cells.

   Respiration is needed to make energy. The reactants are oxygen and glucose. The products are carbon dioxide and water.

3. $6O_2 + C_6H_{12}O_6 \longrightarrow 6CO_2 + 6H_2O$

Answers for Student Sheet 6b

1a. How can this idea be used to develop a "scrubber" to keep the crew alive underwater?

Scrubbers could contain calcium hydroxide, or a similar chemical, that reacts with the carbon dioxide produced during respiration.

1b. Why would scrubbers need regular maintenance?

As it is a chemical reaction, the calcium carbonate will need to be removed and the calcium hydroxide replaced. If the calcium hydroxide is not replaced the scrubber will not work.

1c. Submarines need to be efficient. Is there anything else that this scrubber could, in theory, provide for the crew?

The water produced in the chemical reaction could be used as part of the clean water supply the crew will need.

Answers for Student Sheet 6c

Below are some example justifications that the students may come up with. These answers are by no means comprehensive.

I have chosen this shape for my submersible because it allows for controlled raising and sinking at a safe speed.

To launch and recover the sub, the crane has been designed to be stable by using an A-frame structure, and to move using pivots. We use a pulley because it allows a small force to be multiplied to a bigger force capable of lifting the submarine.

The sub is lifted off the back of the boat and not the side because this moves the centre of gravity of the surface vessel further from the crane, meaning that it provides a larger moment. This helps prevent tipping (heaving).

Rusting happens when iron reacts with oxygen, catalysed by salt and water. This is prevented on the submarine by using non-rusting metals where possible, and by painting any iron to prevent a reaction with oxygen.

The crew are kept alive by ensuring a constant supply of oxygen from pressurised tanks, and using scrubbers to remove the carbon dioxide produced during respiration. Clean drinking water is also supplied by condensing the water breathed out during respiration.

Some of the dangers explorers face at depth are high underwater currents and a lack of light. The underwater currents can make piloting the submersible difficult, and cause collisions with rocks causing damage.

The submarine is made neutrally buoyant by using ballast tanks. It raises and lowers by changing the amount of air and water in the tanks. More air lowers the overall density, causing the sub to rise. More water increases the density causing the sub to sink. When the overall density of the sub is equal to the water, the craft is neutrally buoyant.

Most of the structure of the submersible is made from stainless steel because it is cheap, strong and resistant to corrosion. Steel is also easily shaped to produce whatever panels are needed to make the submarine the required shape.

The cabin is made out of clear acrylic because it is a transparent material that allows the crew to see easily, and is capable of withstanding the pressures at depth.

The ballast tanks are made from stainless steel because it is a material capable of holding air at pressure. It is also non-rusting and able to withstand many impacts.