DENSITY

Exploring mass, volume & density
An integrated Science and Mathematics Exploration

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MC SAM making connections in science and mathematics

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Refer to Queensland Studies Authorities
www.qsa.qld.edu.au/assessment/qcar.html
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www.qsa.qld.edu.au/downloads/assessment/qcar_el_maths_kau.pdf
Science
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Mathematics

Assessable Elements

K&U	Knowledge and Understanding
T&R	Thinking and Reasoning
C	Communicating
R	Reflecting

Core Content

N	Numbers
PA	Patterns & Algebra
M	Measurement
CD	Chance & Data
S	Space

Science

Assessable Elements

K&U	Knowledge and Understanding
I	Investigating
C	Communicating
R	Reflecting

Core Content

SHE	Science as Human Endeavour
E&B	Earth & Beyond
E&C	Energy and Change
L&L	Life & Living
N&PM	Natural & Processed Materials

INTRODUCTION

Density in the Middle Years Science and Mathematics Curriculum

This unit of work has been designed to promote students' understanding of density. Density is a topic studied in the Middle Years Science curriculum, but conceptual understanding of density requires understanding of many topics associated with the Middle Years Mathematics curriculum. Such mathematics topics include mass and volume as well as number sense and mental computation. Other knowledge and skills located in both the Middle Years Science and Mathematics curriculum include data gathering, data analysis, interpretation of data, graphing, measuring, using measuring instruments, problem solving, problem posing, conducting experiments and controlling variables.

An investigative approach

This unit takes an investigative approach to the topic of density where learning experiences are designed for active student participation to foster rich conceptual understanding. An investigative approach means that students are provided with opportunities to learn and apply key mathematical and scientific skills in meaningful contexts, rather than being provided with de-contextualised practice exercises that they then apply to realistic situations. An investigative approach is a guided discovery approach where formulae derive from experience and gentle teacher scaffolding. An investigative approach is the principle philosophy of both the Queensland 1-10 Mathematics and Science syllabuses.

Mathematics and Science Integration

This unit is designed as a unit that can be implemented equally with both Middle Years mathematics and science classes. That is, the unit is designed so that both mathematics and science core learning outcomes for the middle years are being targeted simultaneously. The activities can be identified specifically as being either science or maths activities, but they have been interwoven throughout the unit to build key knowledge, skills and concepts required for an understanding of density. The unit is designed for implementation either in junior secondary mathematics classes, junior secondary science classes, or integrated upper primary classes.

Learning Objectives	Assessable Elements				Core Content				
Mathematics ◤	K&U	T&R	C	R	N	PA	M	CD	S
Science ◢	K&U	I	C	R	SHE	E&B	E&C	L&L	N&PM
Elaborate understanding of mass and volume					◤		◤		◤◢
Develop an understanding of the concept of density		◢	◢	◢					◢
Apply the concepts of mass, volume and density to solve qualitative problems		◤◢	◤◢	◤◢					
Collect data about the mass and volume of objects					◤		◤	◤	
Calculate the volume and density of objects based on appropriate measurements					◤		◤		
Apply the concepts of mass, volume and density to solve quantitative problems		◤◢	◤◢	◤◢					
Assess the quality of data obtained by measurement and calculation		◤◢	◤◢	◤◢					
Make predictions of the sinking and floating behaviour of objects based on measurements and calculations		◤◢	◤◢	◤◢					
Explore data to establish relationships between concepts						◤		◤	◤◢

INTRODUCTION

Unit Overview

The unit is made up of a series of episodes, each designed to be of approximately 35–40 minutes duration. The unit includes a pretest for diagnostic purposes and a posttest for comparative purposes. An investigative assessment task concludes this unit. An outline of the focus of each teaching episode is provided in the table below.

Episode	Focus
1	Diagnostic Pretest Introductory Activity – does it sink or float?
2	Exploring volume o of rectangular based prisms o of cylinders
3	Exploring density – Density jars
4	Exploring density formula
5	Formula consolidation
6	Application of density – Ballooning
7	Investigative Assessment Task – Egg sorting Challenge

Purpose

This unit of work has been designed to be a truly integrated mathematics and science unit for students in the middle years of schooling. The underlying conceptual emphasis is on density, but consolidation of the concepts of volume and mass, which are traditionally located in the mathematics syllabus, are also part of the unit.

The development of the unit was based on the premise of integrating science and mathematics in a way that equally favoured the core learning outcomes of both these key learning areas. The entire unit has been designed, therefore, to be taught in either the science classroom, or the mathematics classroom, or in the integrated numeracy class.

Duration

The unit of requires a minimum of 7 class periods, two of which are used for administration of assessment tasks. Time for the density posttest (20 minutes) is also required. The unit can be extended in various ways and can take up more class lessons than suggested. The unit is designed to be implemented in a consecutive manner so that students have maximum opportunity to engage with and consolidate the ideas being presented for an extended period of time.

The complexity of the Density concept

Density is the relationship between an object's mass and volume. Mass and volume are topics firmly located in the school mathematics curriculum. However, taking a scientific view of mass and volume, provides a new dimension to conceptualising these two properties of objects.

Mass, volume and density

Science is about understanding the world, and one of the ways of doing this systematically is to investigate the properties of objects and the relationships between them. Two of the most obvious properties of objects are their mass and volume.

Mass is one of the fundamental concepts of physics and corresponds to the amount of matter in an object. The most common units are grams (g) and kilograms (kg).

The mass of an object is constant in everyday life provided that no matter is added or lost. This is the basis of the Law of Conservation of Mass which indicates that whenever there is a change, the total mass before the change is the same as the total mass after the change. For this unit, the important consequence is that the mass of an object is always the sum of the masses of its component parts.

From an educational point of view, there is a major stumbling block for students because of the way we measure mass. The problem is that we measure it indirectly. What we measure is a force (the gravitational attraction of the object to the Earth) which is proportional to the mass. The mass can be calculated from the force (the weight) by calibrating the scales appropriately in the units of mass. The confusion for students arises because we often use the terms weight and mass interchangeably at a time when students are starting to learn about forces. For the purposes of this unit it is probably best to use the term mass wherever possible rather than the problematic term weight.

Volume is the three-dimensional concept of the amount of space occupied by an object. The strict SI unit for volume is the cubic metre (m3) but the derived unit litres (L) is accepted for use in the SI (Standard International) system. 1 m3 = 1000 L. Technically the symbol for litres can be l or L, but in practice L is more commonly used because a lower case l is easily confused with the number 1.

The volume of any objects can be measured by displacement, and the volume of regular objects can be calculated from measured dimensions.

Unlike the mass of an object which is independent of its temperature, the volume changes with temperature. This is because all matter is composed of atoms and all atoms are constantly vibrating (moving). They vibrate more as the temperature increases and so the general effect is that volume increases with temperature. There are exceptions (such as ice floating) which can be explained when the atomic structure is considered.

Relationships

Much of our scientific understanding comes from thinking about the relationships between the properties of objects and concepts in a more general sense. For example in this unit students will be exploring the relationship between mass and volume and the consequences for whether an object sinks or floats. Thinking about this issue is hard work because the tendency to sink is directly proportional to the mass and inversely proportional to the volume.

This relationship is captured in a derived property, density, which is the ratio of mass to volume. This ratio (which can be expressed as a number) can be used to think about sinking and floating issues much more easily than the underlying concepts of mass and volume. It is therefore a useful concept that is an inherent property of substances and objects. However it is only useful for solving everyday problems if the relationship with mass and volume is well understood.

For example if a swimmer wants to float for a few minutes on the surface of a swimming pool they need to decrease their density so that they are less dense than the water in the pool. The easiest way of doing this is to take a deep breath so that they inflate their lungs and increase their volume without significantly increasing their mass.

Density

The formal definition of density is mass per unit volume and is represented by the formula:

$$\rho = \frac{m}{V}$$

units of g/mL or kg/m^3

The density of an object changes with temperature because the volume is temperature dependent (see above).

At a given temperature the density of a pure substance is a useful property of the substance and is constant. For example the density of pure water at 4 ^{o}C is 1.0 g/mL.

Part of the utility of density as a property arises because it is an intensive property (which is independent of the amount of the substance) unlike mass and volume which are extensive properties. You can see the value of this idea because you can say that the density of water is one (g/mL) whereas to say that the mass of water is 1 kg is nonsense.

From an educational point of view, the concept of density has a long and problematic history partly because understanding density requires a measure of proportional reasoning and partly because it is a property that is more abstract than mass or volume. However learning about density has value both because it rehearses student's ideas about proportional reasoning and because it is one of a number of concepts that appear in the introductory science curricula such as speed, force and concentration that have similar forms and cognitive demands.

Prior Knowledge

Density requires knowledge of mass and volume. During this unit, students are engaged in activities that further consolidate understanding of both of these concepts, with the expectation that students have engaged in activities to promote initial conceptualisation of them.

INTRODUCTION

Expected prior knowledge includes:

- conceptualisation of mass as 'heaviness' of an object, or amount of heft required to lift the object
- conceptualisation of volume as amount of space taken up by an object
- conceptualisation of area as amount of covering
- knowledge of common units for mass (g, kg)
- knowledge of common units for volume (cubic centimetres, cubic metres)
- knowledge of common units for and area (square centimetres)
- measurement sense of size of square centimetre
- measurement sense of size of cubic centimetre
- familiarity with terms: pi, circumference, radius, diameter
- understanding of formula for finding area of circles
- understanding of fractions as division (e.g., that 4/3 is the same as 4÷3).

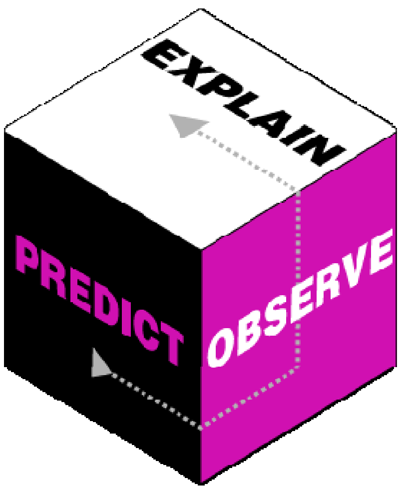
Unit Adaptability

This is an seven episode unit that targets the concept of density in a focused way. However, further episodes may be added to this unit depending upon the prior knowledge of the students. If students have a limited prior knowledge (see list above), further episodes may be developed and slotted into the unit to match the specific learning needs of the students. The pretest will provide further evidence of students' prior knowledge as will the introductory activity following. Hence, this unit can be implemented in a web-like manner with diversions into other episodes to complement the original eight episodes.

Teaching Approach

The unit is based on teaching that adopts an investigative approach. As such, the teaching episodes are designed to provide opportunities for students to actively work with materials and to discuss ideas to build rich frameworks of conceptual knowledge and understanding. From a constructivist perspective, students need to be provided with engaging and intellectually challenging learning environments and activities so that they can actively construct deep understanding of topics, concepts and issues being explored. Within the description of each teaching episode in this unit, there are suggestions for the types of questions that can be posed to students to encourage them to think about situations and activities presented.

A powerful tool for encouraging higher order thinking that is often used in Science Teaching Strategy is the P-O-E strategy, which stands for Predict – Observe – Explain. To use this strategy, provide students with a situation that encourages them to predict the outcome. Students' predictions should be valued (regardless of how unrealistic they may seem) and recorded in some format for later reflection. The students then observe what happens and then explain the result. The explanation can be matched to the students' predictions. The teacher's role is to guide students' to use evidence to provide their explanations.



The P-O-E strategy is used throughout the unit of work, or if not directly mentioned, should be used at suitable time when activities are being presented and the outcome is unknown..

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EPISODE 1

Diagnostic Pretest and Introductory Activity

Diagnostic Pretest

Overview	The diagnostic pretest is designed to provide a quick survey of students' current knowledge of density, mass, volume. This is a pen and paper test that includes 'tick a box' items, true/false items and some items that encourage the use of drawings or diagrams to express meaning. Students should be allowed 20 minutes for the test completion. Teachers will be able to quickly glance through students' responses on particular items to gauge prior knowledge of density. Formal scoring and recording of students' responses can be undertaken for a more detailed analysis.
Purpose	To provide a snapshot of students' prior knowledge of density
Time	20 minutes
Materials	Copies of Diagnostic Pretest (Appendix 1)
Procedure	1. Ask students to prepare themselves for a quick quiz. 2. Ensure students have a pen to write their responses to each item. 3. Instructions to students: *This is not a test* *Your results will not affect your report card* *Don't worry if you are unsure of how to answer some questions* *Just do your best and try to show your thinking* *Do your own work because I want to know what you know, not how well you can copy what your neighbour has written* *If you're unsure, just leave that question and go on to the next one* 4. Provide students with maximum 20 minutes to complete the test. 5. Collect and peruse.

Density Pretest

Name | Class | Teacher | Year

Score /15

1. What does each of the following words mean? Write something and/or draw a diagram that will help others in your year level to understand the meaning of these words. (3 marks)

density | mass | volume

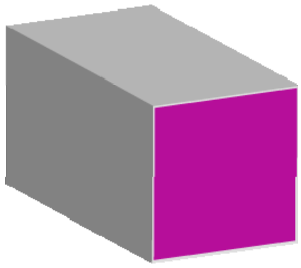
2. Choose the best estimate for the volume of a tennis ball. (1 mark)

- ❑ a. 4000 mL
- ❑ b. 1500 cm^3
- ❑ c. 250 cm^3
- ❑ d. 2.3 L
- ❑ e. 200 g

3. Choose the best estimate for the mass of an apple. (1 mark)

- ❑ a. 500 g
- ❑ b. 2 kg
- ❑ c. .5 mg
- ❑ d. 3 t
- ❑ e. 250 g

4. This block has the following properties:



length:	2 cm
width:	1 cm
colour:	red
mass:	10 g
surface area:	10 cm^2
age:	3 years
volume:	2 cm^3
height:	1 cm

What is the density of this block? (2 marks)

5. In each of the following sentences, circle the correct word to make the sentence true. (1 mark each)

   a. A fresh egg sinks in a bowl of water but an old egg floats because the fresh egg is **MORE LESS** dense.

   b. When a submarine needs to dive, the crew makes it **MORE LESS** dense.

   c. In Beijing, the population density is higher than in Brisbane because **MORE LESS** people live in a given area.

   d. Aluminium is less dense than iron. This means that a 1 kg block of aluminium is **BIGGER SMALLER** than a 1 kg block of iron.

   e. A hot air balloon rises because the hot air is **MORE LESS** dense than the surrounding air.

6. a. In the middle column of this table is a list of units that are used for measuring particular things. Read through the list and decide whether the unit can be used to measure mass and/or volume by ticking the appropriate place in each column. (1 mark for all units of mass identified; 1 mark for all units of volume identified)

Mass	Units	Volume
	cubic metres	
	kilograms	
	square metres	
	kilometres per hour	
	degrees	
	grams	
	millilitres	
	litres	
	tonnes	
	metres	
	cubic centimetres	

6. b. Name one set of units that is used for density (1 mark)

Density Results Data

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Density Pretest and Posttest Results Data

Teacher	Year Level	School Name

Student's Name	Pretest	Posttest

EPISODE 1

Diagnostic Pretest and Introductory Activity

Introductory Activity

Overview

This activity gives students the chance to explore the phenomenon of sinking and floating and the factors that influence it. This activity is designed to augment the Diagnostic Pretest and further explores students' prior knowledge on the topic. During this activity, try to resist any temptation to tell students current science and mathematical ideas. This opportunity comes later when the students are immersed in activities that will help them develop their ideas.

The primary aim of this activity is to discover how students are thinking about the concepts of mass and volume. The secondary aim is to find out whether students can think qualitatively about proportional relationships and to unearth possible student misconceptions about density. Lastly the activity will uncover students' ideas about density. The unit is written to introduce the concept of density but can be readily adapted to elaborate the understandings of students who have prior knowledge of the concept.

Purpose

Exploration of factors influencing sinking and floating of objects in water

Time

15 minutes

Materials

- ❑ Collection of four objects of the following criteria
  - ▪ a large object that floats (e.g., apple)
  - ▪ a large object that sinks (e.g., potato of similar size as apple)
  - ▪ a small object that floats (e.g., 2cm plastic cube)
  - ▪ a small object that sinks (e.g., pebble of similar size as cube)
- ❑ Collection of other objects that may sink or float.
- ❑ Plastic bucket (10 Litre) or transparent container of similar size (storage box)

Procedure

1. Orient students to the focus of the lesson by asking students to suggest three objects that sink and three objects that float in water.
2. Draw a table on the board and have students create a similar table in their books. Ask students to volunteer other objects that can be listed in the appropriate columns:

Sinking and Floating

Objects that sink in water	Objects that float in water

3. Pose the question: What makes objects sink or float in water? Note students' responses on the board, organising words, terms, phrases that particularly refer to either mass (heaviness), or volume (size) in one part of the board and putting other words, terms, phrases in another part (e.g., type of material, colour). Indicate that all these variables will be tested in this activity.

Introductory Activity (continued)

Procedure

4. Show students the collection of 4 objects (apple, potato, cube, and pebble), informing them that they will be testing these objects to see whether they sink or float. Draw students' attention to the shape of each object and the similarities and differences between them. Ask students to construct another table in their books

Object	*Prediction (sink or float)*	*Reason*	*Test Result*	*Explanation*
apple				
potato				
cube				
pebble				

5. Distribute a collection of 4 objects to each group of students (3-4 students per group) and a bucket (empty). Instruct students to take each (of the four) objects in turn and record their prediction of whether it will sink or float. Ensure students record a reason for their prediction.

6. When they have made all four predictions, allow the groups to add water to their bucket and test their objects, recording their results with explanations.

   This is probably the most critical part of the lesson. Encourage students to argue why you can't just make the general assumption that: "Lighter things tend to float." The important thing is the relationship between mass and volume in consideration of the property of floating/sinking. You want to know if they can think about both mass and volume at the same time. Identifying the nature of the proportionality is more important than working with quantifying mass and volume at the same time. This will be the focus of later activities in the Unit.

7. Provide students with other objects from the second collection and test whether they correctly predicted if the object would sink or float. Encourage exploration and discussion.

Concluding discussion

8. Bring the class back together at the end of the lesson and have the groups report on what they have found. Draw up a list of questions that have arisen that remain to be answered. Encourage students to use the terms mass and volume rather than describing how big and how heavy objects are.

9. Close with the idea that measuring the objects will allow much more confident predictions and a much more detailed understanding of sinking and floating.

Possible Variations

If time and equipment is an issue, this activity can be undertaken as a demonstration at the front of the class using a transparent container so that all students can see the result as different objects are tested.

EPISODE 2

Exploring Volume

Overview	In this episode students measure the dimensions of cylinders and rectangular-based prisms and find the volume of each object by making the appropriate calculations. The orienting activity in this episode uses a MAB 1000 cube (from the Maths Department) as a benchmark to help students estimate volumes of small objects.
Purpose	The lesson is designed to promote students' understanding of the standard formulae (V=LxWxH; V= area of base x H) for finding the volumes of rectangular-based prisms and cylinders respectively and to promote estimation of volume skills.
Time	35-40 minutes
Materials	❑ MAB 1000 cube (or similar object) ❑ Collection of rectangular-based prisms and cylinders (e.g., small cans of corn, small cans of tuna, beetroot cans; fat cylindrical candles, tea-light candles; blocks of cheese wrapped in foil; chunk of polystyrene; erasers, dowel, wood offcuts; etc). ❑ Rulers ❑ String ❑ Tape measures ❑ *Calculated Volumes* Worksheet (Appendix 2)
Procedure	**Orienting Activity (5 minutes)** 1. Show MAB 1000 cube to the class 2. Ask students to state the number of cubic centimetres in the 1000 cube. 3. Ask students the name of units for measuring volume (cubic cm or cm3). 4. State volume of MAB as 1000 cm3. 5. Select 2 or 3 objects from the collection of objects gathered for this lesson and ask students to estimate the volume of each. Record on the board. 6. Inform students of the focus of this lesson (calculating volume) so that they will be able to check the reasonableness of their estimates.
	Exploring Volume by measuring and calculation (15 minutes) 1. Provide each group of students with 4 rectangular-based prisms and 4 cylinders (see list above for suggestions), measuring tape, ruler, calculator. 2. Distribute Calculated Volumes data sheet (Appendix 2) to each student (also displayed as Table 1 below). 3. Students take each rectangular-based object in turn and estimate its volume (in cubic centimetres). Record estimate in the first column on the sheet. 4. Measure the length, width and height (e.g. 8.3 cm – cm to one decimal place) of each object and enter measures on the data table. 5. Remind students of the formula for volume of rectangular-based prisms. Students calculate the volume of each object using the calculator. 6. Repeat for all rectangular-based objects.

EPISODE 2

Exploring Volume (continued)

Procedure

Table 1 Calculated Volumes of Rectangular-Based Objects

Item	Estimation of volume (cm3)	Length (cm)	Width (cm)	Height (cm)	Volume LxWxH (cm3)
eraser					
tuna can					
cheese 1					
cheese 2					

7. Students take each circular-based object in turn and estimate its volume (in cubic centimetres). Record estimate in the first column of second table on Calculated Volumes sheet (displayed as Table 2 below).
8. Measure the diameter of base and enter diameter and radius on sheet.
9. Calculate area of base.
10. Measure height of object and enter on sheet.
11. Calculate the volume of each object.
12. Repeat for all circular-based objects.

Table 2 Calculated Volumes of Circular-Based Objects

Item	Estimation of volume (cm3)	Diameter and Radius of Base	Area of Base (cm) πr2	Height (cm)	Volume = Area of Base x Height (cm3)
corn	250	D= 6.7.. R= 3.4	36.3	8.5cm	309
beetroot		D= …….. R= ……..			
tomatoes		D= …….. R= ……..			
		D= …….. R= ……..			

Exploring Volume (continued)

Concluding discussion

Bring class together and ask each group to report on their data (briefly). Guide the discussion by directing students' attention to the data:

- Look at estimates and measured volumes. Were they close? Did your estimates become more accurate?
- Discuss why two different formulae were used to calculate the volumes of the two different types of 3D objects. How are they different? How are they similar?
- How useful are these two formulae for other shapes?

Teacher Demonstration of Volume by Displacement

As a finale to this lesson, you can draw students' attention to the fact that volume can also be found by displacement. Exploration of volume by displacement should have been an early experience that students had in primary school. If you have time, you can also provide students with opportunities to find volume by displacement. As a short closure to the lesson, you can demonstrate finding volume by displacement:

1. Select one of the objects that all students measured and calculated the volume.
2. Write a list of the measurements that students calculated and also discuss whether it is appropriate to average the measures on the board, or to conduct some more measuring.
3. Discuss how to find volume by displacement and whether the volume of liquid displaced should relate to the cubic volume calculated.
4. Conduct the experiment by placing the object in the water and measuring the result.
5. Compare to measures on the board.
6. Discuss the relationship between liquid and cubic volume and the metric system units:

$1\ cm^3 = 1g = 1\ mL$

(of water under normal circumstances)

The metric system is based on water as a measuring tool.

Volume Data Worksheet

Name	Class	Teacher	Year

Table 1 Calculated Volumes of Rectangular-Based Objects

Item	Estimation of volume (cm3)	Length (cm)	Width (cm)	Height (cm)	Volume LxWxH (cm3)
eraser					
tuna can					
cheese 1					
cheese 2					

Table 2 Calculated Volumes of Circular-Based Objects

Item	Estimation of volume (cm3)	Diameter and Radius of Base	Area of Base (cm) πr2	Height (cm)	Volume = Area of Base x Height (cm3)
corn	250	D= 6.7.. R= 3.4	36.3	8.5cm	309
beetroot		D= …….. R= ……..			
tomatoes		D= …….. R= ……..			
		D= …….. R= ……..			

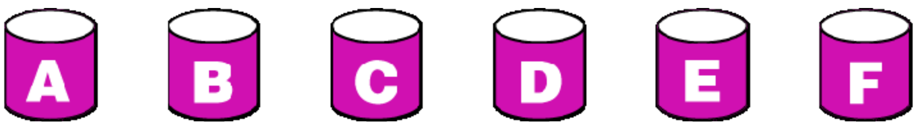
EPISODE 3

Exploring Density

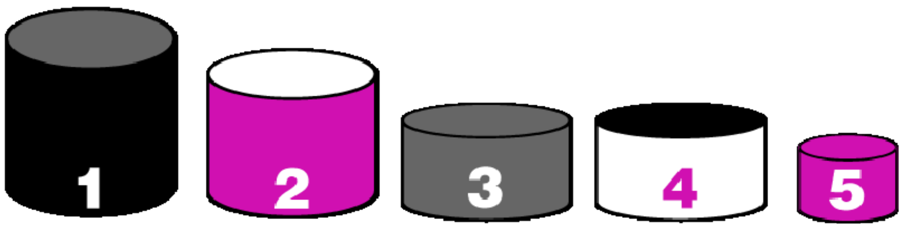
Overview	In this episode, students are provided with two sets of jars. The first set of jars has the same volume but each one has a different mass. The second set of jars all have the same mass but vary in volume. There are three tasks in this episode. The first task requires students to measure and calculate the mass and volume of the first set of jars. The second task is to do the same for the second set of jars. Time is required to discuss accuracy in measurement and to reach consensus on the measures of mass and calculations of volume. The third activity requires students to create a graph showing an object's mass and volume and to write the mass and volume of each jar as a ratio. Students also predict whether each jar will sink or float. The lesson concludes with each jar being tested in water.
Purpose	To draw students' attention to consideration of both the mass and volume of an object when predicting whether an object will sink or float in water. This lesson is designed so that students might discover the formula for density as mass divided by volume.
Time	35-40 minutes

Materials

- ❑ Set of 6 jars (labelled A-F) of same size



- ❑ Set of 5 jars (labelled 1-5) of different sizes but with same mass



- ❑ Weighing scales
- ❑ Tape measures
- ❑ Rulers
- ❑ Pen and paper
- ❑ Calculators
- ❑ *Sinking and Floating Worksheet*
- ❑ *OHT Sinking and Floating Data Table and Graph*
- ❑ Overhead projector (OHP)

EPISODE 3

Exploring Density (continued)

Procedure

Activity 1—Jars A-F Mass and Volume

1. Provide each group of students with the first set of jars (labelled A-F) and other equipment. Without using the weighing scales, students are to arrange the jars in order of heaviness by heft (lifting them and feeling how heavy they are). Write down the order. Reassure students that it is possible that members within their group will not agree on the order.
2. Using the weighing scales, students find the mass of each container and reorder the jars. Record the mass of each jar.
3. Using the tape measure and/or ruler, make the following measurements of one of the jars:

   Diameter of circle at base of jar:
   Radius of circle(diameter ÷2):
   Height of jar:
   Record each of these measurements on the *Sinking and Floating Worksheet.*
4. Calculate the volume of the jar and record it on the worksheet.
5. Bring the students back together to compare their results. Were all students' results the same? Why were there variations in measurement? How do we know how accurate we should be? What is the level of accuracy that can be tolerated in this activity?

Procedure

Activity 2—Jars 1-5 Mass and Volume

1. Provide each group of students with a set of jars labelled 1-5. Ask students to order the jars from greatest to least volume. Prior to this activity, ask students to consider whether they need to actually calculate the volume of each container to complete this task.
2. Ask students to arrange the jars in order of heaviness by heft (lifting them and feeling how heavy they are). Reassure them that it is possible that all group members will not agree on the order.
3. Ask students to estimate the mass of each jar and record this on the *Exploring Density* Worksheet. Ask students to measure the mass of each container using the weighing scales and to reorder the jars. Record the mass of each jar on the worksheet.
4. Ask students to determine the volume of each jar by taking appropriate measurements. Students are to record this information in the data table on the worksheet.
5. Bring students back together to compare their results. Were all students' results the same? Why were there variations in measurement? How do we know how accurate we should be? What is the level of accuracy that can be tolerated in this activity?

Exploring Density (continued)

Procedure

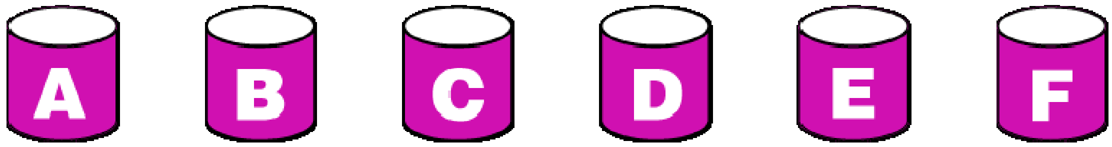
Activity 3— Sinking and Floating

1. Ask students to transfer the data they have collected from the first two activities onto Table 3 of the Exploring Density Worksheet. Complete table on OHT (Appendix 4)
2. Ask students to draw a graph of the relationship of the mass and volume of each shape. Use OHT to draw graph if students need instructions on how to begin.
3. Bring students back together and discuss their graphs. Do they look similar? Should they? What is the graph showing? Complete the graph on the OHT. Label the position of each jar on the graph.
4. Inform students that a demonstration will be performed to determine whether each jar sinks or floats. Ensure that all students have made and recorded their prediction in the table.
5. One at a time, place each jar in the water. Discuss the result. Prior to placing each jar in the water, draw students' attention to the mass and volume of each jar. Ask them to particularly focus on the ratio representation. Draw attention to the location of each jar on the graph. Ask what they notice about the result of each test and the data on the graph.
6. Ask students to write a statement about how they can predict whether something might sink or float in water. If the word density arises, ask students to elaborate.

Sinking & Floating Worksheet

Name	Class	Teacher	Year

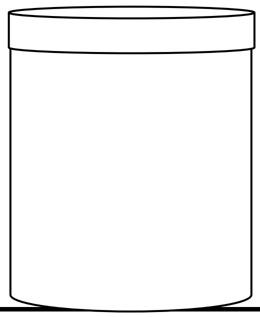
Activity 1—Jars A-F Mass and Volume



1. Estimate the mass of each jar and record your estimate in the table below.
2. Measure the mass of each jar. Record your results in the table below.

Jar: least to greatest mass						
Estimate of mass						
Actual mass						

3. Select one of the jars, make the appropriate measurements and calculations and enter this information on the diagram below.



Diameter of base: ____________________

Radius of Base ____________________

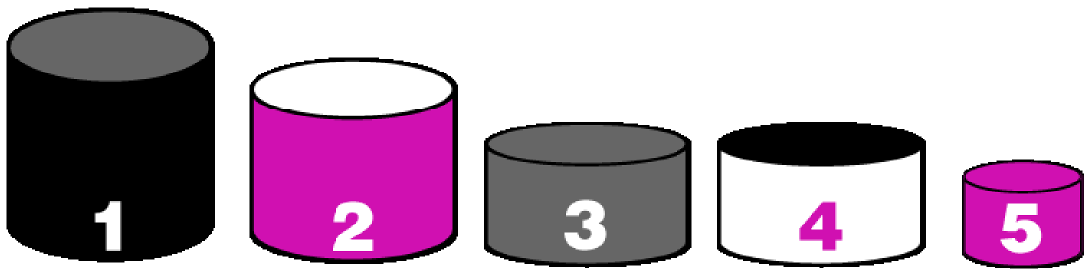
Area of Base: ____________________

Height: ____________________

Volume of jar: ____________________

(area of base x height)

Activity 2— Mass and Volume of Jars 1-5



Item	Estimation of **mass** (g)	Actual **mass** (g)	Estimation of **volume** (cm3)	**Calculating Volume**			
				Diameter and Radius of Base	Area of Base (cm) πr^2	Height (cm)	Volume = Area of Base x Height (cm^3)
1							
2							
3							
4							
5							

Sinking & Floating Worksheet

Activity 3— Sinking and Floating

Jar	Mass (g)	Volume (mL)	Ratio Mass:Volume	Sink (S) or Float (F)?	
				Prediction	Outcome
A					
B					
C					
D					
E					
F					
1					
2					
3					
4					
5					

Draw a graph to show the relationship between the mass of each jar and its volume. Put mass on the X axis and volume on the Y axis.

How can you predict if something will sink or float in water? Refer to examples in the table and your graph to support your statement.

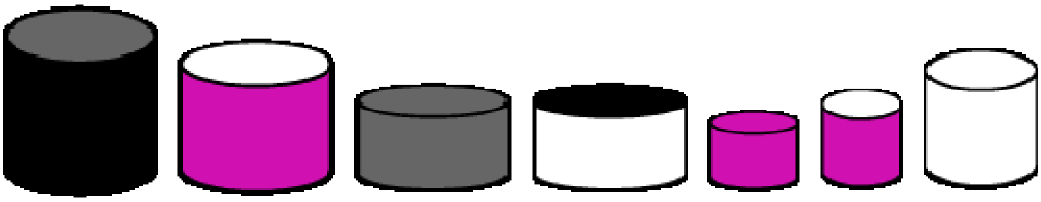
EPISODE 4

Exploring Density Formula

Overview	In this episode, students are provided with a range of objects that are measured for mass and volume. They are directed to predict whether an object will sink or float as they analyse the relationship between the mass and volume. The worksheet provides further consideration of density.
Purpose	To further develop the concept of density as the relationship between an object's mass and volume.
Time	35-40 minutes

Materials

- ❑ Set of 6-8 cans of household products of various volumes and masses (e.g, tinned pineapple, corn, mushrooms, etc).



- ❑ Weighing scales
- ❑ Tape measure
- ❑ Ruler
- ❑ Cloth for wiping up spills
- ❑ Pen and paper
- ❑ Calculators
- ❑ Water bath
- ❑ Tea towel for wiping jars
- ❑ Large measuring jug marked in mL
- ❑ OHT Sinking and Floating data table and graph
- ❑ *Exploring Density* Worksheet

Procedure

1. Revise findings from previous lesson. Select some students to share their ideas about predicting whether objects will sink or float. Using OHT, select specific examples from the data table for the previous lesson's activity.
2. Draw students' attention to the ratio column of the data table. If it has not come up in discussion previously, draw students' attention to the comparison of the mass and the volume and whether an object sinks or floats. Taking specific examples from the graph, write the ratio of the mass to the volume as a fraction (select examples where the mass is greater than the volume) and ask students to predict what the actual ratio will be in simplest form (e.g., simplifying fractions). Also, reinforce that a fraction is also a symbolic way of expressing division.
3. Take each jar one at a time and have a student volunteer to come to the front to take the appropriate measurements to determine its volume. All students should record the details on their worksheet (Exploring Density - Appendix 5). Have another student weigh each item. All students now determine the density of each object using a calculator.
4. Ask students to record whether they think each jar will sink or float.
5. Draw students' attention to the remaining tasks on the worksheet. Ask them to continue working through the activities on the worksheet. Periodically review particular tasks to focus students' attention

Exploring Density Formula (continued)

Procedure

Concluding discussion

6. Check the answers on the worksheet.
7. Draw students' attention to the table at the top of the worksheet where they had to determine the density of each of the jars in the set and predict whether they would sink or float.
8. Ask students how to calculate density. Ask students which jar has the greatest density and how they know.
9. Place each jar in turn, in the water, to test their predictions.
10. Make the Coke dunking a bit of a finale to the lesson. Delay placing each one in the water. Also, provide plenty of time for students to consider the volume and mass of each of the cans so that they are certain of their density. Check that all students have similar results. Place the cans, one at a time, in the water and stand back and see the results. Ask students to explain the outcome.
11. As a concluding comment, remind students that all these objects were tested for sinking and floating in water. Ask them to consider what might happen if they were placed in some other liquid (such as salty water, oil, cordial, muddy water, soy sauce).

OHT Sinking & Floating Data Table & Graph

Jar	Mass (g)	Volume (mL)	Ratio Mass:Volume	Sink (S) or Float (F)?	
				Prediction	Outcome
A					
B					
C					
D					
E					
F					
1					
2					
3					
4					
5					

Draw a graph to show the relationship between the mass of each jar and its volume. Put mass on the X axis and volume on the Y axis.

How can you predict if something will sink or float in water? Refer to examples in the table and your graph to support your statement.

Exploring Density Worksheet

Name	Class	Teacher	Year

Density is the relationship between the mass and volume of the object. Density means considering both mass and volume at the same time. Density is calculated by finding the ratio of the mass to its volume.

1. Record the mass and volume of the objects shown in class. Calculate the density of each object and predict whether it will sink or float in water.

Density of objects

Object	Mass (g)	Volume (mL)	Ratio m/V	Density m÷V	Sink (S) or Float (F)? Prediction	Sink (S) or Float (F)? Outcome	Explanation

2. Jar X weighs 500g and has a volume of 400cm3. It sinks in water.
   Jar Y weighs 600 g and has a volume of 700 cm3. It floats on water.
   For each of the following jars, say whether they will sink or float in water and why you think so.

Jar	Mass (g)	Volume cm^3	Sink	Float	Explanation
a.	500	300	❑	❑	
b.	500	750	❑	❑	
c.	250	200	❑	❑	
e.	1500	1800	❑	❑	
f.	900	1200	❑	❑	

Exploring Density Worksheet

3. A model ship weighs 3000 g. If it is to float, what can you say about its total volume?

4. I got a plastic submarine out of my cereal packet this morning. Sometimes it floats and sometimes it sinks. Its total volume is 5cm^3.

a. What must its mass be to make it sink?

b. What must its mass be if it is to float?

5. Feathers and bricks …

a. What size will the bag of feathers be that would weigh the same as a brick? Explain.

b. What must its mass be if it is to float?

c. Will a kilogram of feathers have the same density as a kilogram of feathers? Explain.

d. Which has the greater density, a brick made out of clay or a brick the same size made out of foam? Explain.

EPISODE 5

Formula Consolidation

Overview	In this episode, students work through exercises on density, applying the formula to calculate density, to rearrange the density formula to find volume and mass respectively, and consolidate division estimation and mental computation skills.
Purpose	To consolidate the density formula and to promote number sense in division calculations.
Time	45 minutes
Materials	❑ Density Formula Calculations Sheets
Procedure	This lesson is a skill development lesson. The Density Formula Calculations sheet is the basis for practising density calculations. Teachers are encouraged to design this lesson in any way they feel will support students' understanding.
Concluding discussion	Closure for this lesson will most likely be in relation to checking calculations. Using a quiz can also serve to close this lesson and recap on the procedures practised. Ensure that mental computation and estimation is reinforced in all activities.
Possible Variations	There are numerous online quizzes and activities on the internet. Some of these quizzes are self-correcting with students being asked questions and then given feedback on their responses. Some websites are listed here: Density word problems An on-line quiz http://algebralab.net/practice/practice.aspx?file=Word_Density.xml Don't let it weight you down Ballooning calculations http://quest.nasa.gov/aero/planetary/teachers/weigh.html

Density Calculation Worksheets

Density Calculations

Density is a comparison of the mass of an object compared to its volume. When you think about the density of an object, you need to consider its heaviness in relation to its size. Because of the relationship between the mass and volume, density is a ratio:

Density = mass compared to volume

Density = mass : volume

This relationship is expressed as a formula:

$$\rho = \frac{m}{V}$$

units of g/cm^3 (or g/mL) or kg/m^3

1. What is the density of a sample if its mass 44 g and its volume is 22 cm^3?
   - (a) 2 g/cm^3
   - (b) 88 g/cm^3
   - (c) 968 g/cm^3
   - (d) 0.5 g/cm^3

2. What is the density of a substance that has a mass of 54 g and a volume of 3 cm^3?
   - (a) 18 g/cm^3
   - (b) 18 g/cm^3
   - (c) 1.8 g/cm^3
   - (d) .055 g/cm^3

3. If a sample has a volume of 5 cm^3 and a mass of 95 g, its density would be:
   - (a) 19 g/cm^3
   - (b) 190 g/cm^3
   - (c) 1.9 g/cm^3
   - (d) .053 g/cm^3

4. If a sample has a volume of 30 cm^3 and a mass of 220 g, its density would be:
   - (a) 7.31 g/cm^3
   - (b) 73.1 g/cm^3
   - (c) 73.3 g/cm^3
   - (d) 7.33 g/cm^3

5. If a sample has a mass 760 g and a volume of 4 cm^3, its density would be:
   - (a) 19.0 g/cm^3
   - (b) 190 g/cm^3
   - (c) 0.005 g/cm^3
   - (d) 120 g/cm^3

6. If a sample has a mass of 56 g and volume of 5 cm^3, its density would be:
   - (a) 12 g/cm^3
   - (b) 11.2 g/cm^3
   - (c) 112 g/cm^3
   - (d) .09 g/cm^3

7. If a material has a mass of 77.2 g and a volume of 11 cm^3, its density would be:
   - (a) 0.142 g/cm^3
   - (b) 7 g/cm^3
   - (c) 70 g/cm^3
   - (d) .7 g/cm^3

8. A piece of metal has a mass of 32 g and a volume of 25 cm^3. Its density would be:
   - (a) greater than one
   - (b) less than one
   - (c) approximately equal to one

9. A sample has a mass of 20 g and a volume of 30 cm^3. Its density would be:
   - (a) 1.5 g/cm^3
   - (b) 15 g/cm^3
   - (c) 0.66 g/cm^3
   - (d) 0.15 g/cm^3

10. What is the density of a material when the mass is 20 g and the volume is 10 cm3?
    - (a) 2 g/cm^3
    - (b) 0.2 g/cm^3
    - (c) 200 g/cm^3
    - (d) 0.5 g/cm^3

Density Calculation Worksheets

11. Complete the following table by **mentally** calculating the density of each of the following. Make sure that you include the correct units for each density calculation:

	Mass	Volume	Density
(a)	11.5 g	5 cm^3	
(b)	68 g	4 cm^3	
(c)	84 kg	6 m^3	
(d)	125 g	5 cm^3	
(e)	1080 kg	60 m^3	
(f)	570 kg	3 m^3	
(g)	6.4 g	4 cm^3	
(h)	64 g	40 cm^3	
(i)	5600 g	7 cm^3	

12. (a) Using a **calculator**, calculate the density of the following substances

Substance	Mass	Volume	Density
gold	123.4 g	6.39 cm^3	
silver	45.3 g	4.3 cm^3	
titanium	54.6 g	12.1 cm^3	
magnesium	44.3 g	26 cm^3	
iron	79.5 g	10.1 cm^3	
nickel	23.4 g	2.6 cm^3	
copper	55.4 g	6.2 cm^3	
zinc	65.4 g	9.2 cm^3	
chromium	78.9 g	10.9 cm^3	
aluminium	20.5 g	7.6 cm^3	
barium	65.4 g	18.2 cm^3	
mercury	97.4 g	7.2 cm^3	
lead	123.5 g	10.9 cm^3	
bromine	2.3 g	0.8 cm^3	
platinum	132.4 g	6.1 cm^3	

12. (b) Using the blank table below, reorder the table showing substances, from the table above, from greatest to least density. In the third column of the table, list any properties that you know about that substance.

Substance	Density	Properties

Density Calculation Worksheets

Exploring the Density Formula

The Density Formula can be rearranged in order to calculate either the mass or the volume if you know the density of a substance.
This gives three formulae using the relationship between density, mass and volume:

$$D = \frac{m}{V}$$

$$m = D \times V$$

$$V = \frac{m}{D}$$

Use these different formulae as required to complete the following calculations. Use a **calculator**.

1. What is the density of a *Substance A* that has a mass of 52.459 g and a volume of 64.5 cm^3?
2. A student finds a *rock* on the way to school. In the laboratory he determines that the volume of the rock is 22.7 $cm^{3,}$ and the mass is 19.943 g. What is the density of the rock?
3. If 30.943 g of *Liquid A* occupies a space of 35 mL, what is the density of the liquid in g/cm^3?
4. The density of *silver* is 10.49 g/cm^3. If a sample of pure silver has a volume of 12.993 cm^3, what would be the mass?
5. How many grams of *tin* would occupy 5.5 L, if it has a density of 7.31 g/cm^3?
6. What is the mass of a 350 cm^3 sample of pure *silicon* with a density of 2.33 g/cm^3?
7. Pure *gold* has a density of 19.3 g/cm^3. How large would a piece of gold be if it had a mass of 318.97 g?
8. How many cm^3 would a 55.932 g sample of *copper* occupy if it has a density of 8.96 g/cm^3?
9. The density of *lead* is 11.342 g/cm^3. What would be the volume of a 200.0 g sample of this metal?
10. The mass of a *toy soldier* is 1.5 grams, and its volume is 3.2 mL. What is the density of the toy soldier?
11. A *mechanical dog* has the density of 3 grams per cubic centimetre. The volume of the mechanical dog is 15.8 cubic centimetres. What is its mass?
12. A *plastic hammer* has the density of 1.5 grams per cubic centimetre. It also has the mass of 550.3 grams. What is the hammer's volume?
13. The volume of a *wooden block* is 63 cm^3. Its mass is 11.392 g. Find its density.
14. The density of *copper* is 4.44 $g/cm.^3$ If the mass of a piece of copper is 26.326 g, what is its the volume.
15. *Sodium* has a density of 0.97 $g/cm.^3$ If the volume of some sodium is 9.0 cm^3, what is its mass?
16. If a piece of *marble* has the mass of 132.796 g and the volume of 26.9 cm^3, what is its density?
17. Calculate the density of the *brass block* that has the volume of 36.2 and the mass of 121.233g.
18. The density of *nickel* is 8.9 g/cm^3. A piece of nickel has the volume of 18.721 cm^3, what is its mass?

Density Calculation Worksheets

Density of some common substances
The following table gives the density of some common substances

Substance	**Density**
water	1 g/cm³
alcohol	0.79 g/cm³
gasoline	0.68 g/cm³
corn oil	0.93 g/cm³
corn syrup	1.38 g/cm³
glycerine	1.26 g/cm³
air	1.22 kg/cm³

Using the information in the table above, and your calculations from the previous exercises, list substances in the appropriate columns in the table below:

Floats in water	Floats in corn syrup	Floats in air

EPISODE 6

Ballooning

Overview	This activity is an assessment task that students undertake individually. The students are provided with a worksheet on which there is a classroom scenario of a science lesson. In the scenario, students are making flying balloon crafts. They are testing whether they float in air or not. They measure the volume and mass of their crafts and this data is recorded on the board for all students to see. The teacher makes a craft and records the mass and volume of her balloon craft. The students must determine whether the teacher's balloon will fly or not. There are two versions of this task. Version A provides the scenario and the data table. Students are required to determine whether the teacher's balloon will fly or not and explain their thinking. They are provided with graph paper as the task suggests that they might like to draw a graph of the data to help them determine whether the teacher's balloon will fly. They are also provided with some pre-drawn blank tables to make rearranging the data table simpler if they would like to use this strategy. Version B of the task provides the students with four responses from students within the grade. The task for the students is to analyse each student's response and to comment on its appropriateness. Both versions of the task will yield rich data on students' thinking and reasoning. Version A will provide a direct measure of students' thinking about density and working with data. Version B will provide insight into students' thinking about possible strategies that could be applied and their evaluation of other students' strategies. In Version A, students are not provided with direct instructions on how to go about analysing the data, although the graph paper and pre-drawn data tables are there to prompt some action by the students. Version B provides a direct focus for students' attention. It is up to the teacher to decide which task is more suitable for use with the class.
Purpose	An individual assessment task that relates to core learning outcomes in mathematics and science, including understanding of density, analysing data, interpreting graphs, calculating.
Time	45 minutes
Materials	❑ Ballooning worksheets (Appendix 7), ❑ calculators
Procedure	1. Determine which version of the ballooning task you will use with your students and make sufficient copies for one per student. 2. Explain to students that this is an assessment task and that test conditions are to be adhered to. 3. Provide guidance to students as per usual test administration. Refer students to particular parts of the worksheet that provide explanatory information (e.g., suggest that they rearrange the data, or draw a graph). 4. Assess using the scoring rubric developed for this task.

Ballooning Worksheet (version 1)

Name	Class	Teacher	Year

In Science class, the students were exploring flight using balloons.

Each pair of students filled their balloon with a different amount of hydrogen gas and tied a wooden block to the end. They then tested to see if their balloon floated in the air. The teacher also created a balloon craft of her own.

After watching the balloons float in the air (or stay on the floor), the students measured the mass and volume of their balloon craft. The students wrote their results on a class data table that showed the mass and volume of each balloon, and whether the balloon floated or not (below). The teacher also included the mass and volume of her balloon.

Pair	***mass (g)***	***volume (L)***	***flight (yes/no)***
Teacher	2.7	2.4	?
A	0.8	1.1	yes
B	1.9	0.9	no
C	2.9	1.5	no
D	0.6	1.6	yes
E	1.6	2.4	yes
F	1.7	1.3	no
G	1.8	1.2	no
H	0.8	0.9	yes
I	2.1	1.7	yes
J	2.3	3.1	yes
K	1.1	0.9	yes
L	0.9	0.9	yes
M	2.6	1.3	no

The teacher then asked the class: “Using the information in the table, see if you can predict whether my balloon will float or not

YOUR TASK:

Using the information in the table, state your prediction about the teacher’s balloon craft. Use the information in the table to explain your response. Feel free to create a new table or tables to present the data differently, or to use a graph to explore the data further and to fully justify your response (you can use the blank tables and grid paper attached to assist if required).

Ballooning Worksheet (version 1)

BLANK TABLES

Ballooning Worksheet (version 1)

Ballooning Worksheet (version 2)

Name	Class	Teacher	Year

In Science class, the students were exploring flight using balloons.

Each pair of students filled their balloon with a different amount of hydrogen gas and tied a wooden block to the end. They then tested to see if their balloon floated in the air. The teacher also created a balloon craft of her own.

After watching the balloons float in the air (or stay on the floor), the students measured the mass and volume of their balloon craft.

The students put their results on a class data table that showed the mass and volume of each balloon, and whether the balloon floated or not (below). The teacher also included the mass and volume of her balloon.

Pair	*mass (g)*	*volume (L)*	*flight (yes/no)*
Teacher	2.7	2.4	?
A	0.8	1.1	yes
B	1.9	0.9	no
C	2.9	1.5	no
D	0.6	1.6	yes
E	1.6	2.4	yes
F	1.7	1.3	no
G	1.8	1.2	no
H	0.8	0.9	yes
I	2.1	1.7	yes
J	2.3	3.1	yes
K	1.1	0.9	yes
L	0.9	0.9	yes
M	2.6	1.3	no

The teacher then asked the class: “Using the information in the table, see if you can predict whether my balloon will float or not

YOUR TASK:

Read each of the four responses and decide who has presented the best reason for why the teacher’s balloon would float or not. Use the coding scheme to indicate your assessment of each of the students’ responses.

Ballooning Worksheet (version 2)

Lenny & Josh
The teacher's balloon is closest in weight to pair M. It is a bit heavier which makes it less likely to fly, but it is a bit bigger too which makes it more likely to fly. But since the M balloon didn't fly, the teacher's balloon probably won't fly either.

1. My comments on this response:

2. My evaluation of this response:

a.	This is a good response	❑ Yes	❑ No	❑ Not sure
b.	This response shows good analysis of the information in the data table:	❑ Yes	❑ No	❑ Not sure
c.	This response makes a lot of sense to me:	❑ Yes	❑ No	❑ Not sure
d.	Lenny & Josh's response is how I would answer the teacher's question:	❑ Yes	❑ No	❑ Not sure

3. My thoughts on this response:

a.	This response is logical:	❑ Yes	❑ No	❑ Not sure
b.	This response is correct:	❑ Yes	❑ No	❑ Not sure

Ballooning Worksheet (version 2)

Lyn & Fred
We think that balloons that are too heavy won't be able to fly. So, we reorganised the table to show mass from lightest to heaviest. Now we can see from the table that balloons weighing more than 1.7 g don't fly, except for two balloons that weigh more than 2.1 g, but we think that these two groups had funny shaped balloons. In general the light balloons fly but the heavy ones don't so we don't think the teacher's balloon will fly."

Pair	*mass (g)*	*volume (L)*	*flight (yes/no)*
D	0.6	1.6	yes
H	0.8	0.9	yes
A	0.8	1.1	yes
L	0.9	0.9	yes
K	1.1	1.0	yes
E	1.6	2.4	yes
F	1.7	1.3	no
G	1.8	1.2	no
B	1.9	0.9	no
I	2.1	1.7	yes
J	2.3	3.1	yes
M	2.6	1.3	no
C	2.9	1.5	no

1. My comments on this response:

2. My evaluation of this response:

e. This is a good response ❑ Yes ❑ No ❑ Not sure

f. This response shows good analysis of the information in the data table: ❑ Yes ❑ No ❑ Not sure

g. This response makes a lot of sense to me: ❑ Yes ❑ No ❑ Not sure

h. Lyn& Fred's response is how I would answer the teacher's question: ❑ Yes ❑ No ❑ Not sure

3. My thoughts on this response:

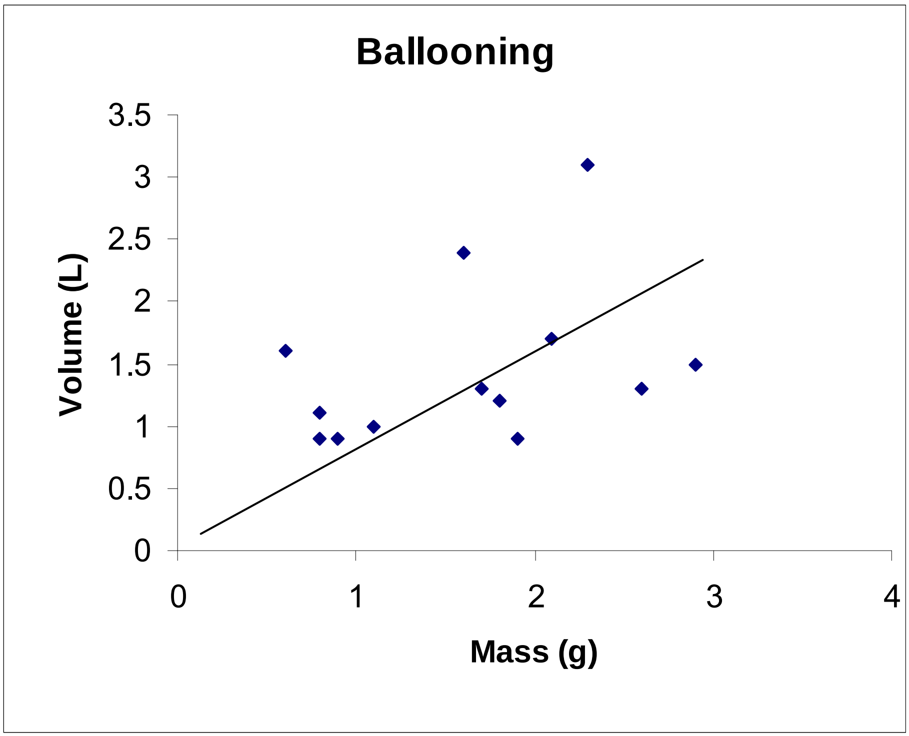
c. This response is logical: ❑ Yes ❑ No ❑ Not sure

d. This response is correct: ❑ Yes ❑ No ❑ Not sure

Ballooning Worksheet (version 2)

Mel & Britt

We decided to draw a graph as there were two values (mass and volume) and plot each balloon on the graph. We then decided to draw a line between those that did fly and those that didn't. Plotting the teacher's point shows that her balloon should fly.



1. ***My comments on this response:***

2. ***My evaluation of this response:***

i.	This is a good response	❑ Yes	❑ No	❑ Not sure
j.	This response shows good analysis of the information in the data table:	❑ Yes	❑ No	❑ Not sure
k.	This response makes a lot of sense to me:	❑ Yes	❑ No	❑ Not sure
l.	Mel & Britt's response is how I would answer the teacher's question:	❑ Yes	❑ No	❑ Not sure

3. ***My thoughts on this response:***

e.	This response is logical:	❑ Yes	❑ No	❑ Not sure
f.	This response is correct:	❑ Yes	❑ No	❑ Not sure

Ballooning Worksheet (version 2)

Jill & Sam
We first looked at the balloons that did fly and those that didn't. At first we thought it was to do with the mass of the balloon, but J's has a rather large mass and a large volume, and it did fly. Balloon E also has a large volume and it could fly too. So then we decided that it must have something to do with the relationship between the mass and volume. We then calculated the ratio of the mass to the volume and reordered the table with the ratio in ascending order. The results show that the balloons with a ratio greater than 1.2 don't fly. Since the teacher's balloon has a ratio of 1.2 it should fly because Balloon I also has a ratio of 1.2 and it could fly.

Pair	mass (g)	volume (L)	Ratio (g/L)	flight (yes/no)
D	0.6	1.6	0.4	yes
E	1.6	2.4	0.7	yes
A	0.8	1.1	0.7	yes
J	2.3	3.1	0.7	yes
H	0.8	0.9	0.9	yes
L	0.9	0.9	1.0	yes
K	1.1	1.0	1.1	yes
I	2.1	1.7	1.2	yes
F	1.7	1.3	1.3	no
G	1.8	1.2	1.5	no
C	2.9	1.5	1.9	no
M	2.6	1.3	2.0	no
B	1.9	0.9	2.1	no
Teacher	**2.7**	**2.4**	**1.2**	**should**

1. My comments on this response:

2. My evaluation of this response:

m. This is a good response ❑ Yes ❑ No ❑ Not sure

n. This response shows good analysis of the information in the data table: ❑ Yes ❑ No ❑ Not sure

o. This response makes a lot of sense to me: ❑ Yes ❑ No ❑ Not sure

p. Jill & Sam's response is how I would answer the teacher's question: ❑ Yes ❑ No ❑ Not sure

3. My thoughts on this response:

g. This response is logical: ❑ Yes ❑ No ❑ Not sure

h. This response is correct: ❑ Yes ❑ No ❑ Not sure

Ballooning Worksheet (version 2)

Tell us more

a) Order the best responses from the students:

Number One (Best) Response: ______________________

Number Two Response: ______________________

Number Three Response: ______________________

Number Four (Worst) Response: ______________________

b) Explain the criteria you used for your ranking.

EPISODE 7

Eggsperiments

Overview

Purpose

Time

Materials

Egg Floating Experiment 1

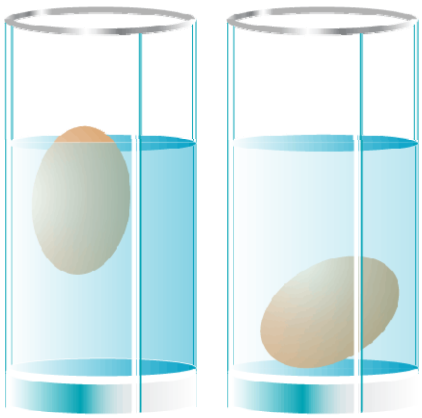
- ❑ Two glasses
- ❑ Salt
- ❑ Two eggs
- ❑ Water

Procedure

1. Mix plenty of salt (about 10 heaped teaspoons) into half a glass of water.
2. Fill half of the second glass with fresh water (no salt added to this glass).
3. Try floating an egg in each glass.

Concluding discussion

You will find that egg will float in the salt water but not in fresh water. This is because egg is less dense than salt water but more dense than fresh water. Since salt water is more dense than fresh water, it is also easier to float in the sea.



Salt water   Fresh water

Eggsperiments (continued)

Overview

Purpose

Time

Materials

Egg Floating Experiment 2

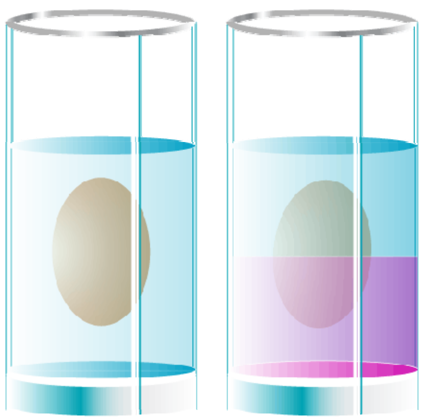
- ❑ Two glasses
- ❑ Salt
- ❑ One eggs
- ❑ Water

Procedure

1. Fill one glass half full of fresh water.
2. Fill one glass half full of very salty water (such as from the original Egg floating experiment).
3. Very carefully pour the fresh water into the salt water. Try not to let the liquids mix.
4. Gently lower the egg into the water that is half salt water and half fresh water.

Concluding discussion

The egg should float on salt water and sink in fresh water. The result looks like the egg is suspended in the middle of the glass. This is sometimes used in Magic Shows for children.



Without dye With dye

Repeat this experiment, but add food dye to the salty water so that the layering of the water can be seen more clearly.

Eggsperiments (continued)

Overview	
Purpose	Place a hard boiled egg in water. Does it sink or float? Conduct an experiment to find out if you can tell if an egg is raw or boiled by the way it floats or sinks in salty water.
Time	
Materials	**Egg Floating Experiment 3** ❑ 3-4 clear plastic cups ❑ 2 raw eggs ❑ 2 hard boiled eggs ❑ Measuring teaspoon ❑ Spatula (or plastic knife) ❑ Salt ❑ 1x 1000 cm^3 measuring cylinder
Procedure	**Task** Experiment with mixtures of salt and water to see if there is a difference between raw eggs and boiled eggs in terms of floating or sinking. Test your hypothesis by trying to make a mixture of salt that allows the raw egg to sink and the boiled egg to float. It might help to mark each egg with a waterproof marker so that you can distinguish between each egg.
	Controlling variables To test your predictions and hypotheses more precisely, try to make your measurements as accurately as possible: ▪ Measure the amount of water placed in the cup ▪ Make sure that every cup of water that you experiment with contains the same amount of water ▪ Measure the salt very precisely every time

Eggsperiments (continued)

Procedure **Recording results**

Record the amount of salt that you put into the water and note whether the egg sinks or floats

Amount of water	Amount of salt	Sink (S) or Float (F)?			
		Egg 1	Egg 2	Egg 3	Egg 4
100 mL	*1 teaspoon*				

Procedure **Some other things to try**

Find the density of each of the eggs:

Egg	Mass	Volume	Density (m ÷ v)
1			
2			
3			
4			

Procedure **Finding the volume of each egg by displacement**

1. Fill the measuring cylinder to a level that will enable the egg to be covered by water.
2. Note the level of the water in the cylinder without the egg.
3. Place the egg into the water and watch the water level rise.
4. Note the new water level.
5. Subtract the original water level from the new water level and you have the volume of the egg.

$$1\ cm^3 = 1\ g = 1\ mL$$

(water under normal circumstances)
The metric system is based on water as a measuring tool (especially temperature).

EPISODE 7

Egg Floating Experiment – Teacher Demonstration

Overview

Purpose Place a hard boiled egg in water. Does it sink or float?

Time

Materials

- ❑ 2 raw eggs
- ❑ 2 hard boiled eggs
- ❑ 4 plastic cups with different salt solutions *

(*you need to ensure that two of your salt solutions enable (a) both types of eggs sink; and (b) the raw eggs to sink and the boiled eggs to float. This depends upon the size of the eggs. For a 50 g egg, a solution of 80 g salt per litre of water generally enables the distinction to be seen).

The following solutions should work for a 50 g egg.

Cup	**Water**	**Salt**	**Bulk mixture**
1	100 mL	10 g	Stir 100 g salt in 1 L water
2	100 mL	8 g	Stir 80 g salt in 1 L water
3	100 mL	5g	Stir 50 g salt in 1 L water
4	100 mL	0 g	No salt in the water

Draw up the following table and record whether each egg sinks or floats as it is placed in each of the salt solutions

Salt Concentration	Egg 1	Egg 2	Egg 3	Egg 4
10 / 100 mL				
8 / 100 mL				
5 / 100 mL				
0 / 100 mL				

Eggsperiments Worksheet

Name	Class	Teacher	Year

Amount of water	Amount of salt	Sink (S) or Float (F)? Egg 1	Egg 2	Egg 3	Egg 4
100 mL	*1 teaspoon*				

Salt Concentration	Sink (S) or Float (F)? Egg 1	Egg 2	Egg 3	Egg 4
10 / 100 mL				
8 / 100 mL				
5 / 100 mL				
0 / 100 mL				

1. What salt concentration is required to tell if an egg is boiled or raw?

2. Why do boiled eggs float and raw eggs sink at this salt concentration?

3. How much salt would need to be added to 1 L of water to make boiled eggs float?

Eggsperiments Worksheet

4. The following amounts of salt need to be mixed to the given amount of water to make the boiled egg float:
   a. 500 mL water requires _____ g of salt to make a boiled egg float.

   b. 1.5 L of water requires _____ g of salt to make a boiled egg float

   c. 200 mL of water requires _____ g of salt to make a boiled egg float

   d. 850 mL of water requires _____ g of salt to make a boiled egg float

5. In which of the following salt mixtures will a boiled egg be most likely to float?
   a. 200 mL of water and 2g salt _____

   b. 400 mL of water and 5 g salt _____

   c. 1.2 L of water and 100 g salt _____

   d. 1 L of water and 90 g of salt _____

EPISODE 7

Eggsperiments (continued)

Overview	Egg Sorting Challenge: An investigative task for density
Purpose	Students are given four eggs, two fresh and two hard boiled. They must write a recipe for a salt solution that will allow the two different types of egg to be distinguished. Once they have completed the challenge, their recipe is tested to check its utility.
Teachers notes	This is an open investigation that is framed as a technology challenge – to design a test that will distinguish raw from hard-boiled eggs. The test is to use density as the distinguishing criterion. The challenge requires students to develop a recipe for the test that is based on careful measurement and a scientific explanation for the way the test works. Distinguishing the two types of egg requires quite precise measurements and hence requires a mathematical approach.

Materials

Egg Sorting Challenge (per group)

- ❑ 3-4 clear (plastic) tumblers or beakers
- ❑ 1 x 100 cm^3 measuring cylinder or large plastic syringe (60 or 80 mL)
- ❑ 1 x plastic desert spoon
- ❑ 2 x fresh eggs
- ❑ 2 x hard boiled eggs
- ❑ 1000 cm^3 of stock salt solution (density 1.13 g/cm3)

Procedure

Pre-experiment Preparation

Unless students are going to be required to make their own stock solution, the solution should be made up by adding 200 g of salt to 900 cm^3 of water and then making up the solution to 1000 cm3. Multiples can be made up as required.

Task and report

Students should work in groups of 2-3

The challenge is to apply knowledge of density to design a test to distinguish fresh from hard boiled eggs. Students are given two fresh and two hard-boiled eggs so that they can develop your test

The report must contain:

- An introduction explaining how the test works (in terms of density).
- A description of the test design including the recipe for making the test solution.
- A description of the experimental results you have obtained including a table of your results. Your table should include the concentrations and/or densities of the solutions you have made up. You should outline the method for you calculations.
- A statement that outlines the confidence you have that your test will work and reasons why it might not work.

Task test	When all groups have designed their test, the recipes will each be tested by a different group.
Adaptations for differing Year levels	The investigation has been designed using a minimal amount of equipment and is appropriate for primary schools. Suggestions are included to allow more sophisticated measurement if equipment is available and for use of the challenge in secondary classes.
Grades 4-6:	The task can be simplified for students by varying the degrees of openness. The following suggestions outline a variety of degrees of openness of the task: ▪ Provide students with a set of solutions with which to test the eggs. They then have to select the solution that best distinguishes the types of egg. Their report would describe their results. Their explanation would state that boiled eggs have less mass than the fresh eggs because the volumes of the eggs would not change significantly due to boiling. The difference is due to density as the boiled eggs are less dense than fresh eggs. ▪ Provide students with a stock solution. Then take them through the process of diluting the stock solution to halve the concentration of salt – to 50 g/100 cm3. They would pour 50 cm^3 of the stock solution into a measuring cylinder and make up the volume to 100 cm3. Allow the students to test their eggs in the two resulting solutions so that they can see that the two extremes of behaviour (both eggs float in the stock solution and sink in the dilute solution. Suggest a series of solution for students to make and test and discover the concentration which best separates the fresh from boiled eggs (55, 60, 65, 70, 75, 80, 85, 90 and 95 g/100 cm3). ▪ Provide students with the stock solution and the dilution method and allow them to experiment with their own dilutions to find the best test solution.
Grades 7-9:	Any of the earlier levels of scaffolding might be appropriate and a more open version is also possible when students have already encountered concentrations of solutions. ▪ In this case students can be provided with a stock solution and allowed to experiment to devise their method. ▪ Students can be given a preliminary task of determining the density of their eggs if they have access to a balance that will measure to 0.1 g and have learnt to measure volume by displacement. They can then predict the density of a successful test solution and make up the required solution and trial it.
Proportional Reasoning:	This task gives students practice in using proportional reasoning as they make up solutions and when they describe how their test works. The key ingredient of explanations that elicit proportional reasoning is that students explain the changes in density in terms of the changes of mass and volume. For example when a solution is diluted the density decreases because there is less salt (mass) in the same volume of water. The density then decreases in proportion to the decrease in the mass of salt. Alternatively, when an egg sinks it means that the egg is denser than the solution because it has a greater mass than the mass of the same volume of solution (that it is displacing). To make the egg float requires that more salt be added to increase the mass per unit volume (density) of the solution.

Volume Changes of Solutions	When salt is added to water the volume of the solution does not increase by the volume of the salt added because the salt particles (ions) take up some of the space between the water molecules. However there is some increase in volume which is why the stock solution needs to be made up to take account of the change (see method above)
Eggs:	Eggs are very variable in the natural setting and the investigation will be easier if the natural variability is minimised. The experiment is based on the idea that boiled eggs lose water and become less dense (because the volume of the egg is unchanged). Since eggs lose water in storage they become less dense with time anyway and so purchase the eggs as fresh as possible. Buy eggs that are fresh (have a long use by date) and are the same brand and size. This will minimise the natural variability.
Egg preparation:	Eggs should be boiled by placing in a saucepan of room temperature well-salted water which is then heated to boiling and boiled gently for at least 10 minutes. The aim is to minimise any cracking of the eggs. The eggs should then be removed from the water and left to cool in the open air (not in cold water) for at least 20 minutes. This method should ensure a significant difference in the densities of the fresh and hard-boiled eggs. Any cracked or damaged eggs should be discarded because their densities will vary unpredictably.
Stock Solution:	Each group of students will probably need at least a litre (1000 cm3) of stock solution for their tests. Pool salt is cheap and readily available. Adding 200g of salt per litre provides a convenient solution that will make all the eggs float. This amount of salt can be weighed reasonably accurately on kitchen scales and litre volumes can be measured reasonably accurately using kitchen measures.
Dilutions	To avoid difficult numbers, especially in primary school, the diluted solutions can be labelled by % stock solution. Thus a 40% stock solution would contain 40 cm^3 of stock solution diluted to 100 cm3.
Measuring cylinders:	100 cm^3 plastic measuring cylinders are best for this purpose but large plastic syringes (60 or 80 cm3) work well too and are often available from pharmacies. Students need to be able to measure to □ 1 cm3.
Accuracy	It is possible to make quite precise measurements with plastic equipment, but the accuracy is often poor because plastic-ware is not usually calibrated. This means that students will get the best results if they use the same pieces of equipment during the experiment (for example if the investigation requires more than one lesson).
Task Test:	Assessment of the tests should be checked by the teacher if there is doubt about a result (see accuracy above).

EPISODE 7

Some Results

A stock solution for the experiment was made up by dissolving 200 g of pool salt in 900 cm^3 of water and then making up the volume to 1000 cm3. This gives a 20 g/100 cm^3 salt solution with a density of 1.13 g/cm3. 100 cm^3 test solutions were made up from the stock solution.

Concentration (g/100 cm^3)	Density (g/cm^3)	Fresh Eggs		Hard Boiled Eggs	
		One	Two	Three	Four
20	1.13	Float	Float	Float	Float
13	1.09	Sink	Sink	Float	Float
10	1.05	Sink	Sink	Sink	Sink