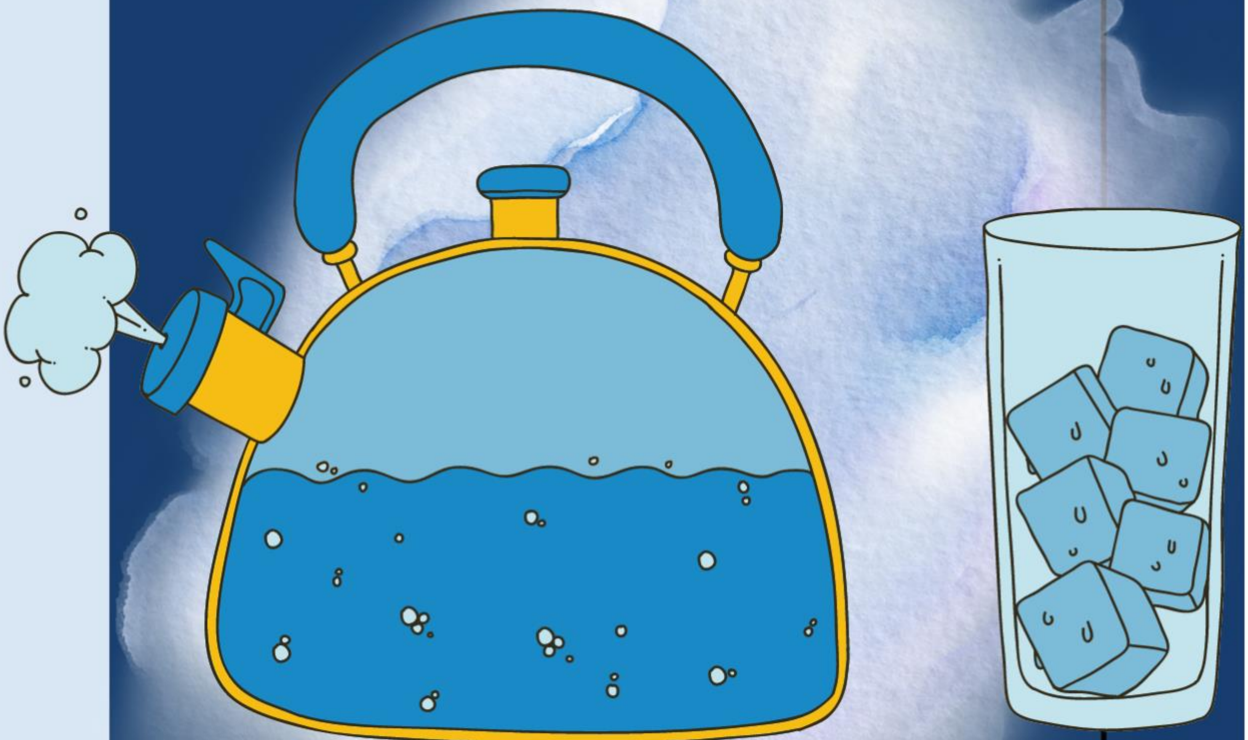


Unit Preparation Booklet

P4.1 Matter

Teacher name:

Science Mastery

Ark Curriculum+

Contents

Steps to Success

		What?	Why?	Who?	Page #
Preparing to teach	**1**	☐ Print this booklet or save a copy in a personal folder	To allow for engagement during planning and co-planning	*All teachers*	
	2	☐ Engage with the unit preparation checklist	To prepare for delivering the sequence of lessons	*All teachers*	4
	3	☐ Read the scope and sequence for the unit	To review the scope and sequence of the unit	*All teachers*	5
	4	☐ Complete the pre-unit quiz reflections task after administering to class	To plan how to remedy prior knowledge gaps	*New to teaching the unit only*	10
	6	☐ Complete the Mastery Quiz and exam-style questions activity	To learn/revisit the key assessment objectives of the unit	*New to teaching the unit only*	11-20
	7	☐ Complete the misconception activities	To develop a strong understanding of the most common misconceptions for the unit and how to address them	*New to teaching the unit only*	21
Delivering the unit	**8**	☐ Use the lesson by lesson objectives to monitor progression through the unit	To maintain a record of completion and to recognise what needs to be reviewed after each lesson	*Novice teachers only*	22-29
Utilise other features of the booklet	**9**	☐ Complete the advanced subject knowledge activity	To develop an understanding of where the unit can lead	*Non A-level specialists*	30
	10	☐ Engage in the keywords	To identify the correct definitions for keywords throughout the unit	*Novice teachers only*	31-32

Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

Scope and Sequence

Scope

This unit starts with a prior knowledge review of the particle model, then a review of density including the required practical for measuring density. It then covers gas pressure and pressure in fluids (for physics only). It links to P3.2 Heating and P4.2 Energy Transfers.

Sequence

The unit begins with a prior knowledge review of the particle model and the arrangement and movement of particles in each of the states of matter. They will also review ideas about what happens during changes of state, including the internal energy of a system. They will also review density and compare the different states of matter in terms of density, as well as how gases exert pressure.

Students will then continue with the review of density, including a theoretical explanation of what the density of a substance actually means before practising the calculation. They will review how to measure or calculate the density of regularly shaped solids (and liquids) and irregularly shaped solids.

Students will then use their understanding of the movement of particles in each state of matter to explain how gases exert pressure and the relationship between gas pressure and temperature, linking back to their understanding of the effect of heating on the internal energy of a system.

Physics only students will also look at Boyle's law and the mathematical relationship between the pressure and volume of a gas. They will also look at pressure in fluids in greater depth, including how fluids are used in hydraulic systems as force multipliers. These students will also revisit the relationship between the pressure exerted on a surface, the force applied and the surface area, which was previously encountered in P2.1. Physics only students will also then look at the relationships between pressure and depth in a fluid, including pressure and atmospheric height.

A full set of knowledge objectives for this unit can be found as **Appendix 3.**

1	**2**	**3**	**4**
Prior Knowledge Review	Density	Measuring Density	Gas Pressure
5	**6**	**7**	
Taking it Further: Pressure	Taking it Further: Pressure in Fluids	Feedback Lesson	

Science
Mastery

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

TASK: Below is the pre-unit quiz available for your pupils. Complete yourself and set for your pupils ahead of starting the unit. There is space to record the key outcomes from marking the quiz for your class. **See Appendix 1 for the mark scheme.**

1. In which state(s) of matter are particles free to move? [1]
   Tick (✓) **one** box.
   (a) Solids and liquids ☐
   (b) Liquids and gases ☐
   (c) Gases only ☐

2. In which state of matter do particles have the most energy? [1]
   Tick (✓) **one** box.
   (a) Solid ☐
   (b) Liquid ☐
   (c) Gas ☐

3. Which state(s) of matter can be compressed? [1]
   Tick (✓) **one** box.
   (a) Gases only ☐
   (b) Liquids and gases ☐
   (c) Solids, liquids and gases ☐

4. Water is boiled in a kettle. Which statement correctly describes what has happened to the particles? [1]
   Tick (✓) **one** box.
   (a) Water particles (liquid) have turned into steam particles (gas) ☐
   (b) Particles have more energy so they are able to move more quickly in random directions ☐
   (c) Water particles have chemically reacted with oxygen to form steam ☐

5. A student filled and sealed two syringes, one with a gas and the other with a liquid, as shown in **figure 1**.

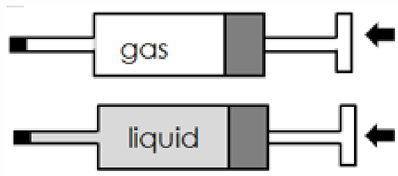


Figure 1

Figure 2 shows the syringes after the plungers were pushed.

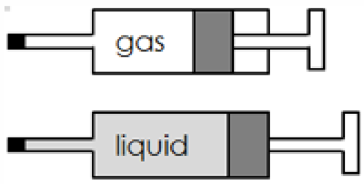


Figure 2

Choose the statement that explains why the gas was compressed more than the liquid. [1]

Tick (✓) **one** box.

(a) The particles in gases are more spread out than the particles in liquids ☐

(b) The particles in gases have less mass than the particles in liquids. ☐

(c) The particles in gases are softer than the particles in liquids ☐

6. Which best explains why oil floats on water? [1]

Tick (✓) **one** box.

(a) Oil is lighter than water ☐

(b) Oil is less dense than water ☐

(c) Oil is more dense than water ☐

7. Which state of matter has the greatest density? [1]

Tick (✓) **one** box.

(a) Solid ☐

(b) Liquid ☐

(c) Gas ☐

8. Choose the correct definition of internal energy. [1]

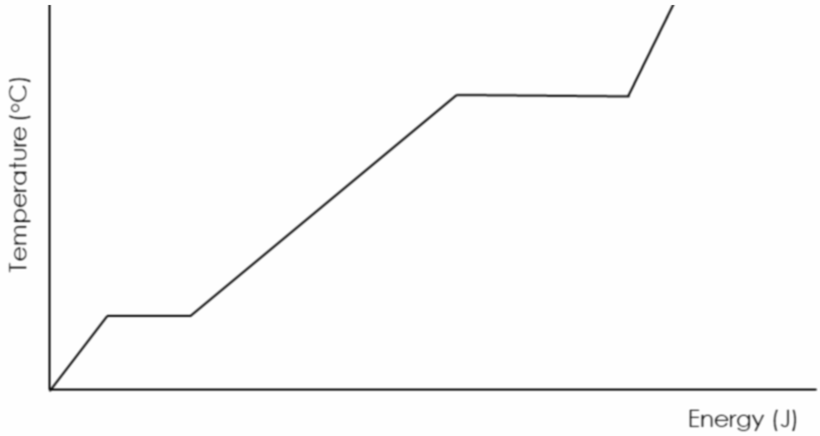
Tick (✓) **one** box.

(a) The total kinetic energy of all the particles in a system

(b) The total kinetic and potential energy of all the particles in a system

(c) The total energy transferred when a substance changes state

9. A student has plotted a heating curve of water.



Choose the statement that is correct for line AB.
Tick (✓) **one** box.

(a) Kinetic energy and potential energy are increasing

(b) Kinetic energy and internal energy are increasing

(c) Potential energy and internal energy are increasing

10. An object has a mass of 10 g and a volume of 2 cm^3.

Choose the density of this object. [1]

Tick (✓) **one** box.

A. 0.2 g/cm^3

B. 5 g/cm^3

C. 20 g/cm^3

Total = ___ /10

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

P4.1 Mastery Quiz: Matter

Section A

1. In which state of matter do particles have the greatest internal energy? [1]

   Tick (✓) **one** box.

   A. Solid ☐

   B. Liquid ☐

   C. Gas ☐

2. Which state(s) of matter can be compressed? [1]

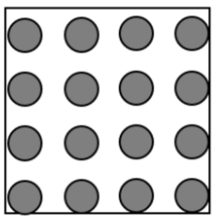
   Tick (✓) **one** box.

   A. Only solids ☐

   B. Liquids and gases ☐

   C. Only gases ☐

3. The diagram shows a particle diagram that a student has drawn to represent the particles in a gas.



   Which explains a problem with the student's diagram?

   Tick (✓) **one** box.

   A. The particles in a gas are randomly arranged rather than in a regular pattern ☐

   B. Gases do not contain many particles, so there should be fewer circles ☐

   C. The particles of a gas should be drawn as white circles ☐

4. Gas pressure is caused… [1]

   Tick (✓) **one** box.

   A. by collisions of particles with each other. ☐

   B. by collisions of particles with the walls of a container. ☐

   C. only when particles in a gas are moving. ☐

5. Which statement is correct about energy of particles when substances are heated? [1]

   Tick (✓) **one** box.

   A. Kinetic energy always increases ☐

   B. Potential energy always increases ☐

   C. Internal energy always increases ☐

6. A student wanted to determine the density of an irregularly shaped piece of rock.

   The method they used is shown below.

   1. Fill a measuring cylinder with water
   2. Add the rock to the cylinder
   3. Measure the volume of water on the cylinder
   4. Use this volume and the mass to calculate density.

   Choose why this method will not allow density to be determined. [1]

   Tick (✓) **one** box.

   A. A beaker should be used to more accurately measure volume ☐

   B. The measuring cylinder should not be filled because water will spill out ☐

   C. The length, width and height of the rock must be measured ☐

7. Select the unit that could be used to describe density.

Tick (✓) **one** box.

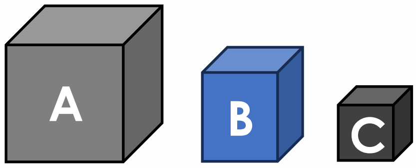
A. m^3/kg ☐

B. $kg\ m^3$ ☐

C. m/kg ☐

D. kg/m^3 ☐

8. The cubes below all have the same mass.



Which of the cubes has the highest density?

Tick (✓) **one** box.

A. A ☐

B. All cubes have the same density ☐

C. C ☐

9. There is 1 kg of oxygen in a sealed container.

The temperature of the oxygen is increased from 18 °C to 100 °C.

Choose the best description of the effect of the temperature change. [1]

Tick (✓) **one** box.

A. Oxygen becomes a gas at the boiling point of 100 °C ☐

B. Particles of oxygen move more quickly causing a higher pressure ☐

C. Particles of oxygen have a lower thermal energy as the temperature has increased ☐

Physics Only

10. Choose where atmospheric pressure is greatest. [1]

    Tick (✓) **one** box.

    A. 1 m above sea level ☐

    B. 200 m above sea level ☐

    C. Atmospheric pressure is the same at different heights. ☐

11. 2 m^3 of a gas had a pressure of 50 Pa.

    The gas was compressed, and the final pressure was 400 Pa.

    Calculate the volume of the compressed gas. [1]

    Tick (✓) **one** box.

    A. 4 m^3 ☐

    B. 100 m^3 ☐

    C. 0.25 m^3 ☐

Higher tier only

12. The deeper a fish swims in water, the greater the pressure becomes because … [1]

    Tick (✓) **one** box.

    A. water is more dense near the surface. ☐

    B. the fish weighs more the deeper it goes. ☐

    C. there is a greater weight of water above the fish. ☐

13. There is 20 kg of nitrogen in a sealed container.

    The temperature is constant.

When the volume increases, the pressure … [1]

Tick (✓) **one** box.

A. increases. ☐

B. decreases. ☐

C. stays the same. ☐

14. In a column of liquid, the pressure is greatest at the deepest point because… [1]

Tick (✓) **one** box.

A. there are more particles exerting a downwards force. ☐

B. there is more gravity the greater the height. ☐

C. the density is greater. ☐

15. A toy boat floats on the water in a bath.

The water exerts a greater pressure on the bottom of the toy boat than the top surface which causes… [1]

Tick (✓) **one** box.

A. a resultant force downwards. ☐

B. upthrust. ☐

C. sinking. ☐

16. A marble is released into a 5 m tall column filled with water.

Calculate the pressure on the marble when it is half way down the column. [1]

The density of water is 998.2 kg/m^3.

The gravitational field strength on Earth is 10 N/kg.

Below shows how to calculate the pressure due to a column of liquid:

pressure due to a column of liquid = height of column × density of liquid x gravitational field strength

$$p = h \rho g$$

Tick (✓) **one** box.

A. 25 kPa ☐

B. 40 kPa ☐

C. 50 kPa ☐

Section B

1. A student measured the volume and mass of a material. The results are shown below.

Mass = 18 g
Volume = 45 cm^3

Calculate the density of this material. Include units.

[3]

2. Describe a method that could be used to determine the density of this toy.

[3]

3. Compare the arrangement of particles in solids and liquids.

[4]

Physics only

4. A pump is used to inflate a car tyre as shown in the photo below.

Image source – Andrea Piacquaido/Pexels

Explain why the internal energy of the air increases as the tyre is inflated.

[4]

Mastery quiz reflections

Which aspects of this unit are likely to be the most challenging to teach?

What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*

How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using Exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors and misconceptions

How would you tackle the following common mistakes, errors and misconceptions by pupils?

TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
Density is the same as weight.	Weight is the effect of gravity on a mass but density is the amount of mass in a given volume.	
Liquids can be compressed because there are spaces between the particles.	There are no spaces between particles in a liquid. They are not held in a regular arrangement but are still packed closely together.	
Weight is measured in kg.	Mass is measured in kg. Weight is measured in N.	
A fluid is liquid.	A fluid is any substance that does not have a fixed shape (i.e. liquid or gas).	

Planning for the misconceptions

Misconception: Density is the same as weight
Often students use the words mass, weight and density interchangeably as a way of describing 'heaviness. Mass is the amount of matter present in an object, regardless of the volume it takes up. Weight is the effect of gravity on a given mass and density is the mass per unit volume, so the amount of matter that is found in a given volume. It is density that affects flotation.
Supporting pupil understanding These are three key definitions that students need to be secure with, as well as the equations that they need to know. To help students understand the difference, it can be useful to show a real life example of how density can be used. It does not matter how much a ship weighs (either by mass or weight with the effect of gravity) – it will still float because of its density.
Taking it further
This can be a really interesting topic for students, so it can be interesting for them to research how ships are able to float when they are mostly made of quite dense metals. It can also be a really interesting project for students to design their own models and test them.

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that TBAT = to be able to

NOTE: All TKT statements can be found in Appendix 5 of this document

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior knowledge review

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document* *This lesson is a review of content from previously studied units relating to this big idea	
TBAT draw particle diagrams to represent the arrangement of particles in each state of matter	Draw a particle diagram to show the arrangement of particles in a gas (or liquid, or solid) Identify the state of matter from a particle diagram
TBAT compare the arrangement and movement of particles in each state of matter	Describe the arrangement of particles in solids, liquids and gases Describe the movement of particles in solids, liquids and gases Compare the arrangement of particles in solids, liquids and gases Compare the movement of particles in solids, liquids and gases
TBAT explain the arrangement and movement of particles in each state of matter	Compare the forces of attraction between particles in solids, liquids and gases Describe and explain the properties of each state of matter
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2: Density

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the [unit overview document]*	
TBAT define density	Define density State the equation that links density, mass and volume State a unit that density could be measured in
TBAT calculate the density of regularly shaped solids	State the equation to calculate volume of a cube State the equation to calculate density Calculate the density of a regularly shaped object given its mass and dimensions
TBAT compare the density of objects with the same mass or volume	Two objects have the same mass but different volumes, which is more dense? Two objects have the same volume but different masses, which is more dense?
What did the Exit ticket data tell me?	
What do I need to review in future lessons?	

Lesson 3: Measuring Density

<table>
<tr><th>Intended outcome</th><th>Example questions</th></tr>
<tr><td colspan="2">*These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document</td></tr>
<tr><td>TBAT describe how to measure the density of an irregularly shaped solid</td><td>Identify whether a shape is regular or irregular in shape
State the equation to calculate density
Describe the function of a displacement can
Describe how to measure volume of an irregularly shaped object</td></tr>
<tr><td>TBAT measure volume of liquid accurately</td><td>Identify a meniscus
Read a given volume
Measure a given volume of liquid</td></tr>
<tr><td>TBAT compare the methods for measuring the densities of an irregular and a regularly shaped solid</td><td>Describe how to measure the mass of a regularly shaped solid
Describe how to measure the mass of an irregularly shaped solid
Describe how to measure/calculate the volume of a regularly shaped solid
Describe how to measure the volume of an irregularly shaped solid
State the equation to calculate density</td></tr>
<tr><td colspan="2">What did the Exit Ticket data tell me?

</td></tr>
<tr><td colspan="2">What do I need to review in future lessons?

</td></tr>
</table>

Lesson 4: Gas Pressure

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT explain what is meant by gas pressure	Describe the movement of particles in a gas Explain the movement of particles in a gas Explain what is meant by gas pressure
TBAT describe the relationship between temperature and gas pressure	Describe the relationship between temperature and gas pressure Describe how heating affects kinetic energy of particles
TBAT describe and explain the relationships between pressure and temperature and pressure and volume	Describe and explain the relationships between pressure and temperature and pressure and volume Describe the effect on pressure of changing the volume or temperature Identify a factor that must remain constant for the relationship to apply
TBAT use the equation $p_1V_1 = p_2V_2$	Calculate the new volume of a compressed gas given its pressure before and after and its original volume Use values from a graph to predict pressure of a gas at different volumes
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 5: Taking it Further: Pressure

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT recall and apply the equation p=F/A	Calculate pressure given force applied and area Calculate cross-sectional area of a regular shape
TBAT describe the property of liquids that makes them useful in hydraulic systems	Identify the state(s) of matter that can be compressed Identify the property of liquids that makes them useful in hydraulic systems Explain why hydraulic systems can be described as force multipliers/transmitters Compare the pressure at different points in a hydraulic liquid
TBAT Use the equation to solve hydraulic calculations	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 6: Taking it Further: Pressure in Fluids

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT calculate the pressure exerted on an object at different depths	Calculate the change in pressure when a diver moves X m further below the surface Compare the pressure at the top and bottom of a column of liquid
TBAT describe and explain the relationship between pressure and depth of a fluid	Describe the relationship between pressure and depth in a fluid Describe the relationship between pressure and atmospheric height Explain why pressure increases with depth Explain why pressure decreases with altitude
TBAT describe the forces acting on an object when they float or sink	Describe how pressure is exerted in fluids Compare the pressure exerted at the top and bottom surfaces of a submerged object
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 7: Feedback lesson

Intended outcome	Example questions
Edit based upon your class's performance in the Mastery Quiz	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

Key learning from this unit is the particle model and the behaviour of particles when heated. This feeds into almost all other units, including the difference between chemical reactions and physical changes. It is particularly important to make links with chemistry, so that students understand the terms melting and boiling point and how the structure of matter relates to its properties.

At A-Level, this unit links into both physics and chemistry, using knowledge of the fundamental properties when looking at topics including quantum phenomena, ideal gases and the effect of temperature on the behaviour of particles.

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS5?
What content from this unit is fundamental to student understanding at KS5?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Degrees Celsius	The unit used for temperature. *The melting point of water is 0* ***degrees Celsius*** *(°C)*.
Density	The mass per unit volume. *Warm fluids have a lower* ***density*** *than cold fluids, causing them to rise.*
Displacement	The movement of something from its original position. *Irregularly shaped solids can be placed into a* ***displacement*** *can to determine the volume of water that is displaced.*
Fluid	A substance with no fixed shape: a liquid or gas. *Convection is thermal transfer when particles in a heated* ***fluid*** *rise.*
Hydraulic	Relating to liquid under pressure. ***Hydraulic*** *systems use liquids to act as force multipliers.*
Incompressible	Cannot be compressed (has a fixed volume). *Liquids and solids are* ***incompressible*** *but gases can be compressed.*
Internal energy	The total kinetic energy and potential energy of all the particles in a system. *When a substance is heated, its* ***internal energy*** *increases.*
Irregular shape	An object that has sides and angles of any length and size, so is not a cube, cuboid, cylinder etc. *A jelly baby has an* ***irregular shape.***
Kinetic energy	A store of energy that any object or particle has when moving. *Particles in a gas have the greatest store of* ***kinetic energy***.
Mass	The amount of matter in an object. ***Mass*** *is measured in kilograms (kg).*

Potential energy	A store of energy related to the position of objects or particles. *Particles in a gas have the greatest store of **potential energy**.*
Pressure	The amount of force exerted per unit area. *Particles in a fluid exert **pressure** on any surface.*
Regular shape	An object that has sides and angles of equal sizes and lengths. *A **cube** has a regular shape.*
State	The physical form in which a substance is in: solid, liquid or gas. *Melting and boiling are examples of changes of **state**.*
System	A body, object or group of bodies. *When looking at the internal energy of a **system**, you must consider the kinetic and potential energy of all of the particles in it.*
Temperature	Related to the average kinetic energy of particles in a system. ***Temperature** is measured in °C.*
Upthrust	The upward force that a liquid or gas exerts on an object. *If **upthrust** is greater than weight, an object will float.*
Volume	The amount of space that a substance or object takes up. *Liquids and solids have a fixed **volume**.*

Appendices

Appendix 1: Mark scheme for pre-unit quiz

P4.1 Pre-Unit Quiz: Matter
Mark Scheme

Qu	Answer	Marks	Supporting information for fix-it tasks
1	B	1	Answering A shows that pupils have not understood the movement of particles in a solid. Answering C shows that pupils are not aware that particles in a liquid can also move around each other. *Task:* Compare the movement of particles in solids, liquids and gases.
2	C	1	Answering A or B shows that pupils are not secure in the properties of the different states of matter. *Task: Describe the movement of particles in the different states of matter and explain this movement in terms of forces of attraction.*
3	A	1	Answering B shows the common misconception that liquids can also be compressed, which comes from students drawing or being shown particle diagrams that do not show the liquid particles overlapping. overlapping. Answering C shows that students may not be clear on the different properties of solids, liquids and gases. *Task: Explain why solids and liquids are incompressible.*
4	B	1	Answering A shows that pupils have the misconception that a change of state means the particles themselves are actually changing, rather than just the arrangement. Answering C shows that pupils have possible mistaken steam for smoke and taken this as a sign of a chemical reaction. *Task: Describe the arrangement of particles in a liquid and a gas and describe what happens to the particles when a liquid boils.*
5	A	1	Answering B suggests that students have the misconception that the mass of the particles of gases are less than particles of liquids. *To fix it. Demo: Place an ice cube on a balance and allow it to melt, noting the mass before and after, to show that the mass remains the same. Ask student to explain why the mass of the ice and the mass of the water is the same.* Answering C suggests that students think that particles have properties such as hardness. *To fix it, ask students to state which arrangement of particles would be the hardest (i.e. Regular pattern, close together, joined together strongly).*
6	B	1	Answering A shows that pupils have the misconception that density and weight/mass mean the same thing. Answering C shows that pupils understand that different densities cause objects to sink or float but they have incorrectly suggested that more dense objects float on water. *7Task: Explain why a cube of metal and a sugar cube have different densities.*
7	A	1	Answering B or C shows that pupils are not clear on the meaning of density or how this applies to different states of matter. *Task: Explain the definition of density and why solids are more dense than liquids (with the exception of ice and water).*
8	B	1	Answering A suggests a misconception that particles only have a

			store of energy when they are moving. *To fix it, reteach the definition of internal energy and how it changes throughout a heating curve.* Answering C suggests a misconception that internal energy only refers to changes of state. *To fix it, reteach the definition of internal energy and how it changes throughout a heating curve.*
9	B	1	Answering A suggests a misconception that potential energy also increases when temperature increases. *To fix it, give students a copy of this graph to annotate and explain what is happening to the particles at each stage.* Answering C suggests a gap in knowledge that the temperature is related to the kinetic energy of the particles. *To fix it, give students a copy of this graph to annotate and explain what is happening to the particles at each stage.*
10	B	1	Answering A shows a gap in knowledge of how to calculate density since A is the result of calculating volume/mass. Answering C shows a gap in knowledge of how to calculate density since C is the result of multiplying volume by mass. *To fix it, reteach how to calculate density then students should write down the formula and then answer practice questions (that do NOT require rearranging).*

Appendix 2: Mark scheme for mastery quiz

P4.1 Mastery Quiz: Matter
Mark Scheme
Section A

Qu	Answer	Marks	Supporting information for fix-it tasks
1	C	1	Answering A or B shows students are not secure with the definition of internal energy and the relative energy of each state of matter. *To fix it, review the definition of internal energy and why gases have the highest internal energy.*
2	C	1	Answering A suggests a confusion that solids can be compressed because their particles are close together. This can sometimes be caused by a language issue where students think solids 'are compressed' because their particles are close together. *To fix it, review what it means for a substance to be compressed.* Answering B suggests the common misconception that liquids can be compressed. This is often caused by incorrect particle diagrams of liquids, showing gaps between the particles. *To fix it, explain why liquids cannot be compressed.*
3	A	1	Answering B or C show that students are not clear on the biggest problem with this diagram. Particles in a gas move at random speeds in random directions, but this diagram suggests a clear pattern.

			To fix it, review the advantages and disadvantages of using a 2D particle model.
4	B	1	Answering A suggests a misconception that it is the collision of particles in a gas with each other that causes pressure. *To fix it, use the PhET interactive animation here that shows visually the particles hitting the walls of the container and explain that this is causing the pressure. Then ask students to explain why adding more particles of gas to a container increases the pressure.* Answering C suggests a fundamental misconception that particles in a gas are sometimes stationary. *To fix it, recap descriptions of motion of particles in solids, liquids and gases and the ask student to compare the motion of particles in solids and gases.*
5	C	1	Answering A shows that students are not clear on what happens during a change of state. Answering B shows that students are not clear on the relationship between temperature and kinetic energy. *To fix it, review the definition of internal energy and how it can be affected by heating.*
6	B	1	Answering A suggests a misconception that a beaker allows volume to be measured accurately. *To fix it, show students a 100 ml measuring cylinder and a 100 ml beaker, then model how a beaker cannot be used to measure volume accurately. Then ask students to explain the different uses of a 100 ml measuring cylinder and 100 ml beaker.* Answering C suggests a gap in knowledge about the purpose of this practical. *To fix it, ask students to explain why the volume of a cube, but not an irregularly shaped rock, can be calculated by multiplying the length by width by height.*
7	D	1	Answering A or C shows that students have confused the relationship between mass and volume. Answering B shows students have almost got the correct symbol but are not secure with the significance of the /. *To fix it, review the definition of density and show students how the unit is derived.*
8	C	1	Answering A shows a lack of understanding of the relationship between mass, volume and density. Answering B shows that students have confused the terms mass and density. *To fix it, review the relationship between mass, volume and density. It can be useful for some students to see this modelled with a particle diagram (same number of particles because mass is equal), or with numerical values used.*

9	B	1	Answering A suggests a confusion of the BP of water and oxygen. *To fix it, recap that all substances have specific MPs and BPs. Then ask students to determine the state of oxygen, nitrogen and water at room temperature (18 °C) when the MP and BP are given.* Answering C suggests the misconception that a lower thermal energy results when the temperature of a substance increases. *To fix it, reteach that temperature is a measure of the average kinetic energy of particles whereas thermal energy is a measure of the total kinetic energy of all particles. Then ask students to explain the difference between temperature and thermal energy.*
10 (Physics only)	A	1	Answering B suggests a misconception that the greater the height in the atmosphere, the greater the pressure. *To fix it, ask students to explain how density of air and pressure exerted varies depending on atmospheric height.* Answering C suggests a misconception that height doesn't affect atmospheric pressure. *To fix it, reteach why height affects atmospheric pressure, linking it to air density and then ask students to explain why it is harder to breathe at the top of a mountain.*
11 (Physics only)	C	1	Answering A show a rearranging error because the incorrect answer 4 is calculated by 400/100 which is p_2 / (p_1 x V_1). *To fix it, ask students to rearrange this equation to make each of the following the subject:* p_1, V_1, p_2, V_2. Answering B shows the error of simply calculating the initial volume multiplied by the initial pressure, rather than consider the constant. *To fix it, reteach that* p_1 x V_1 = p_2 x V_2 *and then model how to carry out this calculation. Then give students more practice examples.*
12 (Physics only, HT)	C	1	Answering A suggests a misconception that water is more dense near the surface. *To fix it, reteach that the converse of this is true – water is more less dense at the surface. Then ask students to explain why water at the bottom of ocean is more dense that water in a puddle.* Answering B suggests a misconception that the weight of an object affects the pressure exerted on it. *To fix it, ask students to state the three factors that affect the pressure acting on the fish in water (hint – equation for calculating pressure due to a column of liquid).*
13 (Physics only, HT)	B	1	Answering A suggests a misconception about the relationship between changing volume and the effect on pressure. Answering C suggests a misconception that changing the volume of a container does not affect pressure. *To fix both issues, use the PhET interactive animation here that shows visually the particles of gas hitting the walls of the container and model how changing the volume of the sealed container changes the pressure.*
14 (Physics only,	A	1	Answering B suggests a misconception that a change in the force of gravity causes the greater pressure. *To fix it, recap that the gravitational field strength will be the same value if the experiment*

HT)			*is conducted on Earth and does not explain why pressure is greater. Then ask students to link why a greater number of particles can cause greater pressure in a column of liquid.* Answering C suggests a misconception that it is density that explains why a greater height causes a greater pressure. This could be caused by thinking about the other factors in the equation to calculate pressure due to a column of liquid. *To fix it, ask students to explain how both height and density of the liquid affect the pressure at a certain point in a column of liquid.*
15 (Physics only, HT)	B	1	Answering A suggests a misconception that an object floats because of a downwards resultant force. In fact, the converse is true, and the resultant upwards force is upthrust. *To fix it, ask students to draw a labelled free body diagram of this toy boat, labelling all the forces.* Answering C suggests a misconception that sinking is caused by the resultant upwards force caused by the difference in pressure exerted on the object. *To fix it, ask students to write a definition for upthrust using information from this question.*
16 (Physics only, HT)	A	1	Answering B suggests an incorrect of substitution of the value of density, as pressure. This could be caused by confusing the similar looking symbols for pressure and density. It also shows an incorrect use of kilo Pa (kPa) instead of Pa. *To fix it, ask students to write out the equation as symbols as shown on the equation sheet. Then ask students to annotate each symbol to describe what it represents and the units. Then give more practice questions.* Answering C suggests an incorrect value for height because 5 m has been used instead the half way down value of 2.5 m. *To fix it, model how to carry out this calculation, focussing on how to deduce the height using information from the question. Then give students similar questions where the marble is either at the top, bottom or some fraction along the column.*

Section B

Qu	Answer	Supporting information ***Suggestions for fix-it tasks***
1	Density = mass / volume **[1]** Density = 18 / 45 **[1]** Density = 0.4 g/cm^3 **[1]**	A common error could be incorrectly recalling the equation to calculate density. *To fix it, ask students to write out several equations that they are expected to recall and then they can revise them either by*

<table>
<tr><td></td><td></td><td>making flashcards or a poster.

A common error could also be not including the correct units. To fix it, model how to derive units in this example by using the units of mass and of volume. Then ask students to write out the units for mass, volume and density.</td></tr>
<tr><td>2</td><td>This question is level assessed.

<table><tr><td>Level 0</td><td>0 marks</td></tr><tr><td>Level 1</td><td>1-2 marks</td></tr><tr><td>Level 2</td><td>3-4 marks</td></tr><tr><td>Level 3</td><td>5-6 marks</td></tr></table>
Indicative content:
Key steps are in bold.

• Measure the mass of the car
• in grams/kg
• Using a (mass) balance (allow scales)
• Measure the volume of the car
• Using a displacement/Eureka can
• By determining the volume of water displaced
• in mL/cm^3/L
• Determine density using mass/volume
• in g/cm^3, kg/m^3 or other correct combination of units</td><td>This question should be marked holistically. Typically, a level 0 answer will contain no (or possibly one) relevant point.
A level 1 answer will contain few relevant points but would not allow density to be determined.
A level 2 answer would not allow density to be determined but may if small changes were made to the method. Level 2 answers may be missing some key steps.
A level 3 answer would allow density to be determined and must mention all the key steps. To achieve the highest level 3 mark, the answer should contain additional details.

If the answer refers to measuring the length, breadth and height to determine volume, a maximum of level 1 can be achieved.</td></tr>
<tr><td>3</td><td>• (Particles in a solid are held in a) regular arrangement [1]
• (Particles in a liquids are) randomly arranged [1]
• Particles are held close together in both (states of matter) [1]
• Forces (of attraction) between particles are stronger in solids (than liquids) [1]</td><td>A maximum of three marks should be awarded if answer is not comparative.

Allow particles are closer in solids than liquids.

The questions specifically asks about the arrangement of particles not the movement of particles, which is a common mistake.</td></tr>
<tr><td>4
(SS, HT)</td><td>Work is done on the air in the tyre [1]

The temperature increases [1]

(As temperature increases,) kinetic energy increases [1]</td><td>A common misconception here is to link the increase in mass of air to the internal energy. The increase in mass during the tyre inflation is not the focus of the question, instead students need to know that the work done on the air increases the internal energy because temperature has</td></tr>
</table>

	Internal energy is the sum of kinetic and potential energy **[1]**	increased. *To fix it, ask students to explain why the internal energy of air increases as a balloon is blown up.*

Appendix 3: Core knowledge statements

- Particle diagrams can be used to represent the arrangement and movement of particles in solids, liquids and gases.
- Solids are the most dense state of matter as the particles are held most closely together due to the forces of attraction.
- Density is the mass per unit volume.
- Density can be calculated using the equation: Density = mass/volume
- $\rho = m/V$, with density, ρ, in kilograms per metre cubed, kg/m^3; mass, m, in kilograms, kg; volume, V, in metres cubed, m^3
- The density of a regular shaped solid can be calculated by measuring its mass and volume, then using the equation.
- The density of an irregular solid or liquid can be determined using its mass and displacement of liquid.

Gas Pressure

- A fluid is a substance with no fixed shape - a liquid or a gas
- Gas pressure is caused by collisions of particles with the walls of a container
- Pressure is measured in Pascals (Pa)
- Changing the temperature of a gas at constant volume changes the pressure exerted by the gas
- Particles at higher temperatures, have higher thermal energy and move more quickly, so they have a higher pressure

Physics Only: Pressure

- In a sealed container, with the same number of particles at constant temperature, decreasing the volume of a gas increases the pressure of the gas
- The pressure of the gas is inversely proportional to its volume. This is because when the volume is decreased, the gas particles will collide more frequently with the walls of the container. More collisions mean more force, so the pressure increases
- *Work is the transfer of energy by a force.*
- *Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas.*
- *Increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure.*
- $p_1V_1=p_2V_2$, *where* p_1 *and* V_1 *are the initial pressure and volume values, and* p_2 *and* V_2 *are the pressure and volume values after change*
- *Fluid particles exert a force on any surface they collide with. This force is always at right angles to the surface*
- *Pressure exerted on a solid is calculated using the equation:*
- *pressure= force/area*
- *Liquids are incompressible so can be used to transmit forces through hydraulic systems*
- *The pressure remains constant in the system so if the area increases, the force is multiplied, which is how heavy objects can be lifted or controlled*
- *The deeper you go in water the greater the pressure becomes, because the greater the weight of water above you*

- *The pressure due to a column of liquid can be calculated using the equation:*
- *pressure = height of the column × density of the liquid × gravitational field strength*
- $p = h\rho g$
- *pressure, p, in Pascals, Pa; height of the column, h, in metres, m; density, ρ, in kilograms per metre cubed, kg/m^3; gravitational field strength, g, in newtons per kilogram, N/kg*
- *In a liquid, pressure at a point increases with the height of the column of liquid above that point and with the density of the liquid because there are more particles exerting a downward force*
- *A partially (or totally) submerged object experiences a greater pressure on the bottom surface than on the top surface. This creates a resultant force upwards. This force is called the upthrust*
- *The atmosphere is a thin layer (relative to the size of the Earth) of air round the Earth. The atmosphere gets less dense with increasing altitude*
- *Air molecules colliding with a surface create atmospheric pressure*
- *The number of air molecules (and so the weight of air) above a surface decreases as the height of the surface above ground level increases. So as height increases there is always less air above a surface than there is at a lower height. So atmospheric pressure decreases with an increase in height*

Practical Skills

45. Determine densities of solid and liquid objects