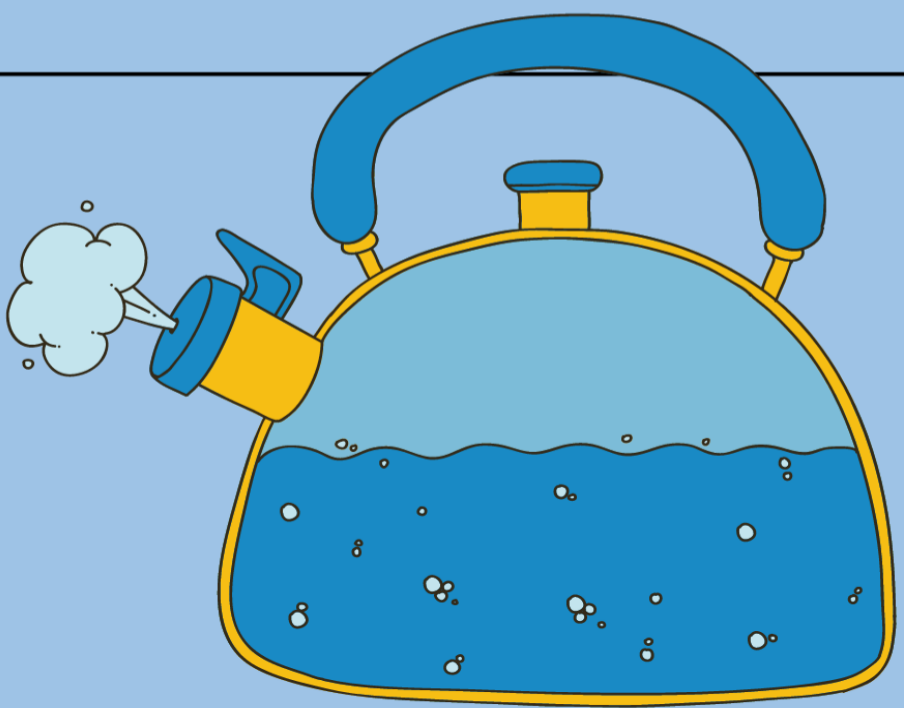
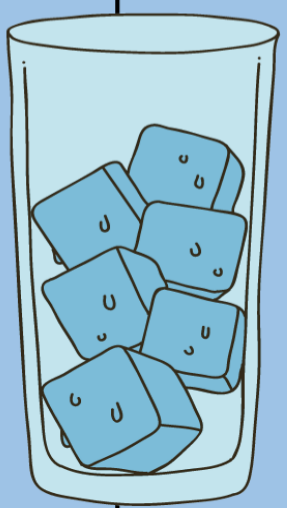




Answer Booklet

P4.1 Matter

Separate Science (Physics)

Science
Mastery

ArkCurriculum+

The Big Idea

Matter

Why do some substances exist as solids and others as gases? What is the difference between solids and liquids? Why do some objects float on water and others sink? How can the density of objects be compared?

Matter makes up everything. All objects in the universe are made of particles and it is the arrangement of these particles that determines their properties. Different materials can exist as solids, liquids or gases at room temperature, which means their particles are arranged in different ways.

This is the **third** unit we are studying as part of the big idea: **Energy is Conserved**

In this unit we will learn about energy in particles and how they are arranged in the different states of matter and their properties. We will look at density and how to measure it, as well as how particles exert pressure.

We will develop our mathematical skills in this unit by practising substitutions into equations.

We will develop our practical enquiry skills in this unit by doing an investigation into how the density of regular and irregular shaped objects can be measured.

TASKS:
What subject will this unit focus on? BIOLOGY CHEMISTRY PHYSICS
(circle the correct subject)

There are lots of keywords underlined above. List these into the two columns:

Words I know	Words I haven't seen before

To answer before the unit:

1. What are you most excited to learn about in this topic?

2. What do you already know about this topic?

3. Why do you think it's important to learn about how energy is conserved?

4. What knowledge from previous science lessons might help us?

5. What questions do you have about this topic?

To answer at the end of the unit:

1. Tick off any words in the 'words I haven't seen before' column that you are now confident with. Circle any you still need more practice to use.

2. What have you most enjoyed about this unit?

3. What more would you like to learn about forces as part of the big idea: 'energy is conserved'?

Pre-Test

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**.

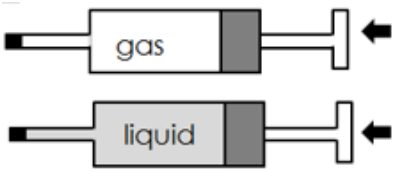


Figure 1

Figure 2 shows the syringes after the plungers were pushed.

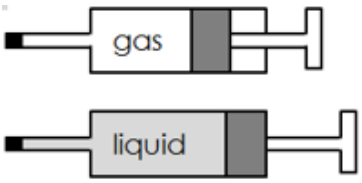


Figure 2

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]

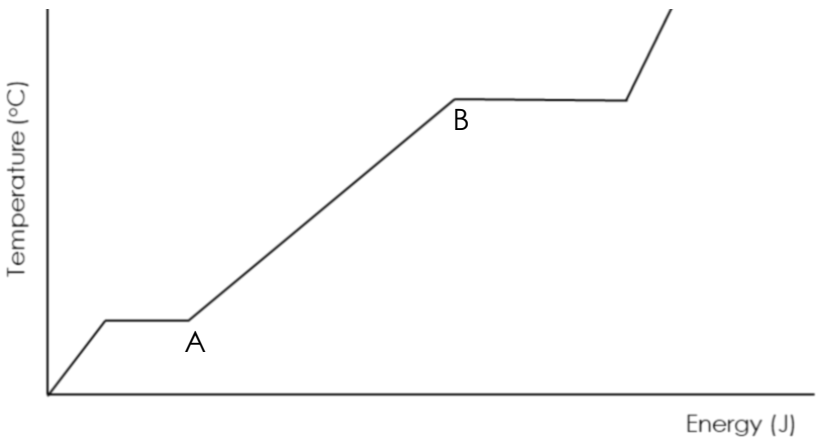
Tick (✓) **one** box.

(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

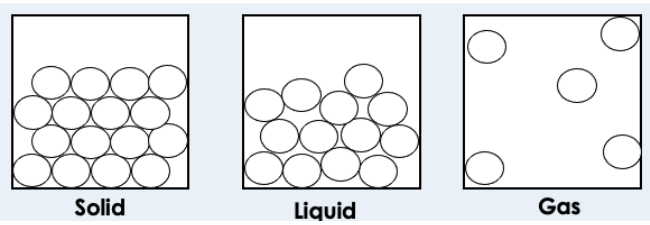
Qu	Answer	Marks
1	B	1
2	C	1
3	A	1
4	B	1
5	A	1
6	B	1
7	A	1
8	B	1
9	B	1
10	B	1

End of Unit Pre-Test. Turn over to see the answers. Give yourself a mark out of 10.

Knowledge Organiser

Particles and Density

1. **Particle diagrams** can be used to represent the arrangement and movement of particles in solids, liquids and gases.

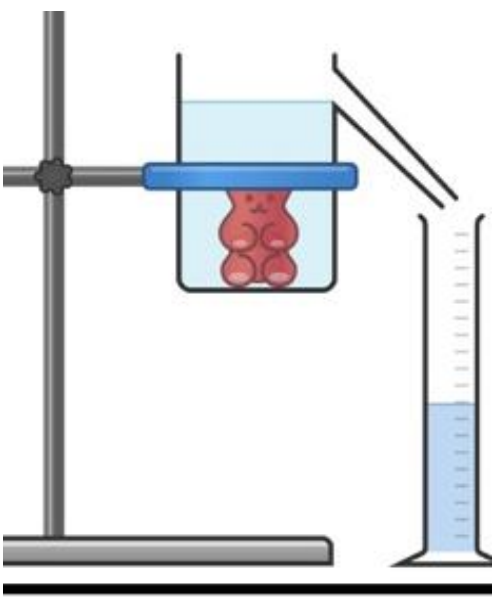


2. Solids are the most dense state of matter as the particles are held most closely together due to the **forces of attraction**.
3. **Density** is the **mass per unit volume**.
4. Density can be calculated using the equation:

$$\text{Density} = \text{mass}/\text{volume}$$
$$\rho = m/V$$

with density, ρ, in kilograms per metre cubed, kg/m^3; mass, m, in kilograms, kg; volume, V, in metres cubed, m^3

5. The density of a **regular** shaped solid can be calculated by measuring its **mass** and **volume**, then using the equation.
6. The density of an **irregular** solid or liquid can be determined using its **mass** and **displacement** of liquid.



Gas Pressure

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

Physics Only: Pressure

12. 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
13. 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
14. ***Work*** *is the* ***transfer*** *of* ***energy*** *by a* ***force****.*
15. *Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas.*
16. *Increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure.*
17. $p_1V_1=p_2V_2$*, 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*
18. ***Fluid particles*** *exert a* ***force*** *on any* ***surface*** *they collide with. This force is always at* ***right angles*** *to the* ***surface***
19. *Pressure exerted on a solid is calculated using the equation:*

$$\text{pressure} = \text{force}/\text{area}$$

20. ***Liquids*** *are* ***incompressible*** *so can be used to transmit forces through hydraulic systems*
21. *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*
22. *The* ***deeper*** *you go in* ***water*** *the* ***greater*** *the* ***pressure*** *becomes, because the greater the weight of water above you*
23. *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

$$p = h\rho g$$

24. *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*
25. *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*
26. *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*
27. *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***
28. *Air molecules colliding with a surface create atmospheric pressure*
29. *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*

Glossary

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**.*

Density

Do Now

1. Put the states of matter in order of increasing internal energy. **Solid→ liquid → gas**
2. In which state of matter are particles held most tightly together? **Solid**
3. Compare the forces of attraction between particles in liquids and gases. **The forces of attraction between particles are stronger in liquids than in gases.**
4. Define internal energy. **The sum of all the kinetic and potential energy of all the particles in a system.**
5. Name a piece of apparatus that can be used to measure the volume of a liquid. **Measuring cylinder, pipette, beaker**

Skills Drill:

1. State the formula to calculate the volume of a cube. **V=lbh**
2. Calculate the volume of a cube with sides of length 4 cm. **V = 64 cm^3**
3. Calculate the surface area of the cube in Q2. **SA = 96 cm^2**

Read Now:

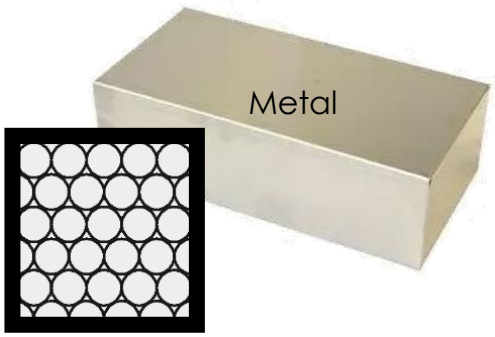
Matter makes up everything, and matter is made of atoms. Atoms can exist individually or as part of compounds or molecules. When we talk about matter, we can describe all these different arrangements of atoms as 'particles'. Density is a fundamental property of matter. It describes how close together the particles are, specifically the mass of particles within a given volume. The SI unit for mass is the kilogram, but often in chemistry the masses we work with are so small that we can use the gram.

1. Explain what matter is made of. **Atoms**
2. Define density. **Mass per unit volume**
3. State the SI unit of mass. **kg**
4. Identify which state of matter is the most dense. **Solids**
5. How many grams are in 1 kg? **1000**

Density

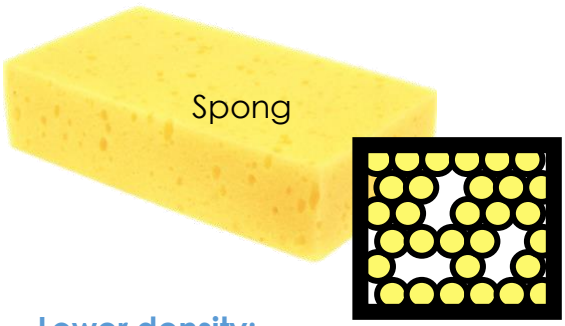
The density of an object is the mass per unit volume.

This means how much matter (particles) is packed into a certain volume.



Higher density:

More particles in a given volume



Lower density:

Fewer particles in a given volume

In order to calculate the density of an object, we need to know its **mass** and **volume**.

Mass (m) is measured in **kilograms** (**g**).

Volume (V) is measured in **metres cubed** (**m^3**).

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

Mass measured in (kg)

Density measured in (kg/m^3)

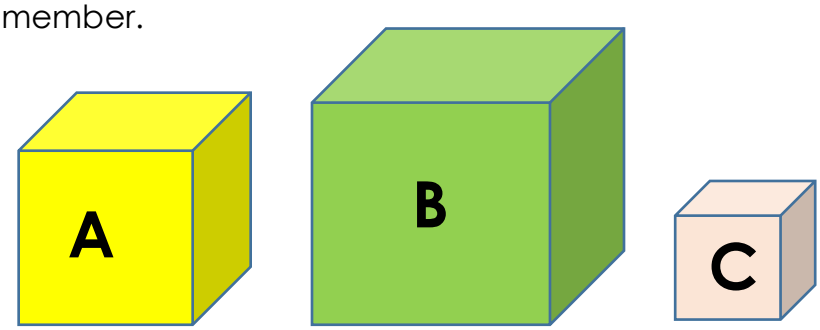
Volume measured in (m^3)

This is an equation you will need to remember.

Think About:

These three cubes are made of different materials.

They all have the same mass.



What can be said about the density of these cubes?

Describe a method you could use to calculate the density of each.

Stretch:

If all the cubes had the same density, what would you expect to note of their masses?

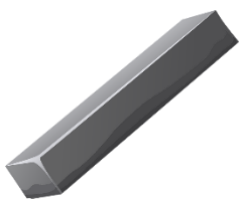
Drill

1. Define density. **The mass per unit volume.**
2. Explain what density means in terms of particles. **Density is a measure of how closely packed particles are in a volume.**
3. Identify the state of matter which has the greatest density. **Solid**
4. State the equation used to calculate density.

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

5. State the SI unit for mass. **kg**
6. State the SI unit for volume. **m^3**
7. State the equation used to calculate the volume of a regularly-shaped solid. **V=lbh**

I Do: Calculating mass, volume and density



This block of steel has a mass of 23 550 g and a volume of 3000 cm3.

Calculate the density of the steel.

HINT: What is the equation that links density, mass and volume?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \qquad \text{Density} = \frac{23\,550}{3\,000} \qquad \text{Density} = 7.85 \text{ g/cm}^3$$

Another block of the same type of steel has a mass of 14 130 g.

Calculate its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \qquad 7.85 = \frac{14\,130}{\text{Volume}}$$

$$\text{Volume} = \frac{14\,130}{7.85}$$

$$\text{Volume} = 1\,800 \text{ cm}^3$$

You Do: Calculating mass, volume and density

This plastic building block has a volume of 2.2 cm3. Its mass is 1.25 g.

Calculate the density of the block.

HINT: What is the equation that links density, mass and volume?

Density = Mass / Volume **Density = 1.25 / 2.2** **Density = 0.57** **g/cm^3**

The same material is used to make a brick that is double the volume.

Calculate the mass of the bigger brick.

Density = Mass / Volume **0.57 = Mass / 4.4** **Mass = 2.5 g**

Exit Ticket

1. Which statement is correct?
   - ❑ A. Density is a measure of how heavy the particles in a substance are
   - ❑ **B. Density is a measure of how many particles are in a given volume**
   - ❑ C. Density is a measure of how many particles there are in a substance

2. Two cubes have the same volume but different masses. Which statement is correct?
   - ❑ A. The cube with the least mass is the most dense
   - ❑ B. Both the cubes have the same density
   - ❑ **C. The cube with the greatest mass is the most dense**

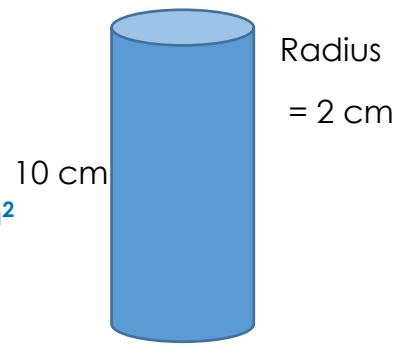
3. What is the mass of a block of iron that has a volume of 1 m^3? Iron has a density of 7800 kg/m^3.
   - ❑ **A. 7800 kg**
   - ❑ B. 7.8 kg
   - ❑ C. 0.000128 kg

Measuring Density

Do Now:

1. Define density. **Mass per unit volume**
2. State the formula to calculate the volume of a cube. **V=lbh**
3. Which state of matter has the lowest density? **Gas**
4. State the volume shown in this image. **17 mL**
5. Convert this volume into litres. **0.017 L**

Skills Drll:



1. State the formula to calculate area of a circle. **A = πr^2**
2. Calculate the area of one end of this cylinder. **A = 12.57 cm^2**
3. Calculate the volume of this cylinder. **V = 125.70 cm^3**

Read Now:

Density is the mass per unit volume, calculated using the mass of a substance divided by its volume. For regularly shaped solids, such as cubes, cuboids and cylinders, we can use mathematical formula to calculate their volumes. For irregularly shaped solids we must use a different method, as these formulae do not apply. We can use a piece of equipment called a Eureka can to measure how much liquid is displaced when the object is placed into it. You can think about this like when you get into the bath and the water rises. If the bath was full to the top and you got into it, the volume of water that spilled out of the bath would be equal to your volume.

1. Define density. **Mass per unit volume**
2. Describe how to calculate the volume of a regularly shaped solid. **Measure mass using a mass balance and calculate volume using lbh, then mass/volume.**
3. Give an example of a regularly shaped solid. **Cube, cuboid, sphere, cylinder, pyramid**
4. Name the piece of equipment that can be used to measure the volume of liquid displaced by an irregularly shaped solid. **Eureka can/displacement can**
5. This paragraph describes how to measure the volume of different solids. How could you measure the volume of a liquid? **Using a measuring cylinder**

Measuring Mass

To measure the mass of an object we use a **balance**.

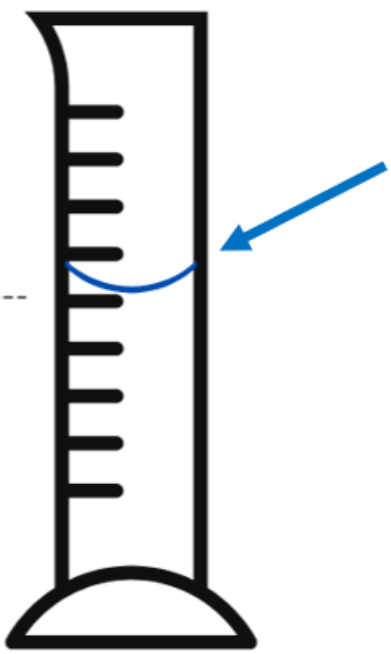
Method for measuring mass:

1. Make sure the balance is wiped clean. **Why**?
   This ensures there isn't any substance on the balance that would add to your measured mass.
2. Check that the balance is on a level surface.
3. Turn on the balance.
4. Ensure that the unit on the display is grams (g).
5. Tare the balance by pressing the 'zero' or 'tare' button. **Why**?
   This ensures the starting mass is 0.
6. Place the item you want to measure onto the balance and note the reading on the screen.

Reading liquid volumes accurately

1. Read from eye level
Bend down so your eyes are level with the water level

2. Read the scale from the bottom of the meniscus
Look at the line on the scale which is closest to the bottom of the 'U' shape.

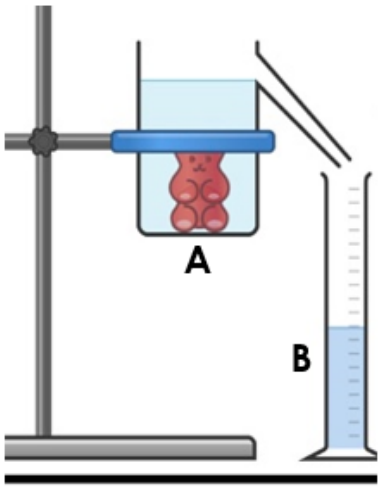


The meniscus
Liquids in long thin containers form a 'U' shaped meniscus.

Using a displacement/eureka can

If an object has an **irregular shape**, the volume can be measured using a **displacement can**, or **Eureka can**.

1. Fill the displacement can (A) with water and wait until the water stops running out of the spout.
2. Place a graduated cylinder (B) under the spout.
3. Carefully lower the irregular object into the displacement can, collecting the displaced water in the graduated cylinder.



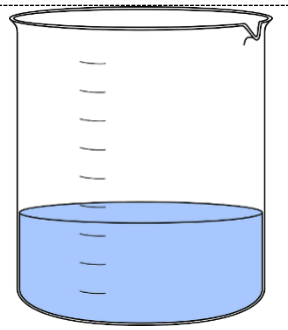
The **displaced** water in the cylinder occupies the same amount of space as the irregular object. **The volume of water in the graduated cylinder is equal to the volume of the object!**

Drill

1. State the equation that links density, mass and volume.
   1. $\rho = \frac{m}{V}$
2. Name the piece of apparatus used to measure mass.
   2. **Balance**
3. Describe how to calculate the volume of a regularly shaped solid.
   3. **using the formula V = lbh**
4. Describe how a displacement/eureka can is used to measure the volume of an irregularly shaped solid.
   4. **The displacement can is filled with water, before the object is added. The volume of water displaced from the eureka can is equal to the volume of the object.**
5. List any units that could be used to measure mass.
   5. **kg, g**
6. List any units that could be used to measure volume.
   6. **L, mL**
7. Describe how to read the measurement of a liquid.
   7. **Measure at eye level, reading from the bottom of the meniscus**

I: Describe: ***to recall facts, events or processes in an accurate way***

Describe how to determine the density of a liquid.



Model answer:

- Measure the volume using a measuring cylinder
- Measure the mass of the empty measuring cylinder using a mass balance
- Measure the mass of the measuring cylinder when the liquid is in it and subtract the mass of the empty cylinder
- Use the equation density = mass/volume

You: Describe: ***to recall facts, events or processes in an accurate way***

Describe how to determine the density of an irregularly shaped object.

Answer:

- **Measure the mass of the object using a mass balance**
- **Part fill a measuring cylinder with water and place next to a displacement can or Eureka can**
- **Add the object to the measuring cylinder and measure the volume of water displaced.**
- **This is the volume of the object**
- **Use the equation density = mass/volume**

Exit Ticket

1.Which measurement is taken using a displacement or eureka can?

- ❑ A. Density
- ❑ B. Mass
- ❑ **C. Volume**

2. Which statement is correct?

- ❑ **A. The volume of water displaced by an irregularly shaped object is the same as the volume of the object**
- ❑ B. The volume of water left in the eureka can is the same as the volume of the object
- ❑ C. Using the volume of water displaced by an object only works for irregularly shaped objects

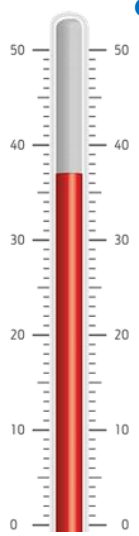
3. What is the density of an object with mass 5 g that displaced 25 cm^3 of water?

- ❑ A. 125 g/cm^3
- ❑ **B. 0.2 g/cm^3**
- ❑ C. 5 g/cm^3

Gas Pressure

Do Now

1. Define density. **Mass per unit volume**
2. State the equation used to calculate density. $\rho = \frac{m}{V}$
3. Describe the movement of particles in a gas. **Particles in a gas move randomly in all directions.**
4. Define internal energy. **The total amount of kinetic and potential energy of all the particles in a system.**
5. Describe what happens to the movement of particles in a gas as they are heated. **They gain kinetic energy so move more quickly.**



Skills Drill:

1. State the unit usually used to measure temperature. **°C**
2. State the temperature shown on the thermometer. **37 °C**
3. State the resolution of this thermometer. **1 °C**

Read Now:

Particles in a gas can take the shape of their container because they are constantly moving randomly throughout the container. The gas particles frequently collide with other gas particles, as well as with the walls of the container. Gas pressure is a measure of how often and how hard the particles of a gas collide with the walls of the container. As gas particles are moving quickly, they exert a force on the wall of the container when they hit it, and the faster the particles are moving, the greater this force will be. On aerosol canisters, such as spray deodorants, there will be a safety warning that instructs the user not to heat the canister. This is because if the particles are heated, they will move more quickly and hit the walls of the container with greater force, causing the gas pressure to build up so much that the canister may explode! State the definition of 'micro-' as a prefix.

1. State two properties of gases. **They do not have a fixed shape or volume, can be compressed and can flow.**
2. Describe the movement of particles in a gas. **They move at random speeds in random directions.**
3. Explain what is meant by gas pressure. **A measure of how often and how hard the particles of a gas collide with the walls of a container.**
4. Explain what happens to the force exerted by particles when they are heated. **It increases.**
5. Explain why it is not safe to heat an aerosol canister. **They gas pressure would increase and the canister may explode.**

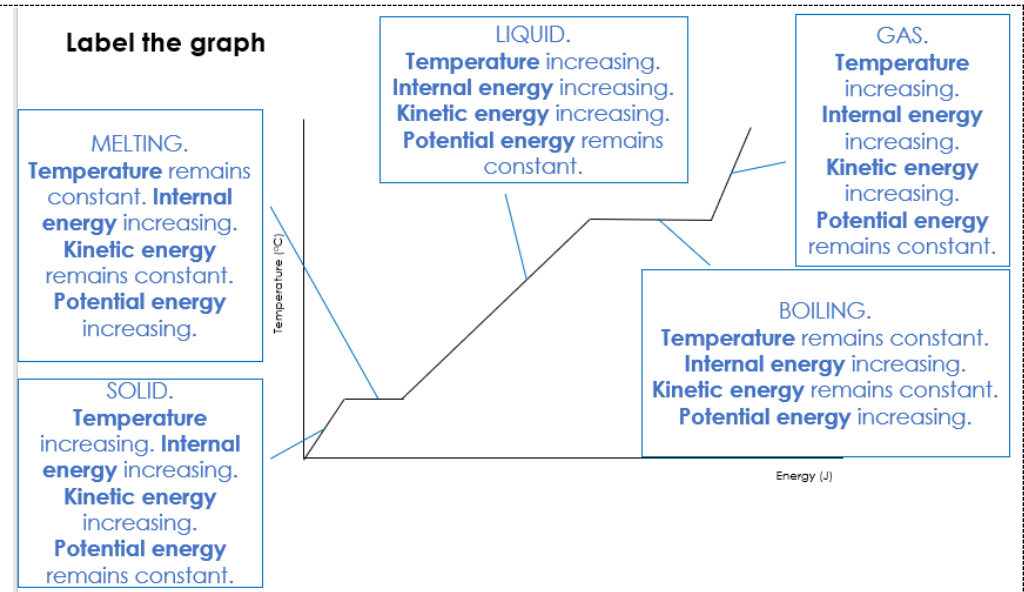
Gas Pressure

Particles is a gas move at **random speeds** in **random directions**.

They **collide** with each other and with the walls of their container.

When they **collide** with the walls of the container, they exert a force on it. This is **gas pressure**.

Pressure is a measure of the **force** exerted per unit **area**.



When a substance is heated, its **internal energy** increases.

Temperature is a measure of the <u>average</u> **kinetic energy** of all the particles in a system.

When temperature is increased, gas particles **gain kinetic energy** and move more quickly.

The gas particles are moving **more quickly** so **collide more often** with the walls of the container and with **more force**.

This means they exert **more pressure**.

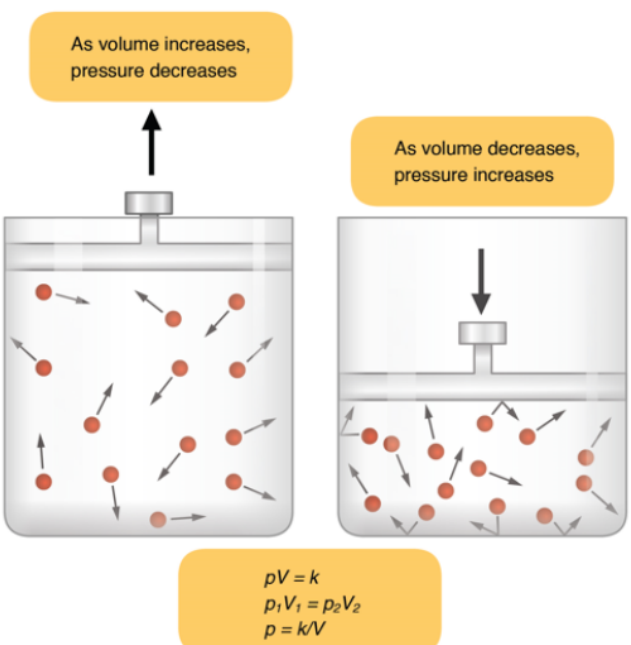
Physics only:

Pressure and Volume

When the **volume** of a container is **decreased**, the **pressure** exerted by the gas **increases**.

Particles have **less space** to move around, so **collide** with the walls of the container **more frequently**.

The **temperature** of the gas and the **mass** of the gas must remain **constant**.



Drill

1. Describe the movement of particles in a gas. **Particles move at random speeds in random directions**
2. Describe the properties of gases. **Gases can flow, take the shape of their container, do not have a fixed shape or volume and can be compressed**
3. Describe what happens to the internal energy of a gas when it is heated. **Internal energy increases**
4. Describe what happens to the movement of particles when a substance is cooled. **Particles lose kinetic energy so move less quickly**
5. Describe the relationship between temperature and pressure. **As temperature increases, pressure increases**
6. Explain the relationship between temperature and pressure**. Particles at higher temperatures have more kinetic energy so move more quickly, colliding with the surface of the container harder and more frequently, exerting more pressure**

Higher Tier only

Work is the transfer of energy by a force.

When a force is applied to a gas, **work** is done on the gas.

This increases the **internal energy** of the gas and can cause an **increase** in its **temperature**.

Physics

1. **Describe the relationship between pressure and volume. Pressure and volume are inversely proportional**
2. **State the two factors that must stay the same for this relationship to apply. The number of particles (mass) and the temperature of the gas**

I: Explain: *to use scientific understanding to make something clear or state the reason for something happening*

Explain what happens to the pressure of a gas as temperature increases.

Model answer:

- Increasing the temperature increases the kinetic energy of the particles in a gas
- This means the particles start to move more quickly and hit the surface of the container more often and with more force
- So, this increases the pressure exerted by the gas

We: Explain: ***to use scientific understanding to make something clear or state the reason for something happening***

Explain what happens to the pressure of a gas as temperature decreases.

- **Decreasing the temperature decreases the kinetic energy of the particles in a gas**
- **This means the particles start to move less quickly and hit the surface of the container less often and with less force**
- **So, this decreases the pressure exerted by the gas**

You: Explain: ***to use scientific understanding to make something clear or state the reason for something happening***

Explain the relationship between temperature and pressure of a gas.

- **Increasing the temperature increases the kinetic energy of the particles in a gas**
- **This means the particles start to move more quickly and hit the surface of the container more often and with more force**
- **So, this increasing temperature increases the pressure exerted by the gas**

Exit Ticket

1. Which describes the movement of particles in a gas?

❑ A. All particles move randomly at the same speed

❑ B. All particles move at different speeds in a pattern

❑ **C. All particles move at random speeds in random directions**

2. What would happen to the pressure in a sealed pot if it was heated?

❑ **A. The pressure would increase**

❑ B. The pressure would decrease

❑ C. The pressure would stay the same

3. Which statement is correct?

❑ A. When particles are heated they expand

❑ **B. When particles are heated their internal energy increases**

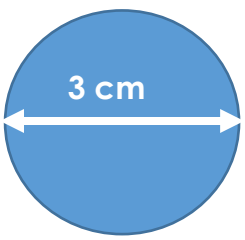
❑ C. When particles are heated they exert less pressure on the walls of a container

Taking it Further: Pressure

Do Now:

1. Describe the relationship between pressure and temperature of a gas. **As temperature increases, pressure increases**
2. Explain what is meant by pressure. **The force exerted per unit area.**
3. Explain why gas pressure increases with temperature. **Particles gain energy so collide with the walls of the container more frequently and with more force.**
4. Which state(s) of matter can be compressed? **Only gases**
5. Suggest why it hurts more when a person stands on your foot with a high heel than a flip flop. **They exert the same force over a smaller area, so there is more pressure.**

Skills Dril:



1. State the SI unit for force. **Newton (N)**
2. State the equation used to calculate area of a circle. $A=\pi r^2$
3. Calculate the area of this circle. **r = 1.5 cm, so A = 7.07 cm^2**

Read Now:

When you apply the brakes in a car, you apply a force to the pedal to make the car come to rest. How does that small force that you apply with your foot manage to make a whole car stop? The answer is hydraulics. Hydraulics means anything to do with liquids under pressure, and the brakes in a car use a hydraulic braking system. Liquids are incompressible, because there is no space between the particles. This means that when a force is applied to a liquid, the pressure is transmitted through the liquid because the force cannot be used to compress the liquid. This means the liquid can exert the same pressure on the other side.

1. Describe the arrangement of particles in a liquid. **They are held close together but are randomly arranged.**
2. Explain the term 'hydraulics'. **Liquids under pressure.**
3. Explain why liquids are described as incompressible. **They cannot be compressed because there is no space between particles.**
4. Explain why a gas could not have the same effect. **Gases can be compressed.**
5. Give an example of a use of hydraulics. **Car brakes, lifting heavy machinery**

General Definition

Adjective: (of a substance) able to flow easily

Adjective: not settled or stable; likely or able to change

Scientific Definition

A substance that has no fixed shape and yields easily to external pressure; a gas or (especially) a liquid

Fluid

'Anger is the fluid love bleeds when cut.'

C. S. Lewis

Synonyms

Adaptable
Flexible
Fluent

Antonyms

Firm
Static
Rigid

General Example

The ballet dancer's movements were fluid and beautiful to watch

Scientific Example

In steady fluid flow, the fluid's density remains constant at every point.

Fluids are substances with no fixed shape.

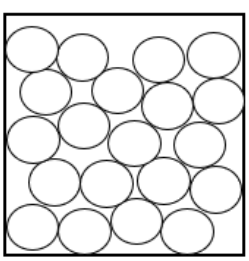
Liquids and gases are fluids.
*Fluid particles exert a **force** on any **surface** they collide with.*
The force acts at right angles to the surface.
They are exerting a force on an area, so they are exerting pressure.
We can use the equation:

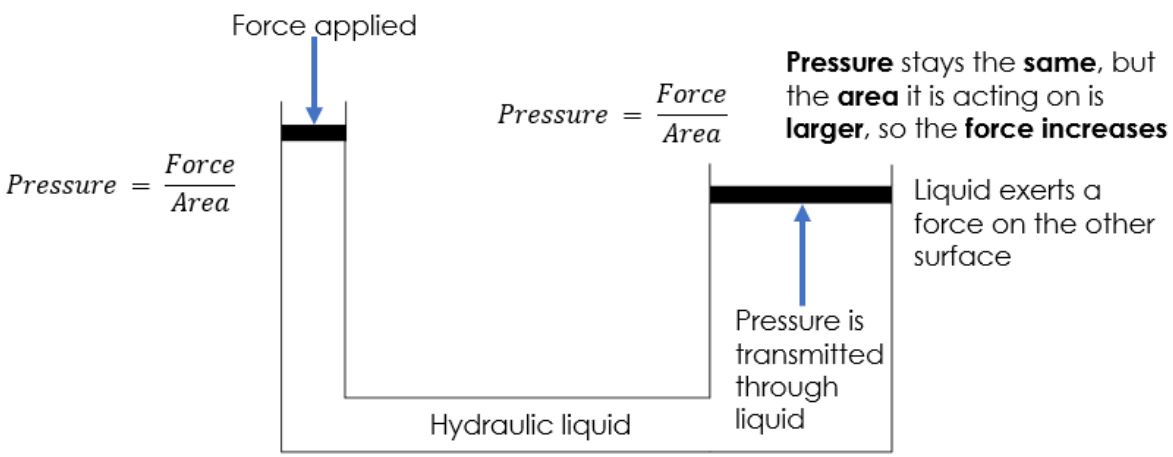
$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

Hydraulic Systems

Particles of a fluid exert a force on any surface they collide with.

A **liquid** is a fluid that cannot be **compressed**, so liquids can be used in **hydraulic** systems.





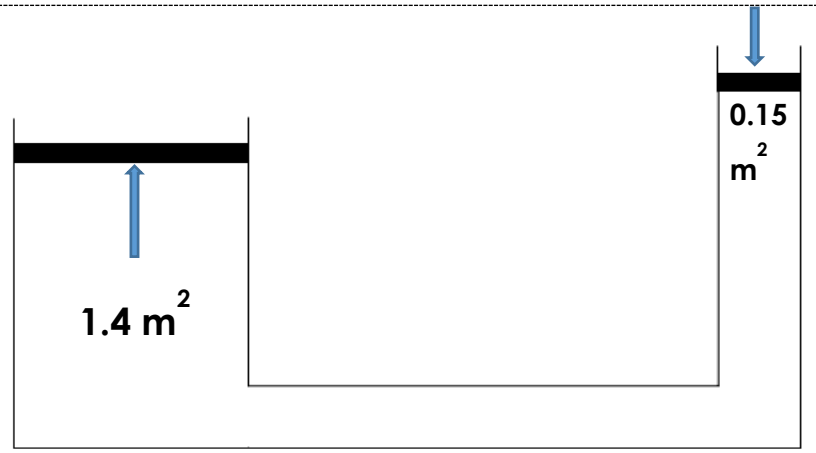
I: Pressure, force and area

This diagram shows a hydraulic syster

The system contains a hydraulic liquic

A force of 900 N is applied to the sm

Calculate the force transmitted to th



Model Answer:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Pressure} = \frac{900}{0.15}$$

$$\text{Pressure} = 6\,000\ \text{Pa}$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$6\,000 = \frac{\text{Force}}{1.8}$$

$$\text{Force} = 10\,800\ \text{N}$$

You: Pressure, force and area

Aeroplanes are an example of pressure in real life. Aeroplanes are kept pressurised to keep pressure inside the cabin at 70 kPa.

When an aeroplane is at 14 000 feet, the atmospheric pressure is 16 kPa.

The area of an aeroplane window is approximately 800 cm². Calculate the resultant force acting on the window when the aeroplane is at 14 000 feet.

70 kPa = 70 000 Pa
16 kPa = 16 000 Pa
800 cm² = 0.08 m²

$$p = \frac{F_{in}}{A}$$

$$16\,000 = \frac{F_{in}}{0.08}$$

$F_{inwards}$ = 1280 N

$$p = \frac{F_{out}}{A}$$

$$70\,000 = \frac{F_{out}}{0.08}$$

$F_{outwards}$ = 5600 N

F_R = 5600 - 1280
F_R = 4320 N outwards

Drill

1. State the equation that links pressure, force and area. **Pressure= Force/Area**
2. State the units for force. **Newtons (N)**
3. State the units for area. **m^2**
4. State the units for pressure. **Pa (or N/m^2)**
5. Describe the effect of increasing the force on the pressure. **Increasing force increases pressure**
6. Describe the effect of increasing the area on the pressure. **Increasing area decreases pressure**
7. State the property of liquids that makes them useful in hydraulic systems. **They cannot be compressed**
8. Explain why this property makes them useful in hydraulic systems. **This means they can be used to transmit forces**

Exit Ticket

1. What property of liquids makes them suitable for using in hydraulics?

- ❑ A. They can be compressed
- ❑ **B. They cannot be compressed**
- ❑ C. They do not have a fixed shape

2. Pressure is exerted by a fluid on a surface. If the area of the surface remains constant but a greater force is applied, what happens to the pressure?

- ❑ **A. The pressure would increase**
- ❑ B. The pressure would decrease
- ❑ C. The pressure would stay the same

3. What force would be exerted by a liquid with pressure 50 N/cm^2 on an area of 0.1 cm^2?

- ❑ **A. 5 N**
- ❑ B. 0.002 N
- ❑ C. 500 N

Taking it Further: Pressure in Fluids

Do Now:

1. Define a fluid. **A substance with no fixed shape**.
2. State the equation used to calculate pressure. $P = \frac{F}{A}$
3. Name the property of liquids that makes them useful for hydraulics. **They cannot be compressed.**
4. What does the g represent in the equation $W = mg$? **Gravitational field strength**
5. What are the units for the quantity g? **N/kg**

Skills Drill:

1. A water bottle contains a mass of water of 500 g. Convert this to SI units. **0.5 kg**
2. The base of the water bottle has a radius of 2 cm. Calculate the area of the base in m^2. **1.26 x10-3 m2**
3. Calculate the pressure exerted by the water on the base of the bottle.

0.5 kg x 10 = 5 N **P = F/A** **P = 3 978.87 N/m^2 or Pa**

Read Now:

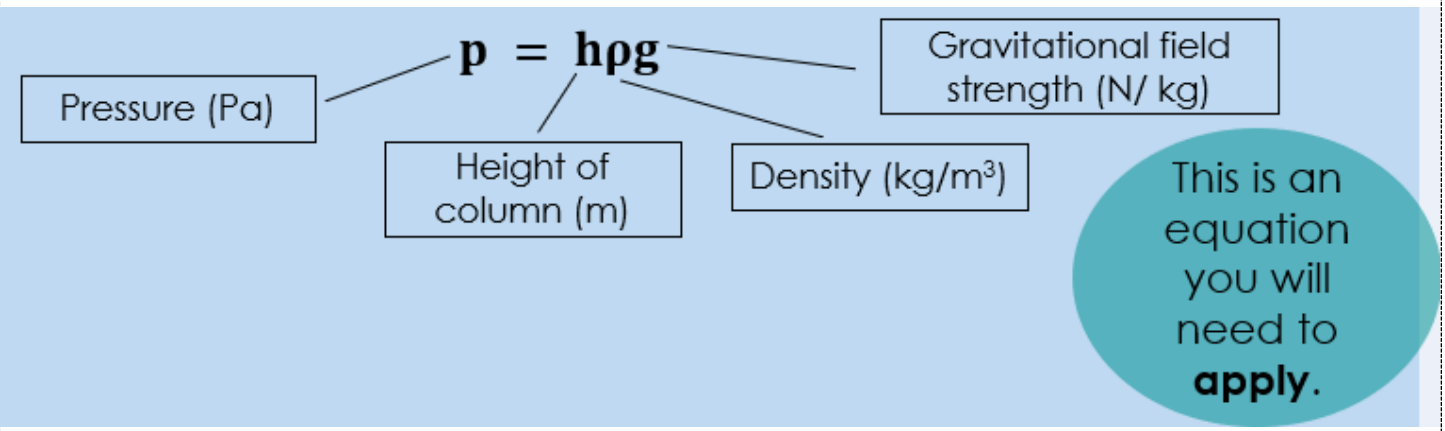
According to PADI (the Professional Association of Diving Instructors) most scuba divers should only explore depths of 40 metres for periods of 10 minutes at a time. This is because as you go deeper under water, pressure increases by an atmosphere with every 10 metres of depth. The deeper you are under water, the greater the weight of the particles above pushing down on you. It can be dangerous to go too deep under water as parts of the body, such as the lungs, can start to be compressed by this pressure, which can be very dangerous.

1. Describe the relationship between pressure and depth. **Pressure increases with depth.**
2. Explain the relationship between pressure and depth. **As you get deeper, the weight of particles above increases.**
3. Explain why PADI recommend a time and depth limit for scuba divers. **Because pressure is higher at depths.**
4. Explain why it can be dangerous for a person to be under high pressure. **Parts of the body could start to be compressed.**
5. Explain why specialist equipment would be needed to explore the deepest parts of the oceans. **It would need to be able to withstand high pressures.**

Pressure and Depth (*Higher Tier only*)

The **deeper** you go in water the **greater the pressure** becomes, because the greater the **weight** of water above you.

The pressure depends on the height of liquid above a point, density of liquid, and the gravitational field strength:



A partially or fully 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 **upthrust**.

Objects float or sink in water depending on the **density** of the object compared to water.

If the object is **more dense** than the liquid it will **sink**, because **weight > upthrust**.

If **less dense** it will **float** because **weight < upthrust**.

Atmospheric pressure is caused by air particles **colliding** with a surface (e.g. our skin).

The higher the altitude the **less dense** the atmosphere.

So, the **number** of air particles (and so **weight** of air) above a surface decreases as the height increases.

As height increases there is always less air above a surface than at a lower height.

This means **atmospheric pressure decreases with an increase in height.**

We: Pressure and depth

These are two blob fish (*psychrolutes mardicis*) in their natural habitat, 800 metres underwater off the coast of Australia.

Density of seawater = 1026 kg/m^3

Gravitational field strength = 10 N/kg

Calculate the pressure exerted on a blob fish at this depth.

$$p = h\rho g$$

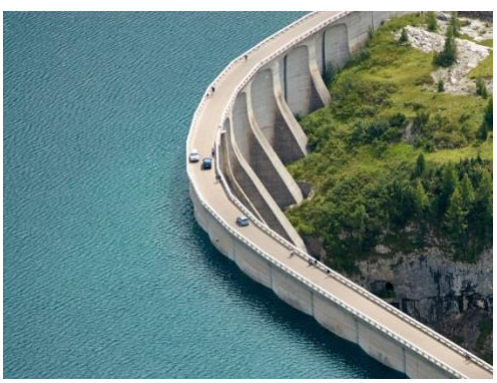
$$p = 800 \times 1026 \times 10$$

$$p = 8\,208\,000 \text{ Pa}$$

When blob fish are taken out of their natural habitat, their bodies appear to collapse. Suggest why.

The blob fish is normally at high pressure, which forces its body to have a rigid structure. When it is not at high pressure, there is no pressure forcing it into the same structure.

You: Pressure and depth



This is a bridge on top of a dam wall. The wall of the dam is built with a shape where it is much thicker at the bottom than it is at the top.

Density of water = 997 kg/m^3

Gravitational field strength = 10 N/kg

Calculate the difference in pressure between a point 2 m below the surface of the water and a point 25 m below the surface of the water.

$$p_2 = h\rho g$$

$$p_2 = 2 \times 997 \times 10$$

$$p_2 = 19\,940 \text{ Pa}$$

$$p_{25} = h\rho g$$

$$p_{25} = 25 \times 997 \times 10$$

$$p_{25} = 249\,250\ Pa$$

$$\Delta p = 249\,250 - 19\,940$$

$$\Delta p = 229\,310 \text{ Pa}$$

How might this pressure difference be related to the shape of the wall?

The wall must be thicker at the bottom because it has to withstand greater pressure.

Drill

1. **Pressure increases with depth in a liquid**
2. **The deeper the point in a liquid, the greater the weight of particles above the point.**
3. **Pressure**
4. **Height of column (depth under surface)**
5. **Density of liquid**
6. **Gravitational field strength**
7. **Pressure decreases with altitude**
8. **The higher the altitude, the fewer particles so the lower the weight of the particles**
9. **An object that floats: upthrust ≥ weight**
10. **An object that sinks: upthrust < weight**

Exit Ticket

1. A student cuts three holes in a bottle of water. Where is the pressure greatest?

- ❑ A. At the highest hole
- ❑ B. At the middle hole
- ❑ **C. At the lowest hole**

2. An inflatable toy floats on water. Which statement is correct?

- ❑ A. The inflatable toy is more dense than the water
- ❑ B. The inflatable toy does not have weight when it is on water
- ❑ **C. The weight of the toy is less than or equal to the upthrust on the toy**

3. How deep is an object under water if it experiences 29 910 N/m^2 of pressure? The density of water is 997 kg/m^3 and the gravitational field strength is 10 N/kg.

- ❑ A. 2.98×10^8 m
- ❑ **B. 3 m**
- ❑ C. 3.33×10^{-3} m

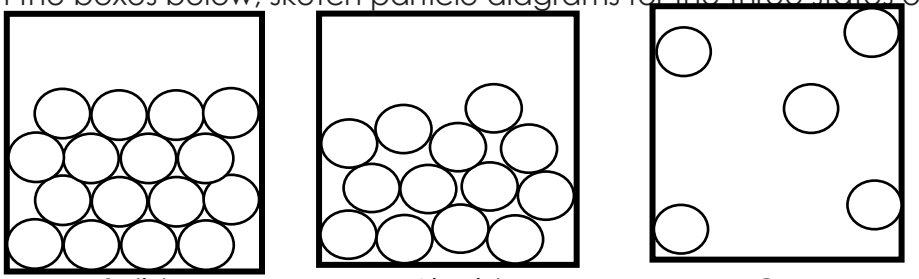
Independent Practice

Density:

Section A

1. There are three states of matter.

   a. In the boxes below, sketch particle diagrams for the three states of matter.



Solid Liquid Gas

   b. Which state of matter has the highest density?

Solid

   c. Use your particle diagrams to explain why.

There are the most particles in a given volume, the particles are packed most closely together.

Which is the correct equation to calculate density? Tick (✓) **one** box.

Density = mass x volume ☐

Density = mass / volume ☐

Density = volume / mass ☐

   d. Density can be measured in kg/m^3. Which of these is another unit that could be used to measure density? Tick (✓) **one** box.

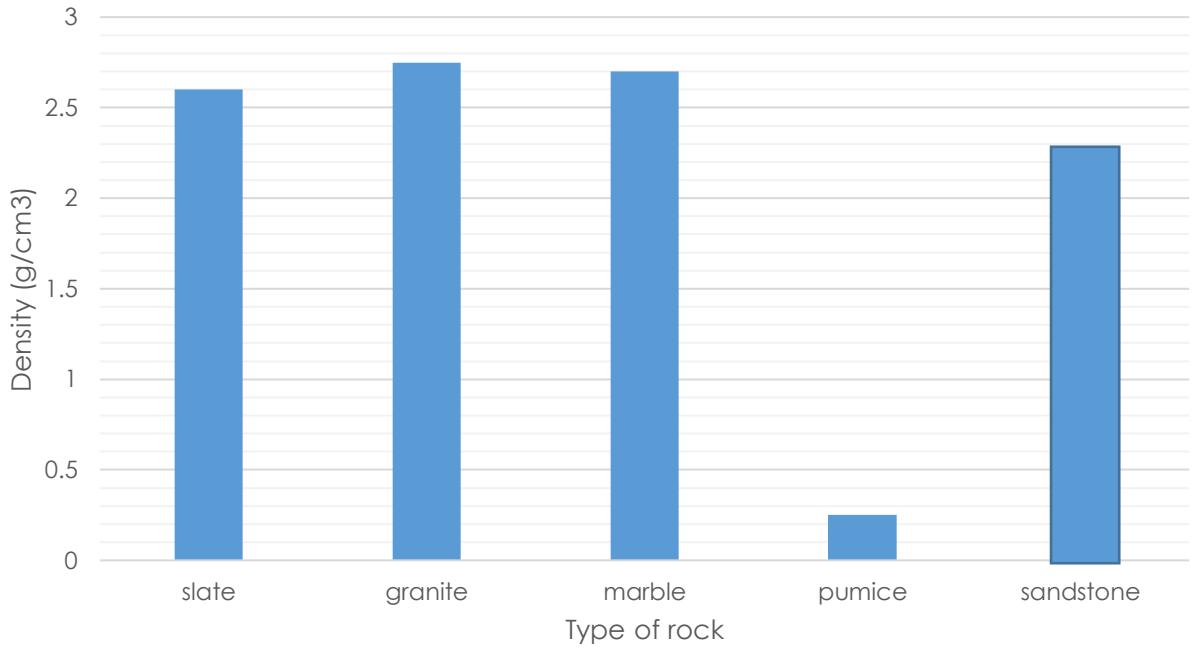
g/cm ☐

cm/g^3 ☐

g/cm^3 ☐

Section B

2. The graph below gives the density of several types of rock.



a. Which type of rock would contain the most particles in a 1 cm^3 sample?

Granite

b. What type of graph is this?

Bar graph

c. Why is this type of graph suitable?

Because the data is categorical/discrete.

d. A scientist has a sample of sandstone with a mass of 0.011 kg. What is this mass in grams?

11 g

e. The sample of sandstone has a volume of 5 cm^3. Calculate the density of the sandstone.

2e. Density = $\frac{\text{mass}}{\text{volume}}$ = $\frac{11\ g}{5\ cm^3}$ = 2.2 g/cm^3

f. Add this value to the graph above.

g. Calculate the volume of a 1.375 g piece of granite, using information from the graph.

Density = mass
volume
2.75 g/cm3 = 1.375 g
volume
Volume = 0.5 cm3

h. Calculate the mass of this block of slate, using information from the diagram and the graph.

Density = mass
volume
Volume = 10 x 6 x 4 = 240 cm3
2.6 g/cm3 = mass
240 cm3
Mass = 624 g

3. Helium-filled balloons float in air. Explain what this shows about the relative densities of air and helium and their particle arrangements.
Helium is less dense than air. This means that its particles are more spread out and there are fewer particles (mass) per unit volume.

Section C

4. Water is a useful substance to demonstrate changes of state because its melting and boiling points can be achieved in the lab.
   a. State what water is called when it exists as each different state of matter.
   b. State the melting and boiling points of water.
   c. Describe what happens to the particles when water changes from liquid to solid.
   d. Define internal energy.
   e. In which state of matter do particles have the most internal energy.
   f. Describe what happens to internal energy when a substance melts from a solid to liquid.
   g. An iceberg has a volume of 35 m^3 and a mass of 32 000 kg. Calculate the density of the iceberg.
   h. Explain why the iceberg floats on water.
   i. The iceberg will eventually melt. Explain why.

Answers

4a. Solid: ice, liquid: water, gas: steam

4b. Melting point = 0 °C, boiling point = 100 °C

4c. The particles are able to move more and flow past each other.

4d. The total amount of kinetic and potential energy of all the particles in a system.

4e. Gas

4f. Internal energy increases

4g. Density = mass / volume
Density = 32 000 kg / 35 m^3
Density = 914.29 kg/m^3

4h. The density of the iceberg is lower than the density of the water.

4i. There is a temperature difference between the ice and the water so energy is transferred (from ice to water) until they reach equilibrium.

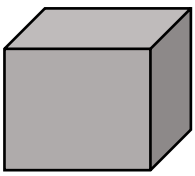
Measuring Density

1. Read the question and the student's answer carefully.

2. Use the mark scheme to award the student a number of marks and annotate their answer with suggestions to improve.

Stretch: Rewrite the answer to show how it should be done!

Question:

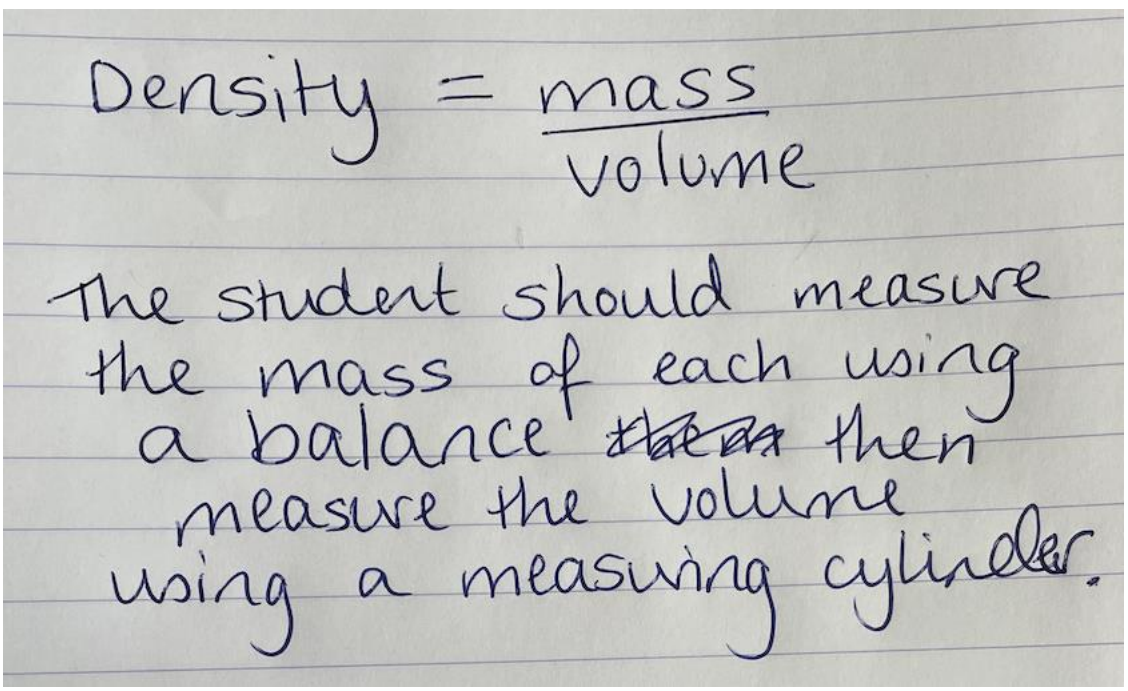


A student wants to compare the density of two objects.

Describe the method(s) that the student could use to measure the density of each object.

(6)

Student answer:



Marks awarded= _____

Mark scheme:

Level 0 (0 marks)	No relevant content
Level 1 (1-2 marks)	**Basic** descriptions of the measurements that should be taken for **one method** but no mention of how to use them, **or** descriptions of the quantities needed to calculate density but no information on how to measure them.
Level 2 (3-4 marks)	**Clear** description of **one method** to measure density **or** basic descriptions of both methods
Level 3 (5-6 marks)	**Clear** descriptions of **both methods** that would allow the density of each to be measured

For both

- Measure mass using a balance
- Calculate density using $\rho = \frac{m}{V}$

Cube (regularly shaped solid)

- Measure length of sides using a ruler
- Calculate volume using lbh

Screw (irregularly shaped solid)

- Use a displacement can/Eureka can
- Measure the volume of water displaced
- Volume of water displaced = volume of screw

Gas Pressure:

Section A

1. This question is about gas pressure.
   a. Which is the correct description of how particles move in a gas?
   Tick (✓) **one** box.

At random speeds in the same direction	☐
At random speeds in random directions	☐
At the same speed in the same direction	☐
At the same speed in random directions	☐

   b. Gas pressure is exerted when particles collide with a surface of a container. Explain what this means.

Particles are moving so they exert a force on the surface when they collide with it.

   c. What is the relationship between gas pressure and temperature?
   Tick (✓) **one** box.

Increasing temperature increases pressure	☐
Increasing temperature decreases pressure	☐
Increasing temperature does not affect pressure	☐

   d. Which property of gas particles is the temperature related to?

Average kinetic energy

Section B

2. The image shows a syringe that contains air. The syringe is placed into an ice bath, which decreases the temperature of the air in the syringe.

   a. What would happen to the average kinetic energy of the particles when the temperature is decreased?

Average kinetic energy of particles would decrease

   b. Explain why the average kinetic energy is used.

Because particles don't all have exactly the same amount of kinetic energy

   c. What would happen to the average speed of the gas particles if the temperature decreased?

Average speed of particles would decrease

   d. What would happen to the gas pressure inside the syringe if the temperature decreased?

Pressure would decrease

   e. The plunger of the syringe is pulled outwards. Why does air move into the syringe as the plunger is pulled outwards?

Pressure would decrease

   f. The syringe is then placed into a hot water bath. Complete the table by ticking the correct box to identify what would happen to the following quantities.

	Increases	Decreases	Stays the same
Mass of the gas			**Y**
Density of the gas			**Y**
Average speed of particles of gas	**Y**		
Pressure exerted by the gas	**Y**		

Section C

3. A group of scientists were investigating the behaviour of air particles at different temperatures. They used the same container throughout, which had a volume of 1 m^3. They cooled the air from 22 °C to 0 °C.
    j. Describe and explain what would happen to the particles of air in the container.
    k. Describe and explain what would happen to the pressure within the container.
    l. Is air an element, a compound or mixture? Explain your answer.
    m. Water within the air froze at 0 °C. The specific latent heat of fusion of water is 330 kJ/kg and the change in internal energy of the water was 0.85 kJ.
    Calculate the mass of ice that formed.
    Use the equation: $\Delta E = m L$
    n. The air also contains oxygen and nitrogen. The melting and boiling points of each substance is shown in the table.

	Melting point (°C)	Boiling point (°C)
Oxygen	-218	-183
Nitrogen	-210	-195

The apparatus the scientists were using allowed them to cool the air to -190 °C. What state would the water, the oxygen and the nitrogen be in at -190 °C?

3a. The particles would lose kinetic energy, causing the average speed of particles to decrease.

3b. The pressure inside the container would decrease because the particles have a lower speed so they exert less force on the walls of the container when they collide with it (which also happens less often)

3c. Air is a mixture because it contains different elements and compounds, which are not all chemically combined together.

3d.

$$\Delta E = m L$$
$$0.85 = m \times 330$$
$$m = 2.58^{-3}\,kg$$

3e. Water = solid, oxygen = liquid, nitrogen = gas

Taking it Further: Pressure:

Section A

1. Which correctly shows the equation that links pressure, force and area
   Tick (✓) **one** box.

$\text{Pressure} = \text{Force} \times \text{Area}$ ☐

$\textbf{Pressure} = \dfrac{\textbf{Force}}{\textbf{Area}}$ ☐

$\text{Pressure} = \dfrac{\text{Area}}{\text{Force}}$ ☐

2. Which property of liquids makes them useful in hydraulic systems?
   Tick (✓) **one** box.

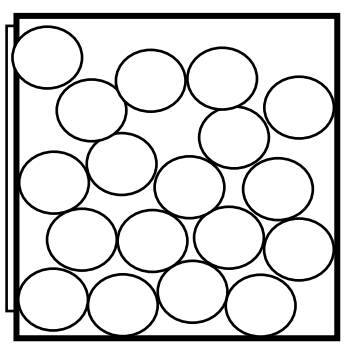
They cannot be compressed ☐

They can be compressed ☐

They do not have a fixed shape ☐

They can flow ☐

3. Draw a particle diagram to show the arrangement of particles in a liquid.

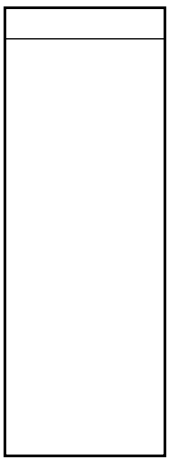


4. Using your particle diagram and your own knowledge, describe the movement of particles in a liquid.

Particles are arranged randomly and not held in a rigid arrangement so can move past each other

Section B

5. The diagram shows a container filled with water. The water exerts a force of 38 N on the bottom of the container.



The bottom of the container has a surface area of 0.005 m^2.

Calculate the pressure exerted by the water on the bottom of the container.

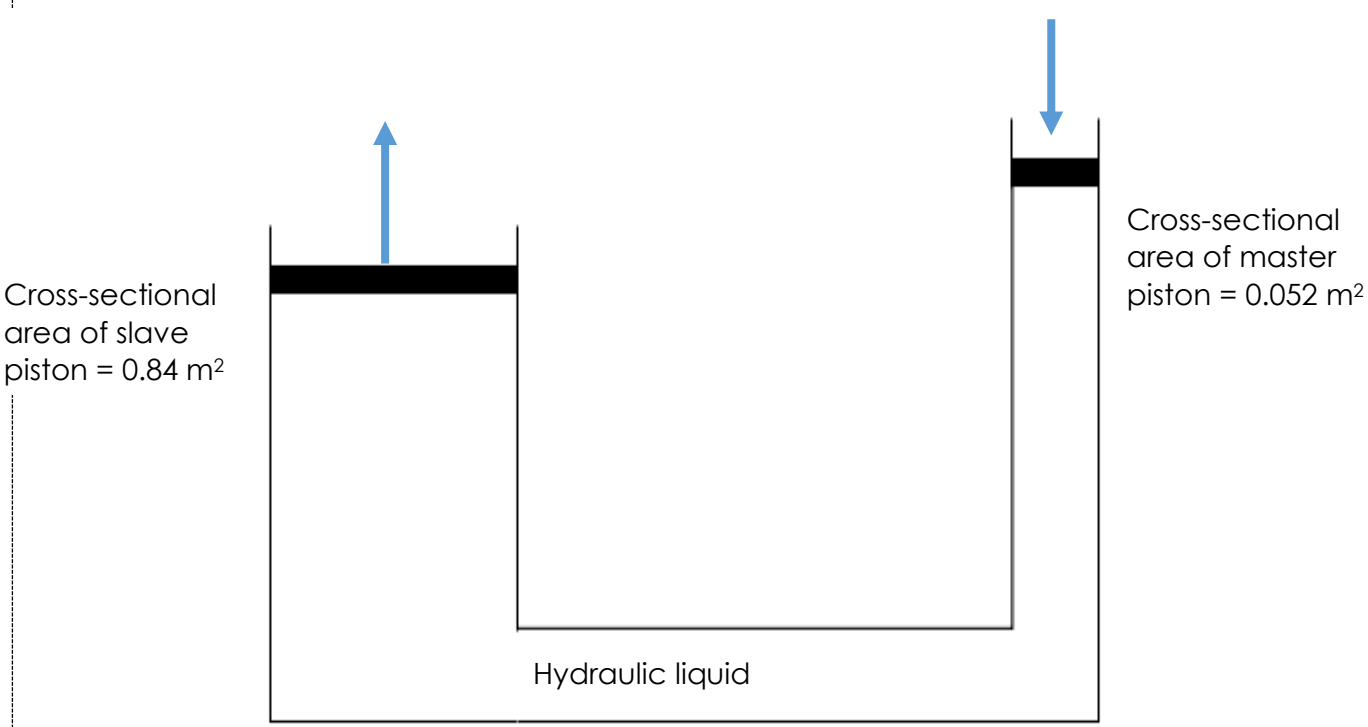
5. $\textbf{Pressure} = \frac{\textbf{Force}}{\textbf{Area}}$ $\textbf{Pressure} = \frac{38}{0.005}$

$\textbf{Pressure} = \textbf{7 600 Pa}$

Circle the correct unit.

m^2/N	Nm	Pa

6. The diagram below shows the hydraulic system used in a car lift. An operator presses a control button which applies a force to the master piston. This makes the slave piston produce a force acting upwards, which lifts the car.



a. When a force is applied to the master piston, it results in a much larger force acting upwards on the car. Use information from the diagram to explain why.

- The downwards force produces pressure in the liquid
- This pressure is transmitted through the liquid/is the same throughout the liquid

- P=F/A
- The area of the slave piston is larger and the pressure is the same
- So the force is greaterA force of 990 N is applied to the master piston. Calculate the force applied by the hydraulic liquid to the slave piston.

b. Calculate the maximum mass of a car that could be lifted by this car lift. Take gravitational field strength as 10 N/kg.

6b. **Pressure= Force/Area**

Pressure= 990/(0.052)
Pressure=19 038.46 Pa

therefore:
Pressure= Force/Area

19038.46= Force/(0.84)

Force=15 992.31 Pa

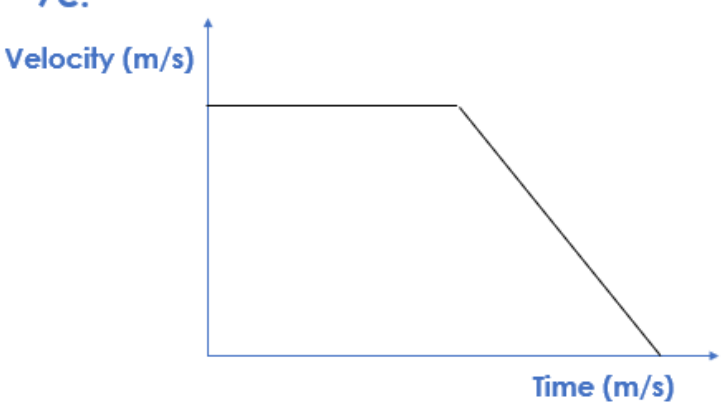
Section C

7. Hydraulic systems are also used in car braking systems.
   a. Explain why hydraulic brakes contain fluid.
   b. Compare the size of the force applied by a person's foot to the brake and the force applied by the brakes on the wheels.
   c. Sketch a velocity-time graph to show a car moving at a steady speed before the driver applies the brake and slows down to a stop.

7a. The hydraulic fluid is a liquid as it is incompressible, so transmits pressure through it.

7b. The force applied by the foot to the brake is much smaller than the force applied by the brakes on the wheels.

7c.



Taking it Further: Pressure in Fluids

Section A

1. Which correctly shows the relationship between pressure and depth in a liquid?
   Tick (✓) **one** box.

   The pressure increases with depth under the surface ☐

   The pressure decreases with depth under the surface ☐

   The pressure does not change with depth ☐

2. Which correctly shows the relationship between pressure and altitude?
   Tick (✓) **one** box.

   The pressure increases with altitude ☐

   The pressure decreases with altitude ☐

   The pressure does not change with altitude ☐

3. Identify each quantity represented by the equation below.

$$p = h\rho g$$

p = pressure

h = height of column

ρ = density

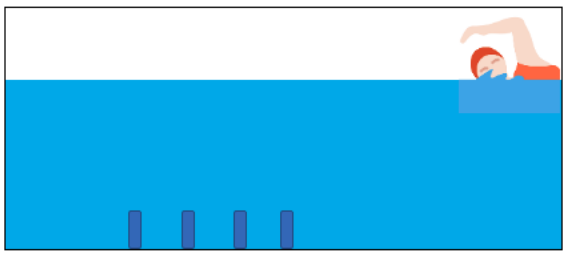
g = gravitational field strength

4. The unit Pa is usually used to measure pressure. Which of these quantities is 1 Pa equal to?

1 m^2	1 kg/N	1 N/kg	1 kg/m^3	**1 N/m^2**

Section B

5. A child is collecting dive sticks from the bottom of a swimming pool.



a. Describe what happens to the pressure on the child as they swim to the bottom of the pool. Explain why.

The pressure increases as they swim to the bottom of the pool, because there are more water particles above the child as they swim deeper, therefore the weight of the water increases.

b. The child drops another dive stick into the water and it sinks to the bottom. Explain what this shows about the forces acting on the dive stick.

The weight of the dive stick is greater than the upthrust

c. Calculate the change in pressure the child experiences when they are 1 m below the water to 2.5 m below the water. The density of water is 997 kg/m^3 and the gravitational field strength is 10 N/kg.

$$p_1 = h\rho g$$
$$p_1 = 1 \times 997 \times 10$$
$$p_1 = 9970 \text{ Pa}$$
$$p_{2.5} = h\rho g$$
$$p_{2.5} = 2.5 \times 997 \times 10$$
$$p_{2.5} = 24\,925\ Pa$$

$$\Delta p = 24\,925 - 9970$$
$$\Delta p = 14\,955 \text{ Pa}$$

6. This image shows a water tank that contains rainwater. A watering can is then filled with water from the tap at the bottom and the rainwater is then used to water gardens.

   a. Suggest how the time taken to fill the watering can would be different if the tap was higher up on the tank.

      The watering can would take longer to fill if the tap was higher up, because the pressure of the water would be lower higher up.

   b. The bottom of the container has a cross-sectional area of 0.13 m^2. When it is full the water inside the tank weighs 45 kg. Calculate the pressure exerted by the water on the bottom of the container.

$$p = \frac{F}{A}$$

$$p = \frac{45}{0.13}$$

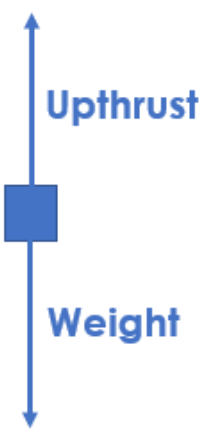
$$p = 346.15 \text{ Pa}$$

Section C

7. A swimmer is standing on the edge of a stationary boat.
   a. Draw a free body diagram to show the forces acting on the stationary boat.
   b. The swimmer jumps forwards off the boat. What would happen to the boat?
   c. Which of Newton's Laws of motions explains this?
   d. The boat has a mass of 3000 kg. Explain how it is possible for the boat to float.

Answers

7a.



7b. The boat would recoil/move backwards.

7c. Newton's Third Law. When object A exerts a force on object B, object B exerts an equal and opposite force on object A. The person exerts a force on the boat, and the boat exerts an equal and opposite force on the person.

7d. The density of the boat is lower than the density of the water.