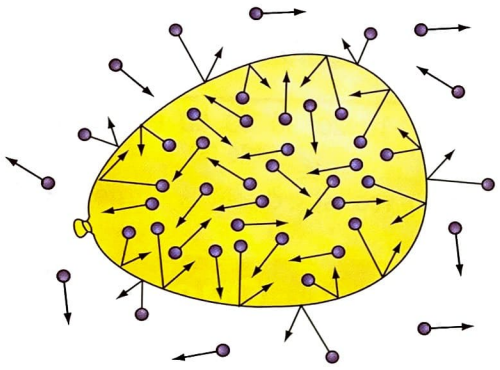
3.3 Pressure in gases

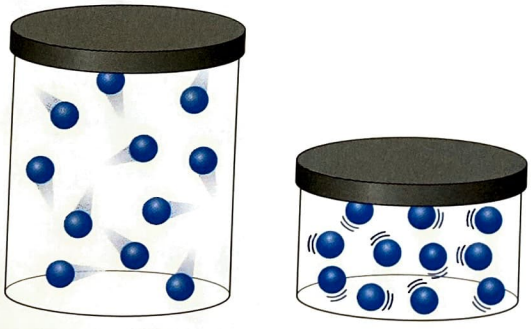
Learning objectives

After this topic you will be able to:

- describe the factors that affect gas pressure
- describe how atmospheric pressure changes with height.



▲ If there are more collisions on the inside than the outside the balloon gets bigger.



▲ In a smaller volume gas molecules will collide more often with the walls of the container.

Have you ever blown a balloon up until it bursts?

◀ The moment when a balloon bursts.

What is gas pressure?

When you blow up a balloon there are millions of air molecules hitting the inside of the balloon.

The collisions between the air molecules and the balloon produce **gas pressure** (air pressure). Lots of collisions make a high gas pressure because there is a big force over a small area. Gas pressure is exerted in all directions.

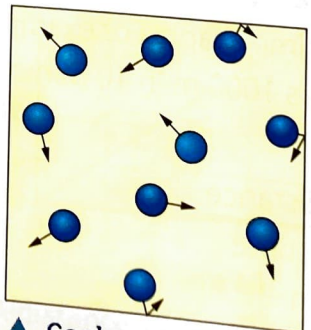
Changing volume

If you squash a gas into a smaller volume there will be more collisions between the gas molecules and the walls of the container. The pressure increases.

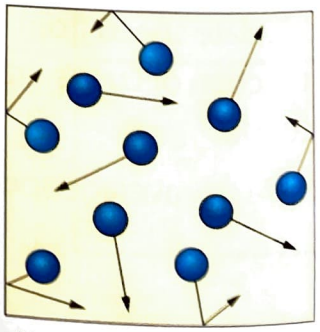
Changing temperature

When a gas cools down its molecules move more slowly. If the container doesn't change shape, then the pressure goes down. There are fewer collisions with the sides of the container.

A State what happens to the speed of gas molecules when the temperature goes down.



▲ Cool gas: fewer and less energetic collisions.



▲ Hot gas: more collisions that are more energetic.

Balloon pressure

A student wants to investigate how the volume of a fixed amount of air in a balloon changes with temperature. Write a plan for the investigation.

Compressed gas

When you pump up a bicycle tyre you increase the gas pressure. As you pump more gas into a container the gas becomes **compressed**. There are more molecules in the same space, so there are more collisions. The pressure is bigger, so the force exerted by the gas over the area of the container is big. You need a strong container to hold a compressed gas.

Atmospheric pressure

There is air all around you. The air exerts a pressure on your body all the time called **atmospheric pressure**. You do not feel the pressure. It is cancelled out by the pressure of the gases and liquids in your body pushing out.

◀ Marshmallows contain pockets of air that expand when you pump out the air around them.

Changing atmospheric pressure

The atmospheric pressure at sea level is bigger than the atmospheric pressure high up a mountain. Gravity pulls the air particles towards the Earth. Where the particles are closer there are more collisions. The pressure is higher.

The gas has a higher **density** at sea level. There is more mass of gas in a certain volume.

The smaller atmospheric pressure makes it hard for mountain climbers to breathe in enough oxygen. Mountaineers often take oxygen tanks when they climb high mountains such as Everest. The tanks contain oxygen gas that has been compressed into a small volume.

B State what happens to the atmospheric pressure as you go up a mountain.

Key Words

gas pressure, compressed, atmospheric pressure, density

Foul Fact

Think of your favourite famous person. When you breathe in you are breathing in at least 10 air molecules that they have breathed out.

Link

You can learn more about gas pressure in C1 1.7 Gas pressure

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

A gas exerts a pressure on the walls of its container because the particles **collide with/stick to** the walls. If the gas gets hotter the pressure will be **bigger/smaller**. If the volume gets bigger the pressure will be **bigger/smaller**. As you go up a mountain the air pressure is **bigger/smaller** because there are **fewer/more** gas particles. *(5 marks)*

2 A climber climbs a mountain.

a Explain why he might take a cylinder of oxygen with him. *(2 marks)*

b Explain why the oxygen needs to be compressed. *(2 marks)*

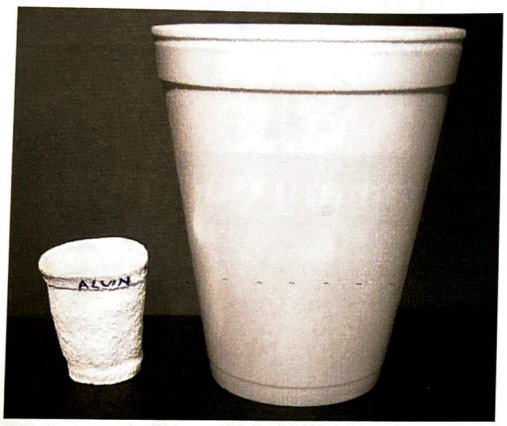
3 A teacher heats some water in a drinks can until it is boiling and steam comes out of the can. She quickly turns the can over and puts it into some water. Explain in detail why the can collapses. *(6 marks QWC)*

3.4 Pressure in liquids

Learning objectives

After this topic you will be able to:

- describe how liquid pressure changes with depth
- explain why some things float and some things sink.



▲ The cup on the left was taken down to a depth of 3000 m.

▲ The water comes out in all directions.

How do you squash a polystyrene cup without touching it? Take it deep beneath the sea and the pressure in the water will do it for you.

Liquid pressure

When you swim underwater the water exerts a pressure on you. The water molecules are pushing on each other and on surfaces, and this **liquid pressure** acts in all directions.

When you squeeze a bag with holes in it the water is pushed out of all the holes because of liquid pressure. The water comes straight out of each hole and then falls because of gravity.

▲ The water behind a dam exerts a pressure on the concrete.

If you put water in a syringe, cover the end, and try to compress the liquid you will find it impossible. Liquids are **incompressible**. This is because the particles in a liquid are touching each other and there is very little space between them. In a gas there is lots of space between the particles so gases can be compressed. Liquids pass on any pressure applied to them.

A Write down what incompressible means.

Pressure and depth

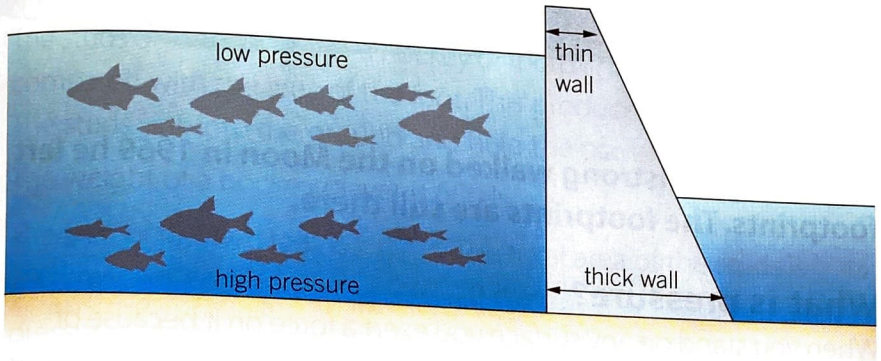
The wall of a dam is not straight. It curves outwards at the bottom.

The pressure at the bottom of the lake is bigger than the pressure at the top. The pressure at a particular depth in a liquid depends on the weight of water above it.

Why does it float?

A primary-school student says that 'heavy things sink and light things float'.

Use the example of a ferry to explain to them why that is not the case.



▲ A dam is thicker at the bottom.

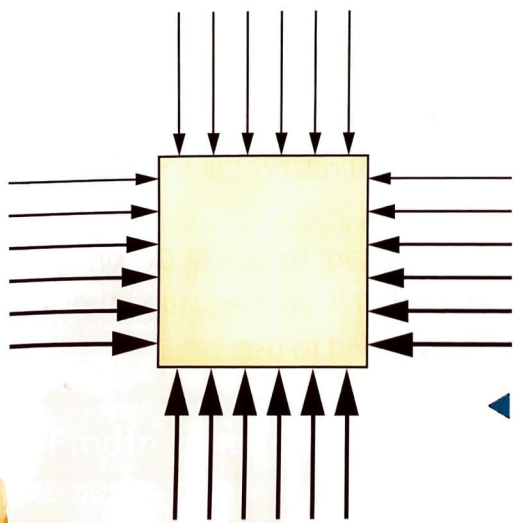
B State what happens to liquid pressure as you go deeper in a lake.

Floating and sinking

It is liquid pressure that produces upthrust, the force that keeps things afloat. If you push a balloon into a bucket of water you can feel the water pushing back. Upthrust acts on any object that is floating, or is submerged in a liquid.

It is easy to work out why a rubber duck floats. There are lots more water molecules hitting the bottom of the rubber duck than there are air molecules hitting the top. This produces the upthrust. The duck sinks until there is enough upthrust to balance the weight.

If the area in contact with the water is too small, there is not enough upthrust to make the object float.



◀ This object is submerged. The arrows show the forces acting on the object because of the pressure in the water.

When a submarine is underwater there is a difference in pressure between the top and bottom of the submarine. That produces a force that pushes the submarine up. This force is upthrust.

Fantastic Fact

The water pressure at the bottom of the Atlantic Ocean is equivalent to the weight of eight cars pushing on an area the size of your thumb.

Key Words

liquid pressure, incompressible

Link

You can learn more about upthrust in P1 1.1 Introduction to forces

Summary Questions

1 Copy and complete the sentences below.

The pressure in a liquid acts in _____ directions. The pressure _____ as you go deeper because the _____ of the water above you gets _____. The difference in pressure explains why there is a force called _____ on a floating object.

(5 marks)

2

a Explain in terms of pressure why a boat made of modelling clay floats. *(2 marks)*

b Explain why the same mass of modelling clay shaped into a ball sinks. *(2 marks)*

3 You push a ping pong ball to the bottom of a bucket of water. Explain in detail what happens to the ball when you let it go.

(6 marks QWC)

3.5 Pressure on solids

Learning objectives

After this topic you will be able to:

- calculate pressure
- apply ideas of pressure to different situations.

▲ There is no wind on the Moon to blow Neil Armstrong's footprints away.

▲ The tracks on the earthmover stop it sinking into the mud.

Key Words

pressure, newtons per metre squared

When Neil Armstrong walked on the Moon in 1969 he left footprints. The footprints are still there.

What is pressure?

When you stand on any surface you exert a force on it because of your weight. Your weight is spread out over the area of your foot. You are exerting a **pressure** on the ground. If you are standing on a soft surface such as mud the pressure might be big enough for you to sink.

An earthmover is very heavy. It has a weight of about a million newtons, the same as about 15 000 people! A single person standing on the same muddy ground might sink. The earthmover does not sink because its weight is spread out over a bigger area.

Pressure is a measure of how much force is applied over a certain area. The pressure acts in a direction that is at 90°, or normal, to the surface.

A State the direction that pressure acts.

How do you calculate pressure?

You calculate pressure using this equation:

$$\text{pressure (N/m}^2\text{)} = \frac{\text{force (N)}}{\text{area (m}^2\text{)}}$$

You measure force in newtons (N) and area in metres squared (m^2). Pressure is measured in **newtons per metre squared** (N/m^2).

Sometimes it is easier to measure smaller areas in centimetres squared (cm^2). If you measure the area in cm^2 then the pressure is measured in N/cm^2.

When you do calculations it is very important to look at the units of area. If you write them next to the number in your equation then you will see which unit of pressure you need to use.

B State the units of pressure.

Fantastic Fact

To produce the same pressure on the floor that you exert when you push in a drawing pin, you would need over 5000 people standing on your shoulders.

Big and small pressure

The studs on the bottom of a hockey or football boot have a small area compared with the area of the foot. This produces a bigger pressure. The studs sink into the ground and help the player to move quickly.

The weight of a hockey player is 600 N.

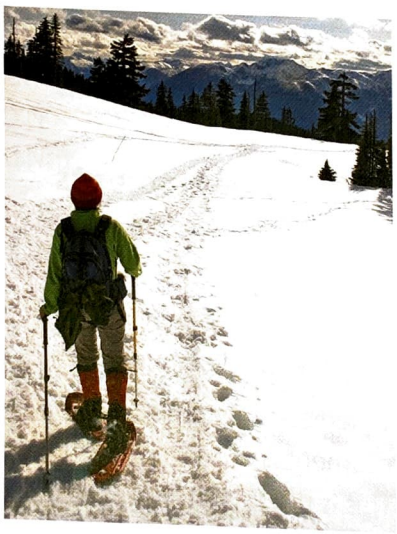
The area of her two feet is 200 cm^2.

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{200\ \text{cm}^2} = 3\ \text{N/cm}^2$$

The total area of the studs is 20 cm^2.

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{20\ \text{cm}^2} = 30\ \text{N/cm}^2$$

▲ The studs increase the grip on the ground.



▲ Snowshoes increase the area of your feet so the pressure is less.

Studs increase the pressure. At other times it is useful to make the pressure smaller, as with the earthmover.

If you need to walk over a soft surface such as snow, you need to increase the area of your feet in contact with the ground so that you do not sink.

Finding the force

Which of these is the correct equation for working out the force?

A force = pressure/area
B force = pressure × area
C force = area/pressure

▲ The pressure is bigger if your weight is concentrated over a smaller area, such as your hand.

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

Pressure is a measure of how much **force/pressure** there is on a certain **area/volume**. If you exert a **big/small** force on a **big/small** area the pressure will be large. Pressure is measured in **N/m^2/Nm**.

(5 marks)

2 A gymnast has a weight of 600 N. The area of each hand is 150 cm^2. Calculate the pressure on the floor when he is doing a handstand.

(3 marks)

3 The point of a nail has an area of 0.25 cm^2, and an average person has a weight of 700 N. Explain in detail why it is possible to lie on a bed of 4000 nails, but not on a single nail.

(6 marks QWC)